

Project VLAB-FIS: a novel approach to engage students on experimental work in Physics

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Abstract. Experimental work is very useful for motivating high school students towards science, leverage learning and also for developing procedural skills. Teachers usually provide their students with protocols of the experiments and expect to obtain good results from this practice, but students must be prepared before going to the lab in order to successfully accomplish the experimental work. The project VLAB-FIS is based on introductory videos that give a holistic view of the experimental works, facilitating a prior understanding of the experiments and their corresponding conceptual goals. The approach is complemented by video recordings of the experiments and computational simulations, for an inclusive participation of all students regardless of reading or physical disabilities. The project was presented to physics teachers in a workshop to better understand the feasibility of the project in Portuguese secondary schools from the teachers' viewpoint. Teachers' feedback shows that they consider the project useful as support for the preparation of laboratory classes.

Keywords: Videos in physics education; physics simulation; experimental work

1. Introduction

Since the end of the 20th century, society has experienced a major revolution due to the advancement of technologies that invade people's daily lives, in the most diverse living environments. However, a relevant point is that this same technological revolution has not reached most schools. Nevertheless, it is generally accepted that the use of multimedia and digital educational resources in class favors the engagement of students in an active learning environment [1-2] besides serving as an instrument of citizenship, social relations and work.

Schools are a space of formal education, where students should find the means to prepare to carry out their life projects. The quality of education is therefore a necessary condition in both their intellectual and moral formation. The laboratory is a particular space in schools where learning can be more effective, because students have the opportunity not only to be involved with scientific method and scientific contents, but also many other procedures that develop their skills. Among those we have: manipulate scientific equipment, draw and build experimental setups, implement techniques, acquire and analyze data, plot graphs, evaluate limitations and uncertainties, test predictions about concepts and laws, confirm theories, and use their creativity on problem solving activities [3-5].

In a world where technology is a great element of interaction, schools still generally present their teaching practices shaped by traditional methodology. In order to adapt to the new reality and thus respond to the demands of a new generation of students, proposals are presented in many teaching

practices, such as the use of interactive whiteboards, computer simulations, educational videos and smartphone applications [6-10]. So, there is a change in the way educational institutions and also enterprises view education and educational resources. Many publishers seek to bring this new trend into textbooks, using web platforms with virtual presentations and thematic videos. However, in this eagerness to provide everything to the school community, virtual pedagogical materials are basically demonstrative resources that can subvert the educational process in the experimental aspect, placing the students in a completely passive position contrary to what would be desirable.

It is known from our experience as teachers that experimental work enhances better knowledge in science if students prepare the activities beforehand [11-13]. To encourage this, teachers often provide their students with pre-laboratory questions and experimental guides, hoping they will respectively answer and read them before attending the experimental class. This homework usually consists of reading texts and watching schematics of materials they frequently do not know or understand. Additionally, for students with some specific learning disability, such as those with dyslexia and dysgraphia, reading texts represents a great difficulty [14]. According to Brassolatti and collaborators [15], many young people have an aversion to reading books in the traditional way, preferring forms of communication based on audio-visual form. Moreover, reading assignments take a lot of time from the student's perspective, and this is why most of them arrive at the laboratory class without being properly prepared.

Consequently, the advantage students could benefit from experimental work is impoverished, as teachers feel compelled to give their students closed recipes protocols to counteract the negative impact of their unprepared condition.

A possible solution to this problem is the use of videos to support the presentation of a particular experiment, as reported by Higgins, Moeed and Eden [16]. The use of videos in schools as curricular material is not new [17-24], although they can be explored in many different ways to contribute to student learning. Within the numerous possibilities, the use of video can highlight awareness, illustration, simulation, teaching and production of scientific content [25]. Videos, as well as simulations, help students to build "cognitive bridges" [26] between the concepts they already know and those to be acquired in the classroom or in the laboratory.

Previous studies suggest that students benefit from receiving pre-laboratory instructions in a video format relative to the usual text lecture form [27]. Rodgers and co-workers [13] have shown that videos used for pre-laboratory preparation are successful, increasing not only the preparedness of the students but also the marks gained in their evaluation. Students' assessments indicate that online pre-laboratory videos and tests improve their psychomotor and affective experiences in laboratory classes [28]. Stieff et al [29] described that the use of online pre-class videos eliminates the need for a face-to-face pre-laboratory lecture with teaching assistants prior to the laboratory activity. Therefore, the use of online pre-laboratory videos can reduce the contact time for a full laboratory session. They observed students to complete laboratory activities almost 10% faster when they prepared for laboratory activity with online pre-laboratory videos. Their analysis shows that the reduced time to complete each laboratory work is probably due to less procedural errors, as it is evident in the reduced amount of time for students to complete each step or restart the entire procedure.

The VLAB-FIS project is aligned within this perspective, and proposes a new didactic approach based on virtual tools (videos and simulations). In this paper we discuss the construction and use of introductory videos (IV) as a preparatory tool for experimental activities for high school laboratory classes, aiming with the digital resources of the project to contribute to meaningful and inclusive learning in a laboratory context, using a language more familiar to the current generation of students.

2 The VLAB-FIS Project

VLAB-FIS is an acronym of the Portuguese expression Virtual Lab – Physics. It is a project based on virtual resources for the experimental work. The project approach is to start, for each experimental work, with an introductory video (IV) of the experiment, recorded specifically to give a realistic perspective of the content to be taught. This IV is not a recording of all the experimental work, it is a holistic view of the experiment that guides the students throughout the experiment. In the introductory video, students are first instructed about what to investigate (Central Question), followed by the presentation of the equipment that will be used, then how to proceed experimentally, the details to take into account, what to conclude and finally how the experiment (methodological domain) is related with theory (conceptual domain).

The VLAB-FIS project is socially inclusive because it enables students with physical disabilities to participate in the discussions about the introductory video and respective experimental goals. This happens because besides the IV, there is a complementary video recording (VR) of parts of the experiment (from which students can acquire experimental data with a video analysis software) and/or a Pedagogical Computational Simulation (PCS). These digital resources encompass a set of activities ranging from pre to post real laboratory activities and allow students with physical disabilities to work at the same time their classmates perform the real experiment. Therefore, IV and both VR and PCS are virtual resources that can be explored by all the students as curricular materials.

Each IV is typically between 2 to 4 minutes long and prepares the students for a responsible role in the laboratory class. It consists of five sections: *Introduction*, *Experimental*, *Details*, *Conclusion* (highlights of the experiment; what is intended to learn; answer to the central question); and *Theoretical-Experimental framework* (combination of the conceptual domain with the methodological domain through a knowledge “V” of Gowin [30]):

- *Introduction* - shows the name of the activity, the Central Question and the equipment needed for the experiment.
- *Experimental* - this section provides the most relevant procedures to be aware of when carrying out the activity, such as the necessary instruments for the measurements, important information about the experimental setup, practical execution techniques and relevant experimental procedures for data treatment.
- *Details* – identifies important details and specific advices that need to be considered in carrying out the experiment, taking into account the technique used. Very often, students do not realize these details and/or technical information simply by reading the experimental protocols and because of this, the experiment is not performed in the best conditions. This section outlines the essential procedures for a proper use of the equipment, to take into account for enhancing experimental performance.
- *Conclusions* – this section summarizes the experimental activity. In this section, the main aspects of the experience and what is expected to learn from it are highlighted, so that the student can reflect critically when discussing, performing and interpreting the results of the experiment.
- *Theoretical-Experimental Framework* – in this last section, it is intended that the student becomes aware that the experiment he/she will perform has a well-defined educational purpose (not just one more activity) and fits into a learning content and sequence. This framework is presented in the form of a semi-filled epistemological “V” of Gowin [30-31].

An example of an introductory video can be found at <https://youtu.be/JTo6HmQtAn4> (Figure 1).



Figure 1. Screenshots of the introductory video of the Bouncing Ball Experiment [32]

Each introductory video has an exploration script built on an inquiry-based perspective. From their observation of the videos, students can discuss the script for each experimental activity with their mates and the teacher, not depending entirely on pre-designed protocols. After the completion of the laboratory activity, students will have to build a knowledge “V” report in order to fit the conceptual wing with the methodological wing, and to give an answer to the problematic question emerging from each activity. The models / theories and principles / laws of the conceptual wing may be pre-filled in the way presented in the video. The fact that the “V” is partially filled does not detract from the students' initiative, since students still have to identify the concepts studied in the experimental activity and all the methodological part will also be completed by them. The “V” is a kind of simplified version of an experimental report, a lighter but equally formative alternative to the traditional report (Figure 2).

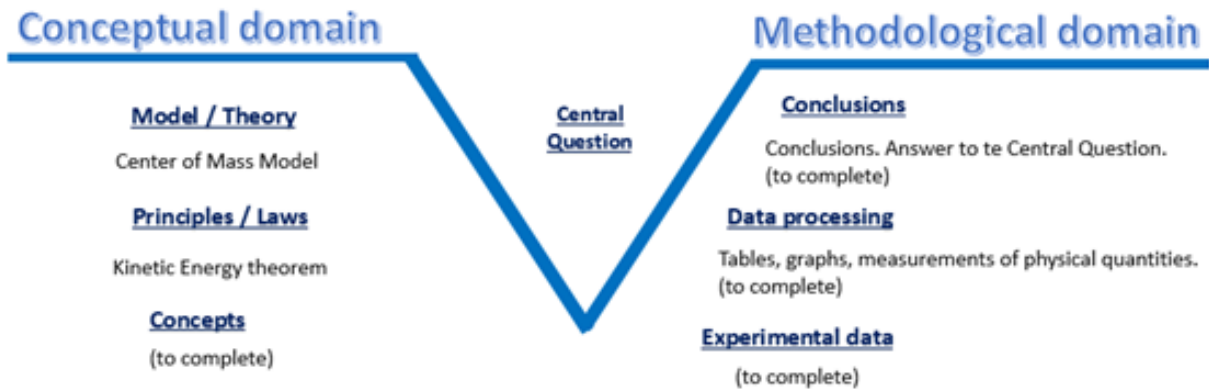


Figure 2. Knowledge “V” report of the Bouncing Ball Experiment [32].

To complement the experimental work, a PCS was built recreating the laboratory conditions and also allowing users to change physical parameters (e.g., ball’s initial height, coefficient of restitution, ...). An inquiry-based exploration is provided in the simulation to promote an active learning environment. Figure 3 shows a snapshot of the simulation in its English version.

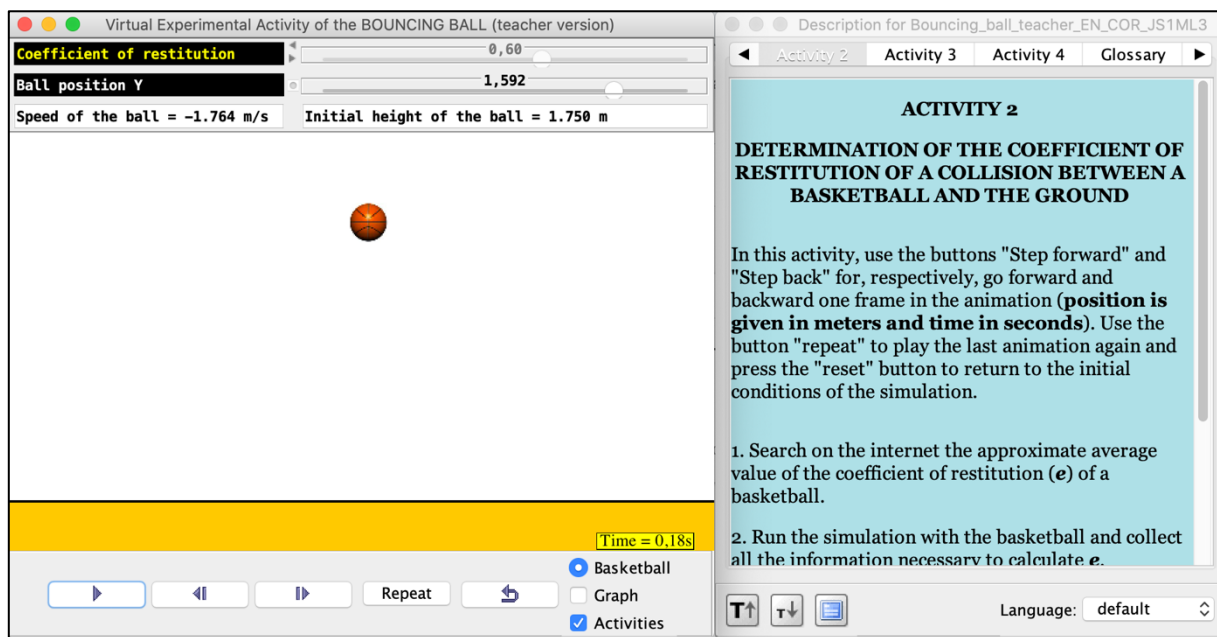


Figure 3. Snapshot of the PCS for the Bouncing Ball Experiment.

It can then be said that the pedagogical novelty offered by the VLAB-FIS project is to provide students with a concrete and real view of the execution of the experimental activity to be performed and its procedural and conceptual aspects. It offers a holistic view of the students' learning experience. Moreover, this resource package also carries a motivational factor, giving the students a real and global view of a given content, which then encourages them to invest in their knowledge. The project also assists teachers in teaching practice in relation to laboratory activities, as it focuses on mandatory experiments at levels K-10 (15 years) and K-11 (16 years) in Portuguese curricula.

Before the project was ready for implementation in high schools for the mandatory experiments, we gathered information to better understand the feasibility of the project in Portuguese secondary schools from the teachers' viewpoint and so, some workshops were held. At the end of the practical workshop in the 1st Meeting of “Casa das Ciências” on the island of São Miguel, Azores, in 2018, we asked the participating teachers to assess the project and give their suggestions and/or opinions concerning their perception and the feasibility of implementation in teaching practice of VLAB-FIS project as a pedagogical resource [33]. Twenty-four local teachers, fifteen females and nine males, responded to that question. All participants were local physics teachers.

The feasibility, applicability and usefulness of the project in the school context, as initially thought, seems to be great in the opinion of the teachers participating in that workshop, as they recognize that besides motivating, guiding and improving students' work, the digital tasks make them more autonomous and responsible. Teachers' responses were then qualified and transformed into data for investigation [34]. All teachers (100%) considered the project useful as support for the preparation of laboratory classes. This result is not surprising, since teachers recognize the usefulness of video in disseminating scientific content [35] and video annotations [36] in student learning. The reasons invoked in the justifications for the responses obtained are somewhat diverse, as shown in Figure 4.

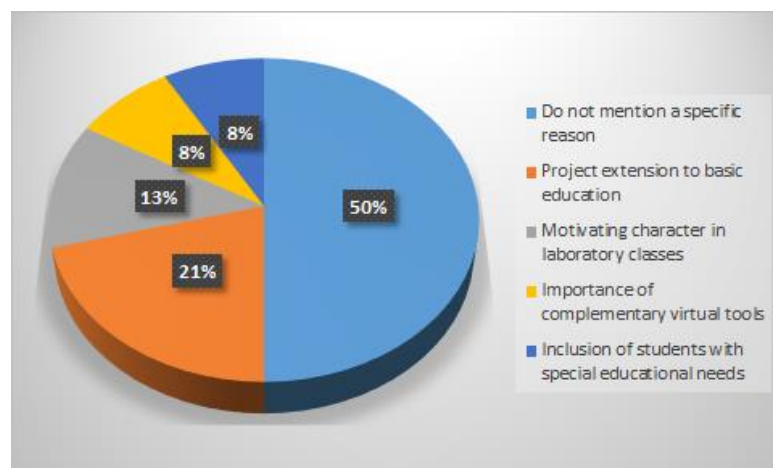


Figure 4. Percentage graph of teachers' responses at the 1st Meeting of “Casa das Ciências” in Azores (2018).

Two teachers (8.3%) recognized the use of introductory videos with students with special educational needs; three teachers (12.5%) pointed out that the project may have a motivating character for laboratory classes, since tools that are familiar to students are used; two teachers (8.3%) gave importance to the existence of virtual tools complementary to the laboratory experiments, especially when the school does not have the necessary material to carry out the experimental activity; five teachers (20.9%) suggested extending the project to basic education and, finally, twelve teachers (50.0%) claimed that the project has good feasibility and applicability, but without clarifying a specific reason. These ideas are expressed in the generality of the comments obtained, of which we transcribe the following two:

Teacher A: “*The presentation of the video with the structure of the [virtual] experimental activity directs the student in the preparation of the experimental class, since it is often found that the student gets lost in the preparation of the experimental activities, which can lead to poor experimental results or even failure in doing so. This strategy can act as motivation for*

the student. It is a great asset for students with motor disabilities who, in addition to being able to participate in experimental activities, perform them simultaneously with other people. For teachers, it is a very useful project to systematize laboratory activities.”

Teacher B: *“These resources are worth using because they help the teacher in the preliminary exploration of the activities with his students. Videos and exploration scripts alert students to certain details that might otherwise go unnoticed. They also allow students to better understand the activity by what they have observed, and they can make the relationships between concepts easier and more conscious.”*

Currently, the project is already being applied in two Portuguese high schools as pilot research studies in the teaching of Physics, as a complement to laboratory classes. The digital resources can be found at the webpages <https://www.fc.up.pt/giedif/vlab-fis-10-o-ano/> for mandatory K-10 experiments and <https://www.fc.up.pt/giedif/videos-vlab-fis/> for K-11 mandatory experiments, in Portuguese language. It involves about 180 students, and next year will be tested at a special school for students with physical disabilities. The project is being implemented in the following way: each introductory video is accompanied by an exploration script (given by the authors), consisting of questions to be answered shortly after viewing the video. This will provide important support for students to think about the Central Question and thus be better prepared to perform the experimental activity. To evaluate the students' video watching task, a Kahoot! [37] test was developed for each IV. Kahoot! is a free learning platform based on games. It allows to create quiz games in which the teacher adds questions, and these are converted into an interactive game with points. In the course of the activity, the teacher receives the statistics of the students' successes and errors, and at the end of the game he/she can access individual information about the performance of each student in an Excel table.

As for the other components of the project, namely VR and PCS, teachers are invited to decide how to explore these digital resources, inside or outside the laboratory class, according to their pedagogical choices and the students' learning needs. Inquiry-based exploration scripts were also developed for the PCS. VR and PCS as well as the corresponding exploration scripts, are freely supplied to teachers willing to participate in the project.

3 Conclusion

The teacher's ability to work with digital resources with students has a positive impact on learning. The contemporary generation is very familiar with the use of media and digital technology, and this is a major factor that can help spark curiosity and the desire to learn. Therefore, the use of videos and simulation-based virtual resources can play an important role in engaging and supporting students in physics lab classes. The VLAB-FIS project allows students to have a global view of experimental work and helps them better understand the content of the experiment. In addition, it offers the teacher a didactic sequence formed by pre and post-laboratory activities that promote the active learning of students. It also allows students with physical disabilities to feel involved in laboratory classes and to be part of working groups, rather than just being registered in a class.

Due to its simplicity, VLAB-FIS allows students to prepare themselves prior to the activity that will be accomplished at the laboratory, i.e. students will be able to become aware of what will be done in the experimental activity and thus have a responsible role in the laboratory. The project is underway for two Portuguese secondary schools to help students better understand mandatory experimental work at levels K-10 and K-11. Work is in progress to create digital resources based on this new approach for elementary schools and also in other European countries through an Erasmus+ project.

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