PROPOSAL OF METHODOLOGY FOR AN ACTIVE LEARNING IN SCIENCES

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Keywords: *student-centered pedagogy, learning active methodology, sciences club, school projects*

1. INTRODUCTION

In Portugal the discipline of Physics and Chemistry is the discipline with the worst results in national exams. This is due, in part, to the fact that physics is a counterintuitive science, as referred by the Portuguese Society of Physics (Visão, 2014). The extent of the contents, the national exams stress and the use of pedagogical approaches little student-centered, little active, collaborative and that do not respect the interests and needs of the students, can be factors that restrict the development of students' capacities and consequently their full integration into public life (scientific, political, economic, social and cultural). The distinction between traditional teacher-centered pedagogy and student-centered pedagogy can be found, for example in Cicchelli (1983). Traditional teacher-centered pedagogy is generally defined as a style in which the teacher assumes primary responsibility for the communication of knowledge to students and is centered in their expertise and authority in the classroom based upon a model of an active teacher and a passive student. Student-centered pedagogy is based upon a model of an active student. The teacher is viewed as a facilitator who assists students in their learning and not as the primary source of knowledge in the classroom.

On the other hand, there is a consensus about the importance of experimental teaching, for understanding the concepts, and about the central role of teachers in their implementation. The teacher has to teach students to learn throughout their lives, to relate content to the real world and encourages them to conduct research beyond the internet. Thus the teacher plays an active role, mediator and advisor in the development of critical and creative thinking of students in order to help them make informed and well-founded decisions.

The Experimental Science Teaching Club (ESTC) has emerged to fill the gap in formal education with regard to linking content with the real world, and because a significant number of students expressed an interest in deepening experimental knowledge related to the school program and day-to-day life (Teixeira and Soares, 2010, 2015; Teixeira *et al*., 2015). The ESTC is a low-cost project with a student-centered pedagogy, non-formal, facultative, open to the community and to the students and/or teachers initiatives. Thus, the main purposes of this work are to present the methodology used in ESTC, the typology of the activities developed, to show the impact of ESTC on students, teachers and community and to present some projects that explore active learning and some of them with social impact.

2. EXPERIMENTAL SCIENCE TEACHING CLUB

We share the opinion that it is unlikely that the teaching of sciences focused only on contents generates procedural skills, attitudes and values to the full exercise of citizenship. Besides that, we feel the need to respond to the students who show willingness to respond to their "whys" in the school labs, and contribute to the promotion of scientific literacy of the school community. Thus the ESTC works in articulation with the formal education, is an interdisciplinary and transversal project that values students' knowledge. Furthermore, ESTC is a non-formal educational space, where teaching and learning are focused on ideas and interests of the students and the teacher has the role of supervisor and promoter of this space. Hence, ESTC has as main mission to make available to the students of the secondary education a place of debate and experimentation of ideas on science and technology or of other subjects of their interest.

The methodology is based on the following topics: discussion of ideas, inside and/or outside the classroom, about projects/activities that the students intend to develop, development of projects in a non-formal environment; conducting lecture cycles; articulation of projects with formal education; obtaining products of the projects; presentation of the products to the community. In the cycle of lectures, researchers from higher education participate to give lectures on the themes of the projects. The ESTC activities are held weekly, are optional and interdisciplinary, focused on students and with scientific humor.

Table 1 shows the type of activities developed in the ESTC since its creation and the percentage of time spent in these activities.

Table 1- Percentage of time spent on activities in the ESTC.

Developed activities	Time spent (%)
Illustrative activities	25
Clarification of doubts. Preparation of school tests	18
Participation in projects and competitions	17
Practical-laboratory activities of the school program	10
Preparation and presentation of the open Laboratory	8
Modeling and virtual laboratories	5
Investigative activities	5
Preparation of the Olympics and “fis” of “PmatE” competitions	5
Creation of a Museum of Natural History, Sciences and Technologies	5
Lectures	2

From the Tab [1] we highlight the following: illustrative activities, which aim to strengthen the conceptual knowledge (Leite, 2001) are very motivating and attract students to the club. They are of short duration, usually take less than 15 minutes, and are followed by an explanation of the illustrated phenomenon and of the respective connection to content taught in the formal education. The activities in support of the study as the clarification of doubts, the preparation of the school tests and the exploration of the practical-laboratory activities of the school program also allow the students to see ESTC as a place of reflection on the concepts and contents taught in the classroom (articulation between formal and non-formal education). In this way, the ESTC also contributes to the improvement of the student's academic performance. The development of projects, investigative activities and the resolution of open problems lead to the construction of new conceptual knowledge (Leite, 2001).

The methodology implemented in the ESTC encourages the students to participate in projects, to discover interests and vocations, and enables the students to make a difference, to be happy and to find their place in society. On the other hand, there is also a concern to involve students in the use of computational simulations, so that they can verify that current science is based on the paradigm of three areas: theory, experimentation and computation.

In summary, the methodology of the ESTC is based on the diversification of activities in order to satisfy the curiosity, needs, interests and expectations of the students, which is the main factor that contributes to the success of the club and has kept it alive with a constant renewal of students.

Furthermore, the commitment, dedication and autonomy of the students, as well as the products obtained from the work developed and their application in other contexts allows the ESTC to be seen as a factory of enterprising students, active and committed to the world today.

Before presenting some of the projects developed at the club, is important to highlight the positive impact that the club has had on the results of the classification of the internal frequency and national Physics and Chemistry A exam. The ratings of the students who attended the ESTC were always superiors to the ratings of the students who did not attended. For example, between the school years 2006/7 and 2012/13 the differences ranged from 1.3 to 5.1 values for the internal frequency and from 1.6 and 5.8 values for national exams (Teixeira and Soares, 2015; Teixeira *et al*., 2015).

3. SOME EXAMPLES OF THE PROJECTS DEVELOPED IN THE ESTC

Of the various projects developed at the club in this paper we present only some of them.

The project of the *Undulatory Effect of the Motion of a Set of Pendulums* (Berg, 1991), was a real challenge for the students of the club since it involved the reproduction of a device observed in a video found on the internet (Teixeira *et al*., 2012). This work involved the three pillars of knowledge; theory, experimental and computational. However the most difficult task was the calibration of the pendulums. The development of a computational model with the *Modellus* software was an added difficulty for the students, but at the same time an exciting task. With this project the students won an honorable mention in the 20th Competition of Young Scientists and Researchers in 2012. Figure 2 shows a representative picture of the work developed by the students.

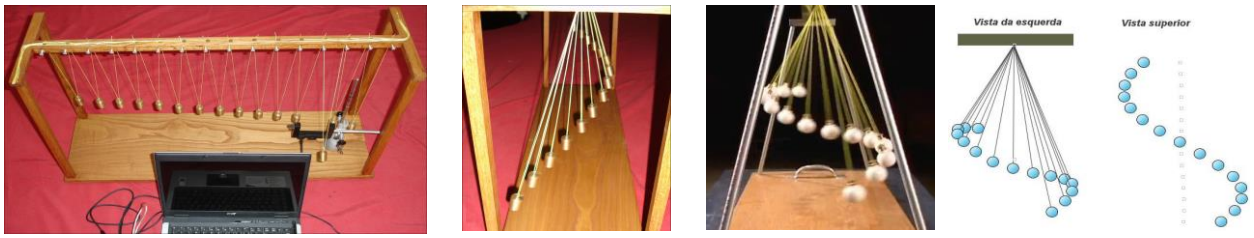

Figure 2- Device of the set of pendulums and image with a computational simulation.

The *Hydrogen-Free Combustion* is an attractive project to the students, due to the noise produced by the shock wave resulting from the violent combustion of hydrogen (Soares *et al*., 2015). The exothermic reaction shows that controlled combustion of hydrogen can be an alternative to the fossil energy sources. Figure 3 shows four instants during the combustion of the hydrogen.

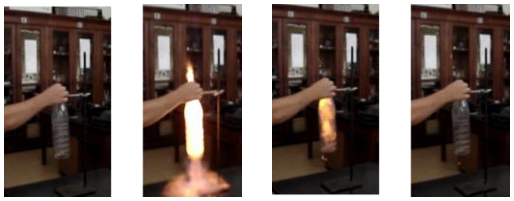

Figure 3- Four instants during the combustion of the hydrogen.

The project *Combustion of a Candle within an Inverted Glass Partly Immersed in a Recipient with Water*, had as objective to verify if the theoretical explanation of the phenomenon presented in the textbooks is correct (Teixeira and Soares, 2015). Overall, this phenomenon is related to the expansion of air during the heating and with its contraction when cools. The candle flame heats the air inside the glass forcing it to expand and to leave and, when it is extinguished, the pressure inside the glass decreases due to the cooling of the air, forcing the water to enter the glass. It was also found that the candle is extinguished when the oxygen concentration reaches approximately 17%, see Fig. [4].

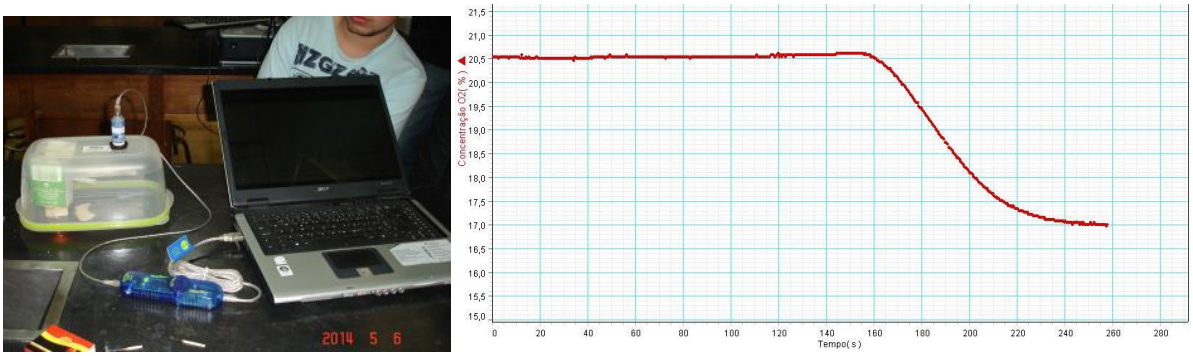

Figure 4- Device for measuring the concentration of oxygen.

From the results of the project, a validated guide was elaborated for teachers with activities that allow explaining the rise of water inside the glass. Some teaching resources, Fig. [5], were developed in the ESTC to explain the variation of the volume of air inside the glass and the fact that the candle goes out (Teixeira *et al*., 2016a). The activities were held in 11 classes of the preschool and 19 classes of the 1st cycle, in Vila Real district, covering a total of 453 students.

Figure 5- Some teaching resources used in preschool and 1st cycle classrooms.

For the project *Museum of Natural History, Sciences and Technologies* the students developed descriptive fiches of various ancient instruments. The work was presented at the 26th Iberian Meeting for the Teaching of Physics and won the prize for the best poster communication (Teixeira *et al*., 2016b).

With the project *Watering with the Humidity of the Air*, the ESTC has built an irrigation system for plants and trees that take the water from humidity of the air, Fig.[6].

Figure 6- Irrigation system for plants and trees that take the water from humidity of the air.

The idea of the project is born with students' concern about drought and forest fires The objective is to develop an apparatus that reduces the number of annual irrigations almost to zero and that it is energetically autonomous. The project mobilizes several areas of knowledge: physics, chemistry, meteorology, agriculture, computer science, electronics, mathematics, mechanics and the arts. Students had the opportunity to test and improve their skills at the level of know-how and obtain a multidisciplinary view of solving problems of social interest. The project culminated with the construction of boxes, which allow the development of plants and trees in extreme drought

zones and a condenser that captures the water vapor from the air. The condenser is portable, noiseless, inexpensive and can be connected to a photovoltaic panel and produces up to 250 mL of water per day. It was selected for the national exhibition of the prize science in the school of the Ilídio Pinho Foundation 2018.

It was also selected for the aforementioned national exhibition the project *Avoid Fires in Portugal: a Pedagogical* Contribution, which involved the ESTC in the preparation and organization of ten laboratory activities for 500 preschool and 1st cycle students. Were also developed and validated a laboratory activity guide for teachers, and a calendar of 2019 with the activities carried out. Its marketing yielded 1000 euros which will be used for the reforestation of a burning area.

Finally, the project *Measuring of the Gravitational Acceleration with the Accuracy of Two Decimal places*, with budget up to 5 euros, forced the students to test various devices so as not to exceed the budget. With this project they won the 2nd prize "ATLAS do Saber 2018". The need to test different equipment allowed an active learning centered in the students.

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