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Simple electrical circuits using simulations and experiments in a High School[1]

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ABSTRACT

It is very important for Science Teaching that experimental activities are planned in a way that promotes the link between scientific theories and reality. In view of this, a Technological-Technical Product (or educational product) was developed in this work, which integrates computational activities through simulations with the online platform PhET, and experimental activities, using the Arduino prototyping board, for teaching physics in High School, specifically for the study of electricity focused on simple electrical circuits. The material is designed for teachers interested in the implementation of active methods aimed at alleviating students' alternative conceptions of electricity. Its application and validation with a group of 3rd grade high school students reinforced the importance of experimental activities and the use of digital technologies in the classroom, such as Arduino and the online platform PhET. In addition, there was an emphasis on the approach of alternative conceptions, indicating the importance of dealing with this issue in teaching and learning relationships.

KEYWORDS: Electricity. High school. Alternative conceptions. PhET. Arduino.

1 INTRODUCTION

Various challenges present themselves to Science Teaching, from difficulties related to teacher updates to the lack of pedagogical materials. Martins (2005) complements, for Physics Teaching, about the difficulty of finding specific methodologies that enable the fulfillment of innovative objectives for teaching and learning relationships. Therefore, this work developed an activity that integrates computational and experimental activities for Physics Teaching at High School, particularly for the study of electrical circuits.

Monteiro and collaborators state: "It has already been widely studied and even reached a consensus among researchers in Science Teaching that experimental activities are very important for the teaching and learning process of scientific concepts" (MONTEIRO *et al*., 2018, p. 1004, our translation). However, the difficulties faced by teachers in exploring experimentation in practice are well known. One of the difficulties encountered is that the teacher does not consider the prior or alternative conceptions (AC) that students bring about a particular subject.

Given the presented scenario, this work is justified. It is part of the research developed in a professional master's degree program, in which a Technological-Technical Product (PTT) was developed for educational purposes, known as an educational product (EP), applied in a 3rd-grade High School class in the Physics discipline. This PTT proposes activities related to the content of electricity, specifically simple electrical circuits.

Regarding the didactic approaches present in the PTT, the material proposes constructing a teaching and learning relationship based on students' alternative conceptions about electricity. An initial test (T1) on simple electrical circuits with direct response options was applied to map students' ACs. At another time, students are encouraged to test their responses using computational simulation from the online digital platform PhET. Subsequently, to empirically validate what was obtained through the computational simulation, circuits are assembled with the help of the Arduino platform. The idea is that the student is instigated with the circuits of test T1 to think about the phenomena of electricity, and then investigate them (similarly to the investigation process that would be done by a researcher facing a research problem). At the end, another test T2, presenting the same questions as T1 but reordered, is applied to lead the participant once again to reflect on which conception they will use to answer the questions.

Thus, the work's methodology involved the development and planning of the PTT. Next, data collection during the classroom application took place. The work's objective is precisely to investigate the potential of the developed material for scientific learning of electrical circuits topics, making its validation in a pedagogical environment essential. This step took place with a group of 20 students from the 3rd grade of High School, in a private school in the municipality of Sarandi, in the state of Rio Grande do Sul.

With this application, the analysis and discussion of the results aimed to ponder over the students' experience during the development of the PTT activities. With tests T1 and T2, numerical data were obtained, which helped to discuss the possible scientific learning of the involved knowledge. Additionally, with the reports from the local teacher who assisted in the EP application, it was possible to discuss and reflect more broadly on the ease and difficulties of its use, both with the teacher's and the students' comments.

It is emphasized that the discussion of the results sought to explore the impacts of practical activities, using digital tools, in this teaching and learning relationship.

The question to be answered in this work is: what are the contributions of an educational PTT based on the integration of real experiments and computational simulations in the formation of High School students?

2 THEORETICAL FRAMEWORK

2.1 Experiments in science classes

O Experimental Work (EW) "is the activity developed in an environment created for this purpose, involving students in planned learning experiences, interacting with materials to observe and understand phenomena" (NEVES; CABALHERO; MOREIRA, 2006, p. 384, our traslation).

EW has been widely studied for its relevance in science learning as a teaching methodology. However, EW has not always been satisfactory, to the extent that some authors advocate the need for its reconceptualization in light of a social constructivist perspective of the nature of science and learning, seeking ways to achieve meaningful learning (NEVES; CABALHERO; MOREIRA, 2006, p. 384). The same authors state:

> The importance of EW is recognized by the most representative models of science teaching, leading us to admit that it indeed possesses relevant educational potential. [...] "hands-on" activities are not sufficient; it is also necessary to resort to experiences that involve "minds-on," that is, beyond manipulating equipment, it is essential to manipulate ideas. [...] it involves placing students in problematic situations where the search for solutions leads to the restructuring of the knowledge they already possess (NEVES; CABALHERO; MOREIRA, 2006, p. 384).

Similarly, Carvalho (2013), discussing knowledge construction and addressing the importance of experimentation as a potential means of this process, says: "[...] the planning of a teaching sequence aimed at leading the student to construct a given concept must start with manipulative activities. In these cases, the question or problem needs to include an experiment [...]" (CARVALHO, 2013, p. 3). Thus, it is inferred that experiments are inevitable in Science classes. Carvalho (2013) says that "[...] overcoming the obstacles already accumulated by everyday life is not an easy task for the school, and one way is [...] to seek to change the experimental culture—from spontaneous experimentation to scientific experimentation—so that students can (re)construct their knowledge" (p. 9).

2.2 Science Teaching and Conceptual Profile

As The first research on the alternative conceptions (AC) that students bring to science classes began in the 1970s. CA are also known as spontaneous concepts, intuitive concepts, spontaneous forms of reasoning, among others. Students' ACs can differ significantly from scientific concepts (NARDI; GATTI, 2004).

Thus, attempts were made to find a model in which the student changes their alternative conceptions to a scientifically accepted conception, being this the first work that describes student learning in terms of conceptual change, proposed by Posner and collaborators (1982). The authors relied on historical and philosophical analyses of science from the works of Kuhn, Lakatos, and Toulmin, and sought to explain how this process of conceptual change would occur.

Many criticisms were made of Posner *et al.*'s (1982) model of conceptual change. According to Nardi and Gatti (2004), these criticisms were important for the development of discussions in the field. Some criticisms are directed at the notion of replacement existing in Posner *et al*.'s (1982) model. Nardi and Gatti (2004) state that subsequent investigations do not present the idea that prior conceptions are replaced by scientific concepts.

Additionally, there is a difficulty in understanding this conceptual change, as "[...] alternative ideas [...] are personal, strongly influenced by the problem context and quite stable and resistant to change [...]" (MORTIMER, 1996, p. 21). This problematizes the idea of a teaching methodology that aims for conceptual change, as students' prior conceptions "[...] are quite resistant to change and, even when subjected to conflict situations, there is often no construction of new knowledge, but reaffirmation of common sense." (SCARPA; SASSERON; SILVA, 2017, p. 10). These authors question:

> Students bring their own conceptions and explanations about natural phenomena, based on their life experiences, the information bombarded every day by the media, by the products on sale, etc. What to do in this scenario? What are the objectives of science teaching in this context? Should the teacher ignore this knowledge? Should they organize their course to make students replace their beliefs and conceptions with scientific knowledge? Or should they provide opportunities to understand the scientific way of thinking about the world? (SCARPA; SASSERON; SILVA, 2017, p. 9).

Given this problem, there is a possibility of an "[...] alternative model to understand students' conceptions [...]: the notion of conceptual profile" (MORTIMER, 1996). The conceptual profile is understood by the notion that a teaching and learning relationship will enable the student to construct new knowledge (scientific knowledge), which will be added to the student's repertoire. That is, the learned knowledge will become part of the student's profile, coexisting with previous ideas, with each being employed in the appropriate context. "This notion allows understanding the evolution of students' ideas in the classroom not as a replacement of alternative ideas by scientific ideas, but as the evolution of a profile of conceptions [...]" (MORTIMER, 1996, p. 23).

Thus, with this understanding, the objective of Science Teaching is to comprehend scientific concepts rather than making students believe in Science. That is, "[...] to understand that theory, without the pretension of believing, but to understand the reasons why some people and the community believe and have shared this knowledge" (SCARPA; SASSERON; SILVA, 2017, p. 17). Therefore, a teaching and learning proposal would seek the construction of scientific knowledge, evidencing that this knowledge will be added to the student's profile.

Additionally, the problem with conceptual change would be a possible suppression of these conceptions brought by the students, thus disregarding traditional knowledge. The dilema would be the inherent thought of scientific superiority, which could escalate to the suppression of any knowledge distinct from Science (whether cultural, religious, philosophical, etc.) (EL-HANI; MORTIMER, 2007; MORTIMER, 1996).

However, as El-Hani and Mortimer (2007) recall, the proposal is one of coexistence, based on ethics, which will guide the dialogues and discussions between these views. Therefore, teaching and learning relationships should seek to provide environments for this understanding to happen. Once scientific learning has occurred, the ethics of coexistence places the two views in dialogues and confrontations.

An interesting point in this context of alternative conceptions would be for Physics Teaching, particularly on the topics of electricity. A typical example of this situation is the analogy of electric current with a water flow. If we consider, for example, an alternating electric current, there are few characteristics that could support this comparison (GRAVINA; BUCHWEITZ, 1994). Andrade *et al*. (2018) comment on the recurrence of these alternative conceptions for electricity and point to the need for specific didactic approaches to these knowledge areas, aiming to address this recurrence.

3 METHODOLOGY

3.1 Teaching Methodology

A teaching methodology aims to address a problem in pedagogical practice and, from there, investigate ways to tackle this educational issue (BORBA; ALMEIDA; GRACIAS, 2019). In this contexto, for example, teachers "[...] consider how to use new digital technologies in the classroom or how to teach a specific content in a more playful manner" (BORBA; ALMEIDA; GRACIAS, 2019, p. 43).

In this work, the teaching methodology focuses on the developed PTT and the proposal of how to use it in the classroom. It is an instructional material for teachers, intended for use in High School Physics Teaching on simple electrical circuits. This material proposes an activity based on the relationship between Science Teaching and the conceptual profile, allowing for a moment of scientific learning that adds to the students' profile.

3.1.1 Technological-Technical Product

An educational product is understood as a tool produced from scientific research, which can be presented in various formats, and is usable by education professionals (BORBA; ALMEIDA; GRACIAS, 2019).

This work proposes an educational product for teaching electricity and applies it, focusing on experimental activities, with an emphasis on the use of the Arduino platform and the online digital platform PhET as technologies for its development.

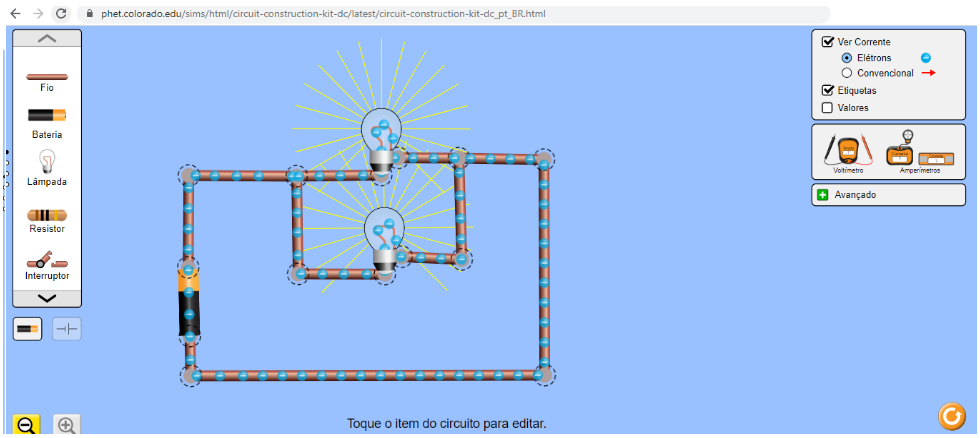
It is an explanatory material for teachers, aiming to guide them so that they can better adapt the activities to their respective contexts and school environments.

The PTT includes suggested activities to map students' ACs. A primary reference to consider is the model of Gravina and Buchewetiz (1994). They indicate that one should start with a survey, through a preliminary test, to map the prior conceptions about electricity brought by the students.

For this, there is test T1, consisting of 10 multiple-choice questions about concepts of electricity in simple electrical circuits, where scientific language terms were avoided as much as possible (see https://drive.google.com/file/d/1yf2zFWrsIs7MaQiWPYj1qZiYx3A7DKp3/view?usp=sharing). After applying T1, the proposal is based on the computer simulation of the circuits in the T1 questionnaire using PhET, which is a free and open computational simulation platform.

Thus, the student uses PhET, drawing the T1 circuits in the software and obtaining the simulation results. That is, the student interacts with a computational model of electrical circuits to obtain the model's predictions for certain circuit configurations. Figure 1 below depicts the PhET simulation screen with a T1 electrical circuit (a circuit with two lamps in parallel).

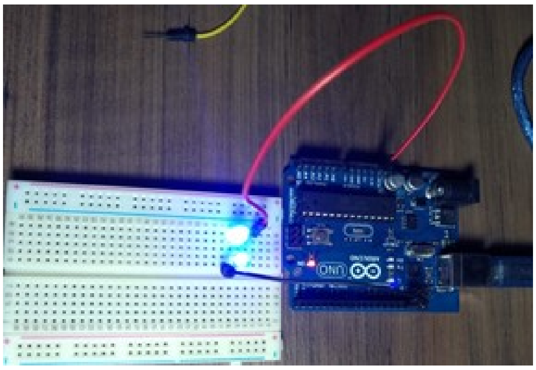
Figure 1 – PhET Simulation ScreenT



Source: UNIVERSITY OF COLORADO (2022).

The tendency would be for the student to consider these computational simulation results as definitive. However, it is also addressed here that every simulation is governed by a computational model developed based on hypotheses, simplifications, and approximations. The natural path of scientific investigation would be to contrast the model's prediction with a real physical system. In this PTT, this would involve creating circuits using the Arduino platform. Figure 2 depicts the use of Arduino to assemble a circuit with two lamps (in this case, LEDs) in parallel.

Figure 2 – Depiction of a Circuit Assembled on Arduino



Source: Authors' Collection (2022).

Regarding this, Arduino is defined as a microcontroller board (a system consisting of hardware and software) developed for various applications (MONK, 2017). As an advantage, this platform is easy to use, allowing even those with basic knowledge to set up initial experiments with the system.

After completing these stages, another test, T2, is applied (see https://drive.google.com/file/d/1SrRKU4jf1Fwd9AXXuX0KasQoKBTzZ519/view?usp=drive_link). The questions were the same as those in T1 but numbered differently, specifically aiming to understand the process that occurred with the students through the activities related to the scientific concepts addressed.

3.2 Research Methodology

The research began with the development of the PTT and the planning for its application in educational settings. The study is qualitative, focusing on observations of specific teaching and learning moments to understand their particularities. According to Borba, Almeida, and Gracias (2019), qualitative research "[...] emphasizes both the subjective and objective dimensions of knowledge [...]" (p. 44). In this context, the research aims to explore the potential of the developed material through observations and analyses of the validation phase conducted in an educational environment.

This research adopts a case study methodology of an exploratory type, aiming to examine a situation to find possibilities and expand knowledge (GIL, 2002). The study seeks to explore the PTT to assess its use in teaching and learning about electricity. Data analysis is based on the characteristics of exploratory research, which involves better understanding the situation of interest by exploring possibilities and challenges encountered (GIL, 2002). This includes analyzing validation reports, perceptions obtained during the activities, and opinions, interpretations, and implications expressed by the participants (whether verbally or in writing). The project, during the development of the material, was registered with the Research Ethics Committee (CEP), with Opinion No. 5.711.144 and Certificate of Ethical Appreciation Presentation (CAAE): 52300121.0.0000.8097.

The validation of the PTT, or its application in an educational environment, occurred with a 3rd-year high school class at a private school in Sarandi, Rio Grande do Sul, with 20 students. The analysis was based on data obtained from tests T1 and T2 of the PTT, student reports, and the teacher's perceptions, to explore the impacts of the proposed experimental activities on the teaching and learning relationship regarding electricity. The previous conceptions of the students about eletrical circuits topics were also explored, and how this potentially influenced the students' learning process. For this discussion, the data from T1 and T2 were analyzed using statistical tools, and the findings were dialogically compared with the data from the pedagogical experience shared by the teacher and students, through the obtained reports.

4 RESULTS AND DISCUSSIONS OF THE PTT APPLICATION WITH A HIGH SCHOOL CLASS

This action was conducted with a class of 20 students in their 3rd year of high school at a private school in Sarandi-RS, with the assistance of the school's physics teacher. The implementation of the proposal in the classroom only began after the students had already covered topics such as electric current, resistor combinations, and other related topics in the curriculum.

The application of the PTT took place over three mettings, each lasting two class periods. The teacher guided all the activities and recorded the students' general report. The activities conducted during these sessions are described in Table 1 below.

Table 1 – General Description of the Sessions with the High School Class

Meeting	Main Activities Performed
1st Meeting: In-person	• Distribution of T1; • Collection of students' responses to T1; • Presentatio of the PhET platform and the simulator to be used; • Simulation of T1 circuits using PhET.
2nd Meeting: In-person, with the authors via videoconference	• Presentation of Arduino: introduction to the platform and initial training experiments; • Assembly of T1 circuits using Arduino.
3rd Meeting: In-person	• Distribution of T2; • Collection of students' responses to T2; • Discussions with students about the activities.

Source: Prepared by the authors (2022).

Although the students had already been exposed to the content, they experienced some difficulty when taking the T1 test. According to the teacher, they claimed they would not know how to solve the circuits. After explaining that it was merely a survey, they agreed to attempt it.

Following this, PhET was introduced. During the computer simulations, the T1 test sheet was returned to the students. The teacher explained how to use PhET and simulated the circuits from the first two questions of T1. The students then took the initiative to run simulations for all T1 circuits in approximately 30 minutes. Despite initial difficulties, the students showed interest in using the simulator and interacted within their small groups. They discussed what they observed and their responses to T1. It was reinforced that these were responses from computer simulations in PhET and that experimental validation with Arduino was still needed.

In the second meeting, the Arduino platform was presented, with researchers participating via videoconference while the local teacher assisted the students in the classroom. Following this, the students used Arduino to build the T1 circuits. At this stage, students were divided into small groups again and demonstrated proactivity and interest in constructing these circuits. They interacted primarily with each other and successfully completed all proposed experiments. The teacher reported that some students expressed a desire to do more activities with Arduino and even requested more complex experiments.

In the final meeting, students took the T2 test, which, as mentioned above, consisted of the same questions as T1 but with different numbering and answer choices. Following this, there were discussions between the students and the teacher about the activities.

To analyze the participants' learning, responses from T1 and T2 were compared for each student. For a meaningful comparison of the results, the T2 test questions were ordered according to the sequence of questions in T1, as shown in Table 2 below:

Table 2 – Responses for T1 and T2 from High School Students

		QUESTIONS										
Student		1	2	3	4	5	6	7	8	9	10	Total correct answers
A	T1	0	1	0	0	1	1	1	0	0	1	5
	T2	1	0	1	0	0	1	1	0	0	0	4
B	T1	0	0	1	1	0	0	0	1	0	1	4
	T2	1	0	1	1	1	1	1	1	1	0	8
C	T1	0	1	0	0	1	0	0	0	0	1	3
	T2	1	0	0	1	1	1	1	1	0	1	7
D	T1	0	0	0	1	0	0	1	0	0	1	3
	T2	1	1	0	0	1	1	1	1	0	1	7
E	T1	1	0	0	0	0	1	1	1	0	1	5
	T2	0	1	0	0	1	1	1	1	0	0	5
F	T1	0	0	0	0	0	0	0	0	0	1	1
	T2	0	1	0	0	0	0	1	1	0	1	4
G	T1	0	0	1	0	0	0	0	0	1	0	2
	T2	1	0	0	1	1	0	1	1	1	1	7

H	T1	1	0	1	0	1	1	0	0	0	1	5
	T2	1	1	0	0	1	0	1	1	0	0	5
I	T1	1	1	1	1	0	1	0	0	0	1	6
	T2	1	0	1	1	1	0	1	1	1	1	8
J	T1	0	0	0	0	0	0	0	0	1	0	1
	T2	1	0	0	1	1	1	0	1	0	1	6
K	T1	0	1	1	1	1	1	1	1	0	1	8
	T2	1	1	0	0	0	1	1	1	0	1	6
L	T1	0	1	1	1	1	0	0	0	1	1	6
	T2	0	0	1	0	1	0	1	0	1	0	4
M	T1	0	0	0	1	0	1	0	1	0	1	4
	T2	1	0	0	1	0	1	1	1	1	0	6
N	T1	0	1	0	1	1	0	1	0	0	1	5
	T2	0	1	0	0	1	0	0	1	0	1	4
O	T1	1	1	0	0	0	0	0	0	0	1	3
	T2	1	1	0	0	0	0	1	1	0	1	5
P	T1	1	1	1	0	0	0	1	0	1	0	5
	T2	1	0	0	1	1	0	1	1	0	1	6
Q	T1	0	1	0	0	0	0	0	0	0	1	2
	T2	1	0	0	1	1	0	1	0	0	1	5
R	T1	0	0	1	0	0	0	0	0	1	1	3
	T2	1	1	0	0	1	0	1	1	1	1	7
S	T1	0	0	0	1	1	0	1	0	0	1	4
	T2	0	0	1	0	1	0	0	0	1	1	4
T	T1	0	1	1	0	0	1	1	1	1	1	7
	T2	1	1	1	1	1	0	1	0	0	1	7
Total per question	T1	5	10	9	8	7	7	8	5	6	17	
	T2	15	9	6	9	15	8	17	15	7	14	

Source: Prepared by the authors (2022).

For these students, there was an improvement in the score in T2 for 12.60% of the class (students B, C, D, F, G, I, J, M, O, P, Q, R), while 4 students, 20% of the class, maintained the same result (students E, H, S, and T), and the remaining 4, 20% of the class, had a lower score in T2 compared to T1 (students A, K, L, and N). Overall, this information may indicate that there was a tendency towards learning the scientific concepts with the application of the educational product, allowing for a greater identification of the domain of use of thse concepts.

In detail, except for students F and O, all other students showed a variation in the number of correct answers between T1 and T2, meaning that correct answers in T1 were not maintainde in T2. This data may indicate that, despite the initial correct answer, the student's conception was not consistent with the scientific conception, or even that their prior conception was not solid. Thus, during the activities, these assumptions were confronted, and the students were in a process of identifying their conceptual profile, leading to uncertainty about which concept to use when choosing alternative.

Individually, for each question, participants showed a decrease in the number of correct answers only in questions 2, 3 and 10, while there was a significant improvement in the number of correct answers for questions 1, 5, 7, and 8. The results indicate that students identified the characteristics of series or parallel associations of circuits with two lamps, as well as the function of the switch and the notions of current and electrical resistance. For more complex questions, such as circuits with 3 lamps, they had difficulty providing the correct scientific answer.

Next, to complement this analysis, the Jamovi software (THE JAMOVI PROJECT, 2021) was used to perform a statistical test with the T1 and T2 scores data from the students, comparing these two data columns in the software. Applying the Wilcoxon test, a non-parametric test for paired data comparison, the first step is to find its significant value p. With Jamovi, the obtained p=0.007. This means that the T1 and T2 data have a statistically significant difference. We then proceed to the results of descriptive statistics, i.e., parameters that help describe the characteristics of the samples (see Table 3).

Table 3 – Statistical Analysis of T1 and T2 Scores of High School Students.

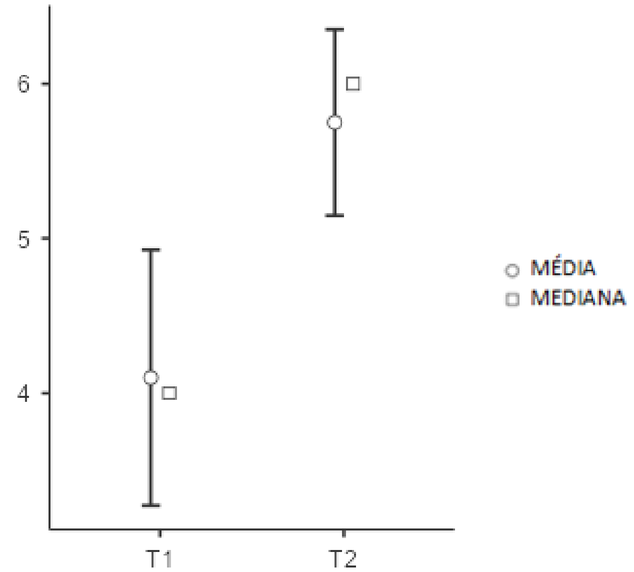
Descriptor	**T1**	**T2**
Mean	4,1	5,75
Median	4,00	6,00
Standard deviation	1,89	1,37
Minimum value	1	4
Maximum value	8	8
1st quartile	3,00	4,75
3rd quartile	5,00	7,00

Source: Prepared by the authors (2022).

With the help of these results, it can be observed that the Mean, Median, Minimum Value, 1st Quartile, and 3rd Quartile increased in T2, which may indicate that learning occurred through the activity. That is, there was potentially an improvement in the students' understanding of the scientific concepts of circuits after completing the proposed PTT activities.

The following graph, also obtained from the Jamovi software (THE JAMOVI PROJECT, 2021), reinforces this perception of scientific learning after the activity. It shows a smaller standard deviation in T2 compared to the Mean, which is higher than in T1 (see Figure 3).

Figure 3 – Statistical Graph of high school students' T1 and T2 scores.



Source: Prepared by the authors (2022).

The continuation of the analysis involves feedback from the class's physics teacher. She highlighted the relevance of the material and its potential for use in the classroom. She emphasized the importance and necessity of incorporating practical experimental activities into physics classes, as this make the lessons more engaging and stimulating for students.

She also reported difficulties with planning, particularly regarding time management for carrying out the activities, which were only possible after the regular theoretical lessons.

Although the application of the PTT was intended to precede the theoretical electricity lessons, it is noted, as stated in the teacher's guide, that the material provides suggestions for teachers to plan and adapt it according to their classroom reality.

However, the teacher's rfeport points to the challenge of introducing innovative and different methodologies into the classroom, in contrast to the rigid traditional planning of regular lessons (in terms of time and extensive content coverage), as discussed by Martins (2005) in his survey of issues in physics teaching.

Despite this, the teacher's perception of student behavior suggests a continued need to seek these methodological innovations. The main point raised by the teacher was regarding students' receptiveness and engagement with the use of PhET and Arduino. According to her, the simulator was well-received and interested all students. During this phase, there was intense interaction and discussion among students about the results obtained. Regarding Arduino, there was generally interest in its use. Although some students had prior experience with Arduino-based robotics classes, they engaged with the circuit assembly.

The teacher also noted that initially, students tended to want immediate answers without going through more careful reflection. Over time, this immediacy decreased. These comments reinforce the importance of research and educational materials that explore and clarify how to engage students actively.

Thus, the application of the material in the classroom indicates its potential for enhancing the teaching and learning of scientific knowledge about electricity, a perception mainly supported by students' feedback during the activities. The reports reinforces the premise of the importance of experimental activities for understanding electrical circuits, aligning with Carvalho's (2013) theoretical framework on the crucial role of practical and experimental work in science education. The results indicate that the use of technological tools can be a valuable resource in the educational environment, providing a more dynamic approach.

Moreover, the methodology adopted for obtaining numerical data (through T1 and T2) demonstrated potential for addressing students' prior conceptions (a core premise of the proposal). This approach allowed for verifying that participating students went through a process of reflection and construction of new knowledge, leading to the observed diversity in scores between T1 and T2 (as presented and discussed).

5 FINAL CONSIDERATIONS

This work was based on the need to provide an experience for students, as "[...] the complex reality imposes difficulties on those who seek to delve into the paths of scientific education" (MARTINS, 2005, p. 54, our traslation). Thus, a Technological-Technical Product (PTT) was developed for teaching electricity in High School, aiming to bring digital technologies into the classroom (PhET platform and Arduino), along with innovative and engaging methodologies.

The application of the material reinforced the need for continuous innovation in the classroom, the importance of incorporating digital and technological tools, and the demand for methodologies that deviate from traditional approaches. It was highlighted that the integration of computational activities using PhET and experimental activities was satisfactory.

In the validation of the PTT, there were significant comments on the importance and relevance of Arduino and the PhET platform. The use of these tools was seen as a differentiator in motivating and engaging students, as well as developing skills in handling and interacting with materials and competencies in arguing with their peers, providing a real scientific learning experience.

The application of the PTT faced some challenges. Its validation occurred during the Covid-19 pandemic, which complicated the process. The initially planned number of presentations was reduced. Additionally, during the validation, it was not possible to conduct all the face-to-face meetings, nor to reschedule them. Due to various periods of the year when face-to-face classes were not allowed, there was limited flexibility for planning practical lessons that would use the PTT.

RBECT
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CIRCUITOS ELÉTRICOS SIMPLES UTILIZANDO SIMULAÇÕES E EXPERIMENTOS EM UMA ESCOLA DE ENSINO MÉDIO

RESUMO

É muito importante para o Ensino de Ciências que as atividades experimentais sejam planejadas de forma a promoveram a vinculação entre teorias científicas e a realidade. Frente a isso, elaborou-se neste trabalho um Produto Técnico-Tecnológico (ou produto educacional) que integra atividades computacionais, por meio de simulações na plataforma online PhET, e atividades experimentais, através da placa de prototipagem Arduino, para o Ensino de Física no Ensino Médio, especificamente para o estudo da eletricidade focado em circuitos elétricos simples. O material é dirigido a professores interessados na implementação de métodos ativos visando a amenização de concepções alternativas dos estudantes sobre eletricidade. Sua aplicação e validação com uma turma de alunos da 3ª série do Ensino Médio reforçou a importância das atividades experimentais e o uso das tecnologias digitais na sala de aula, como o Arduino e a plataforma online PhET. Além disso, teve-se o destaque para a abordagem das concepções alternativas, indicando a importância de se tratar essa questão nas relações de ensino e aprendizagem.

PALAVRAS-CHAVES: Eletricidade. Ensino Médio. Concepções alternativas. PhET. Arduino.

NOTE

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