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An intervention in the teaching of electricity and domagnetism using the photoelectric effect

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ABSTRACT
This work consists of a proposal to insert a content of Modern Physics, the photoelectric effect, in a didactic sequence on electricity and magnetism, discussing that it is possible to work concepts that, normally, are approached in an isolated way, within a "box" of Modern Physics, along with the contents of the so-called Classical Physics. For the elaboration of this proposal it was necessary to analyze how it would be possible to correlate the study of the photoelectric effect, through an experimentally demonstrated application, with topics of the contents of Electricity and Magnetism. After this initial study, it was understood that the phenomenon, along with the suggested application could be addressed within the topics of electrification processes, electrical circuits and magnetic field. It was then possible to produce a didactic unit with the sequence of classes and a methodological proposal for the application with the aid of a simulator available on the internet and a demonstration experiment on the application of the photoelectric effect in automated lighting systems. Respecting the sequence of presentation of the topics, usually arranged in textbooks, it was possible to realize that the proposal is feasible and has the potential to facilitate the understanding of the contents related to the theme, since it provides learning through an application of Physics in everyday life.

Keywords: Photoelectric effect, Modern physics, Classical physics, Electricity, Physics teaching.

1 INTRODUCTION

The teaching of Modern and Contemporary Physics (FMC), despite having had an intense and positive movement for its insertion in High School over the last two decades, little is taught during the final years of Basic Education, either because it is taught only after all the content of the so-called Classical Physics and end up compressed by the short time at the end of the last year of High School, sometimes not even being addressed, or else because many teachers believe that students would have difficulty assimilating the contents of the same (ALVES and SANTOS, 2021; NORMANDO and COSTA, 2019).

However, we increasingly see devices that use physical phenomena in our daily lives, such as the lighting of streetlights at dusk in which a device called a photoelectric relay is used that works by virtue of electrical resistivity and where the phenomenon of the photoelectric effect occurs. It is then necessary to find ways to insert the studies on the phenomena explained by FMC in high school physics classes.

The general objective of this work is to verify the feasibility of approaching a content of FMC, the photoelectric effect, within the traditional content of electricity. The specific objectives are the production of all the material that makes up the didactic unit and its application in a high school class with application of activities.

The methodology used for the development of the work was the production of a didactic unit that involves the content to be worked, with the theoretical explanation, the mathematical language, the historical context, the applications and the experimentation as a didactic strategy. In addition, in the proposal of application of the didactic unit are suggested activities, with the use of digital tools focused on teaching that can contribute to the teaching and learning process of the phenomenon studied. From the pedagogical point of view, the methodology used for the application of the didactic unit was an intervention in a class of the Integrated Technical High School of IFRN - Campus Santa Cruz, during the Physics classes. We opted for the inverted classroom strategy, in which students had access to the content asynchronously through a video lesson and performed activities synchronously.

In the following chapters will be described in more detail the methodology of all the work, the results obtained both from the point of view of material production, as well as the application of the didactic unit and the pertinent discussions making a general evaluation of the work. Finally, the final considerations point out the difficulties faced and indicate other possibilities of proposals for the inclusion of the teaching of FMC in Physics classes in the current educational context.

2 THEORETICAL FRAMEWORK

In general, physics classes in high school boil down to the presentation of mathematical concepts and formulas. Often, this teaching method causes a lack of interest in science, because it does not value important aspects of the study of the natural sciences such as research and creativity.

Thus, the use of historical context in classes enables a better understanding of this curricular component, as well as makes the teaching of physics more interesting.

According to Gleiser (1997, p.13 apud PEREIRA et al., 2017):

> The importance of knowing the History of Sciences, in general, is to have the notion of how our understanding of Nature and the Universe developed hand in hand with Physics, from its origins with the pre-Socratic philosophers of Ancient Greece, to the introduction of quantum mechanics and the theory of relativity during the first three decades of the twentieth century data interpretation. We venture to say that there is poetry in physics, that physics is a profoundly human expression of our reverence for the beauty of Nature. (PEREIRA et al., 2017, p. 252)

With the advancement of technology come more and more didactic resources to make teaching more dynamic and more pleasurable. In the teaching of physics, the use of simulators has become an alternative for those schools that do not have laboratories of this discipline, thus making the classes more interesting and with greater participation of the students.

According to Santos (2016):

> In practice, the discipline Physics represents for the student, in most cases, only a very difficult discipline, in which it is necessary to memorize formulas, whose origin and purpose are unknown. Therefore, through the free software PhET Interactive Simulations, it is desired to introduce modeling and simulations in the teaching-learning process in order to demystify this image of Physics, enabling a better understanding of its content and contributing to cognitive development in general, because modeling and simulations facilitate the construction of relationships and meanings, favoring constructivist learning. (SAINTS, 2016, p. 12)

It is increasingly common for teachers to search for new methodologies to make teaching more dynamic and more participatory. Thus, experimentation emerges as a very viable alternative, since in Physics there are many didactic experiments and this would imply a greater participation of students, because they would learn in practice various concepts and laws of Physics.

According to Abib and Araújo (2003) the "use of experimental activities as a strategy for teaching Physics has been pointed out by teachers and students as one of the most fruitful ways to minimize the difficulties of learning and teaching Physics in a meaningful and consistent way". Also according to these authors:

> The analysis of the role of experimental activities developed widely in recent decades reveals that there is a significant variety of possibilities and trends in the use of this strategy of teaching Physics, so that these activities can be conceived from situations that focus on the mere verification of laws and theories, to situations that privilege the conditions for students to reflect and review their ideas about the phenomena and concepts addressed, thus being able to reach a level of learning that allows them to carry out a restructuring of their explanatory models of the phenomena. (ABIB, ARAÚJO, 2003, p. 177)

This type of research involves the questioning of a specific group, whose particular knowledge we want to know through an open questionnaire. After the collection of data and information, through quantitative analysis, obtaining the corresponding conclusions, we have to collect data in its majority

> [...] not all members of the population studied are surveyed. Before we select, through statistical procedures, a significant sample of the entire universe, which is taken as the object of investigation. The conclusions obtained from this sample are projected for the entire universe, considering the margin of error, which is obtained through statistical calculations (GIL, 2010, p. 35).

Sample surveys are widely used by social researchers and others.

Its main characteristic is direct knowledge, economy, speed and quantification.

3 METHODOLOGY

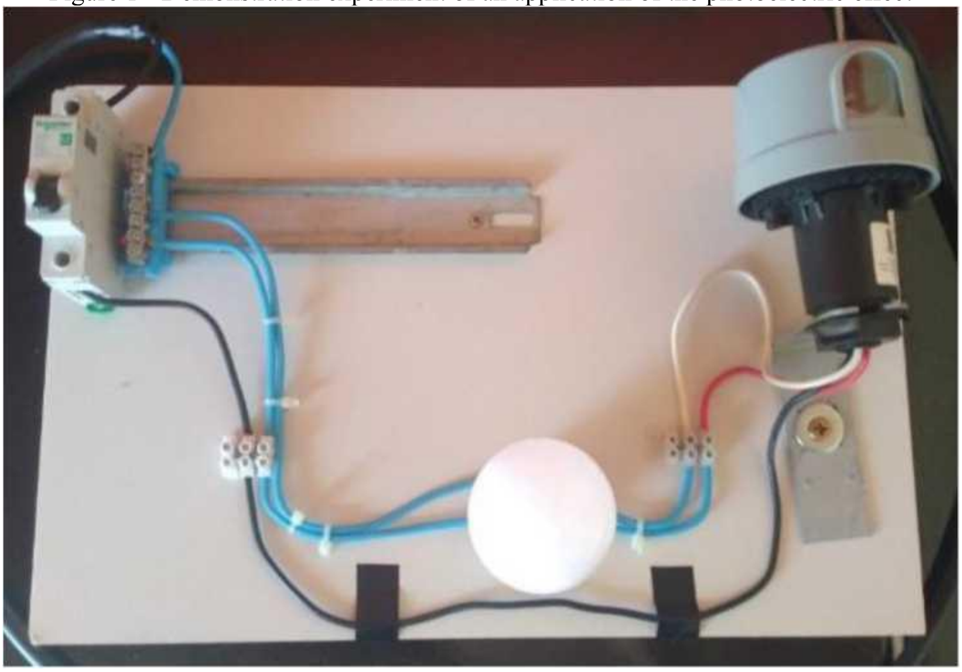
This work began with the choice of the theme of the photoelectric effect. This choice occurred from the objective of dealing with a content of Modern Physics within the didactic sequence of the so-called Classical Physics, more specifically the contents of electricity and magnetism.

The target audience of the application of this work was the class of the second year of High School of the Integrated Technical Course in Informatics of IFRN - Campus Santa Cruz. The choice of the class was motivated by them meeting the minimum requirements of the contents addressed in the didactic unit.

As fellows of the Initiation Program to Teaching (Pibid), the application was carried out in the period of remote classes during the covid-19 pandemic in the month of August of the year 2021 and after the students had contact with the contents of Electricity and Magnetism.

The first part developed in this work was the construction of an experiment where it is possible to demonstrate an application of the photoelectric effect (Figure 1). The experiment consists of the automatic activation of a lamp through a photoelectric cell. As it was not possible to carry out the experimental demonstration in person, it was decided to record a video of the experiment[1] and make it available along with the video lesson that deals with the content.

Figure 1 - Demonstration experiment of an application of the photoelectric effect



Source: Author's Collection (2022)

The first action with the participation of the students occurred with the application of the open questionnaire with eight questions to probe the previous knowledge of the students about the topics that are part of the context of the photoelectric effect and in the sequence the link was made available. The video lesson began with the experiment and with the following question: how does the lamp turn on and off in this electrical circuit? Then the explanation continued with the theory that explains the phenomenon studied. The historical context, the explanation of the phenomenon with the use of an online simulator of the photoelectric effect and some technological applications in use in society were addressed.

[1] Video available in: https://youtu.be/SmD2MWmFL50 Accessed: 17 nov. 2022.

One week after the questionnaire and the video lesson were available, the synchronous moment occurred. In the first part of this moment, the students of the High School class were able to share the doubts that arose while watching the video lesson, in addition to the comments in general. The planned activities were applied in sequence, still during the synchronous moment. The quizz, composed of ten questions, was performed using the kahoot online quizz tool in teach mode (questions and answers in real time) and almost all students participated by answering questions about the content. A few students had connection problems and could not answer the questions during the synchronous moment, but had the opportunity to answer them later also by kahoot in assign mode (assigned activity to be performed within the given deadline). The other planned activity was explained during the synchronous moment, but students were able to complete it later. It consisted of conducting a research on the applications of the photoelectric effect, in addition to the one that was presented in the video class. To share their research, the students had access to a mural, previously created, in the padlet (platform of murals and screens with shared posts).

4 RESULTS AND DISCUSSION

Regarding the questionnaire about the students' previous knowledge, the texts of the first two questions were, respectively: "with your words, explain what a wave is from the point of view of physics" and "describe, according to your understanding, what light is". It is possible to affirm that the answers to questions 1 and 2 were, for the most part, satisfactory. This data shows that most of the class already had some knowledge about waves in general and about light in a more specific way. The following questions were interconnected two by two (3 and 4, 5 and 6, 7 and 8) and were discussed on FMC topics. Table 1 presents questions 3, 5 and 7 and the percentages of answers (yes or no) for each one. It is worth remembering that these issues were personal. The student should honestly answer whether he knew anything about the subject.

Table 1- Analysis of the answers to questions 3, 5 and 7 of the questionnaire on previous knowledge.

No. question	Question	Answer Answer	
		yes	No
3	Do you have any knowledge about the quantization of energy?	23,1%	76,9%
5	Do you know what a photon is?	84,6%	15,4%
7	You know or have heard of the effect photoeletric?	53,8%	46,2%

Source: Created by the author (2022)

It is important to note that in the questions subsequent to each of the questions in the table above, the student had the option of writing what he understood about what was asked. In general, the answers to the questions in this form showed that most of the students had some knowledge about topics normally worked on in FMC, even though they had studied only contents that are part of the so-called classical physics. However, specifically regarding the phenomenon whose understanding is the focus of this work, the answers to question 7 were practically a half and half, that is, half of the class stated that at least they had heard of the phenomenon and the other half said no. The analysis of the responses of the proposed activities at the synchronous moment (one week after the availability of the questionnaire on previous knowledge), arranged in the following paragraphs, will show a more accurate picture regarding the knowledge of these students about the content.

In the synchronous class with the class, it was possible to clear the doubts and clarify the questions that arose in the asynchronous moment of the students. It is possible to infer that the students watched the video class carefully, because several doubts arose about the quantization of light, about photons and about the applications of the phenomenon. Some doubts were: "whether it was applicable to solar energy and how it worked", "whether light is wave or particle". During this dialogical process with the students, the importance of understanding light not only as an electromagnetic wave, but also with the behavior of small packets of energy (particles) in some phenomena was emphasized. The idea of quantization of energy was highlighted. In addition, doubts about the emergence of an electric current from the photoelectric effect were clarified.

Regarding the quizz performed at the synchronous moment through kahoot, it can be highlighted that the result was not as expected. Most of the questions had a low percentage of correct answers and only 30% of the questions had more than half of the correct answers. It is believed that the time to answer the questions was not the most appropriate. In addition, a more careful analysis of the wrong answers would be necessary in order to be able to diagnose the greatest difficulties.

The second activity, in which each student should post on the padlet's wall their research on the applications of the phenomenon had a satisfactory result. Most of the students made interesting posts, showing several different applications of the technologies involving the photoelectric effect. The fact that all students can see their peers' research makes the activity very interactive and enriching. Among the applications researched are night vision, televisions, cameras, automatic doors and solar panels.

Overall, students demonstrated engagement in their learning. It is possible to consider that the results were satisfactory, since there were about 48% of correct answers in the first evaluation and almost 100% in the second. In addition, there were reports of students saying that it was interesting to understand how the lights of the streetlights of the city come on, because it often goes unnoticed how they work. Thus, the intervention performed met expectations.

5 FINAL CONSIDERATIONS

The proposal to insert a content that is usually addressed in the didactic sequence of modern physics, within the study of electricity proved feasible and effective. Even with the difficulties of the moment experienced due to the COVID 19 pandemic, it was possible to perceive the engagement of the students in learning a subject that arouses a lot of curiosity. It is important to highlight that not all the results of the activities were satisfactory from a quantitative point of view, but we believe that the objectives were achieved, because the students demonstrate interest in learning when they interacted intensely even remotely. The demonstrative experimental apparatus proved to be very useful to arouse the curiosity of the students and serve as a model of technological application of the photoelectric effect. The junction between the experimental part and the theoretical content facilitated the whole approach to the content and made the explanation less abstract.

The difficulties arising from the short time in the period of remote classes did not compromise the development of this work, but it was clear that, for a better evaluation of learning, more time would be needed. However, the students made an effort to learn more about the photoelectric effect as an electrification process and to show interest in its applications. In addition, the students were flexible and skilled with the technologies used in the teaching and learning process.

The set of actions of this work, from the use of the experiment to the proposal of insertion of the photoelectric effect as a topic of electricity and the use of e-learning tools proved effective as a methodological innovation for the teaching of Modern and Contemporary Physics. We believe that this work opens new possibilities of approaching the contents of FMC together with traditional contents of Classical Physics.

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