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Use of a virtual laboratory to improve the understanding of direct current electrical circuits

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ABSTRACT:The purpose of this project was to analyze a way to improve the understanding of direct current electrical circuits in students of the fourth semester of High School of the College of Bachelors of the State of Hidalgo. The methodology used is based on the constructivist approach, based on problem-based learning. The results obtained show that a large percentage of the students improved their understanding of the topics when doing virtual practices. It is concluded that the teacher can use virtual simulators in institutions where, due to lack of infrastructure, there is no science laboratory.
KEYWORDS: Improving understanding, electrical circuits, virtual laboratory.

I. INTRODUCTION

The problem of the lack of understanding of electrical circuit concepts is manifested in students showing little interest in the subject of physics and in the subject, difficulty in adequately explaining everyday physical phenomena, as well as the basic functioning of electrical devices, memorisation of concepts and mechanisation of exercise resolution processes.

In educational institutions located in rural areas there is the problem that due to their situation they lack infrastructure (specifically they lack a science laboratory), which causes a backwardness in science students. The problem originates in the lack of practical experimental activities, since due to the context of the school and the economic situation of the students; the experimental practices in the school are very restricted. This situation limits the understanding of the contents of the subject of physics, which specifically prevents students from contextualising and interacting with electrical circuits.

The school where the project was developed is a school that belongs to the College of Bachelors of the State of Hidalgo in Mexico, this school is located in a rural area, lacks a science laboratory, but has a computer lab. The students are low-income students, so there are no materials or a place to practice electrical circuits.

Faced with this problem, the use of a virtual laboratory with free software was proposed in order to carry out experimental practices, where the students could test the concepts they had seen and design their own electrical circuits.

II. PHYSICS IN COLLEGE OF BACHELORS

Over the years, some researchers have found that when teachers develop their classes in a traditional way - understanding this way of teaching as the execution of classes focused purely on the teacher and the continuous repetition of exercises and application problems by the teacher - students do not internalise the concepts presented, but only memorise mathematical processes that do not allow them to contextualise this knowledge in situations different from those they have memorised.

Students successfully solve problems by applying laws, such as Ohm's and Kirchhoff's law, among others; however, they do not develop a conceptual structure coherent with scientific theories, as it has been proven that when students are presented with qualitative situations, they respond erroneously. These conceptual errors may be the result of all the concepts that derive from informal experience throughout life.

On the other hand, during the previous visit to the institution, an observation exercise was carried out aimed at the attitudes of the students. In this exercise, little motivation and boredom were perceived in the physics class, and in the experimental practices proposed, fear of damaging and hurting oneself with the laboratory materials was observed. Some students solve exercises involving the application of Ohm's law and Kirchhoff's laws; however, when presented with a problem situation, they do not show a conceptual structure that associates theory with practice in order to deal with it (Becerra 2014).

Likewise, the current challenge in the teaching of Electrical and Electronic Circuits is to have multidisciplinary hardware and software platforms that adequately integrate theory with practice (Ni 2020).

In a class that turns out to be traditionalist, students show certain apathy towards learning the concepts of DC electrical circuits. As a result, students memorise the mathematical procedures of problem solving, without fully understanding the concepts.

It could be said that through laboratory practice the student interacts with the material, assimilates the concepts and manages to interpret the phenomena related to electrical circuits. However, the reality is different: the student manipulates the laboratory instrument (very scarce most of the time) with a certain fear of damaging it and being charged for it, so it is not possible for him to experiment and check the physical laws, and therefore he does not appropriate the knowledge as he should.

Over the past two decades, many researchers have also explored the role that technology can play in constructivist learning, demonstrating that computers provide an appropriate creative medium for students to express themselves and demonstrate that they have acquired new knowledge. Collaborative online projects and web-based publications have also proved to be a new and exciting way for teachers to engage their students in the learning process. Some research has shown that constructivist teachers, unlike traditional teachers, encourage their students to use computers for school activities. In contrast, traditional teachers promote, as a learning system, sitting in front of the class to teach the lesson, limiting students' opportunities to think freely and use their creativity, while also discouraging the use of technology in class. Other research proposes that the availability of low-cost computing in the existing culture should change the basic ideas that the content of knowledge should be the whole essence of education, and encourage technology to go beyond modifying and improving the way educators teach and the content of what they teach. (Requena 2008)

A virtual reality physics laboratory simulates laboratory experiments, so that the student can see the practice as if they were in a real laboratory. In an electrical circuit simulator, the student can interact with the elements that make up the circuit, can change the physical properties of these components and in this way can build their own knowledge.

Virtual laboratories are characterised by being self-contained (they come with support guides or tutorials that explain their use), interactive (they promote intuitive, entertaining and motivating work that enhances student learning), they present two-dimensional and three-dimensional images; they contain sound and video animations to represent the reality of a high school physics laboratory.

The changes that can be achieved with the use of the virtual laboratory are mainly the breaking of the monotony of the class, which would attract the attention of the students, awakening their curiosity and motivating them to explore and experiment. In the same way, through experimentation, students will improve their understanding of the concepts of the subject being seen.

Likewise, with the Education Reform, the Collegeof Bachelors, the educational institution to which the school belongs, promotes the use of virtual simulators as a means of substitution for those schools that lack the infrastructure for science laboratories due to their context.

From the New Mexican School, it can be observed that for the curriculum, the subject of physics is found in the field of natural sciences, studied in the general baccalaureate in the fourth semester; the previous subject is physics I and it does not have any consequent subject.

Physics II is a 60 hours per semester, divided into 5 hours per week. It is made up of hours for both theory and practice.

The subject is made up of 3 blocks, with very little continuity between them or with other subjects:

- Block 1 fluids: presents topics in hydrostatics and hydrodynamics.
- Block 2 thermology: presents the topics of heat, temperature and heat transmission.
- Block 3 electricity: takes into account the concepts of electrostatics and electrodynamics.

Therefore, the subject of direct current electric circuits is left to the end of the course.

The subject is oriented to be linked with the subject of mathematics, since the topics reviewed in physics require mathematical knowledge obtained in the first semesters for their solution. (NEM 2020)

III. VIRTUAL LABORATORY

The project was designed to be

implemented in twenty fifty-minute sessions. It consists of the use of free software for the physics class on the subject of electrical circuits.

In order to implement this alternative, the following is needed:

1. Minimum Technical Means and Resources Needed:
a. 1 Gb in RAM memory in each of the electronic devices, to be able to run the virtual simulators (Circuit construction kit: CC. 2017) (Electrodynamics simulation TM s / f) (Resistance in a wire 2013) (Parallel and serial resistance calculator S / f) (Ohm's Law 2013) (Capacitor laboratory: basic concepts 2017) (Circuit simulator applet s / f) (Kirchhoff's Laws s / f).
b. Basic internet connection on each of the devices.
2. Minimum Required Means and Material Resources:
a. 1 Computer with internet access for the teacher.
b. 1 electronic device with internet access for each student (computer, mobile phone or Tablet).
c. 1 projector.
3. Times and Spaces to Carry Out the General Work Strategy:
a. Time: 2 sessions of 50 minutes per week.
b. Space: computer lab.

The 20 sessions planned were as follows:

- Activity No. 1 Presentation of the virtual laboratory of direct current electrical circuits.
- Activity No. 2 Movement of a free electron.
- Activity No. 3 Movement of electric charges.
- Activity No. 4 Elements of a direct current electric circuit.
- Activity No. 5 Resistance of a wire.
- Activity No. 6 Connecting resistors in series.
- Activity No. 7 Connecting resistors in parallel.
- Activity No. 8 Calculation of series resistors.
- Activity No. 9 Calculation of resistors in parallel.
- Activity No. 10 Ohm's Law.
- Activity No. 11 Calculation of electrical circuits using Ohm's law.
- Activity No. 12 Ohm's Law in series circuits.
- Activity No. 13 Ohm's Law in parallel circuits.
- Activity No. 14 Connecting resistors in a mixed system (series and parallel).
- Activity No. 15 Calculation of resistors in a mixed system (series and parallel).
- Activity No. 16 Ohm's Law in mixed system circuits (series and parallel)
- Activity No. 17 Stored energy of a DC electric circuit.
- Activity No. 18 Capacitance of a DC electrical circuit.
- Activity No. 19 Complex DC electrical circuits.
- Activity No. 20 Kirchhoff's Laws.

Each session begins with a couple of trigger questions proposed by the teacher, which are answered through brainstorming by the whole class.

Subsequently, the teacher indicates the link to the simulator that will be used during the practice, together with the minimum specifications of the design or the problem to be solved.

The students enter the virtual laboratory to carry out their activity.

Subsequently, two students proceed to present their designs to the group and, as a conclusion; a new answer is given to the trigger questions.

IV. RESULTS AND DISCUSSION

The project of using a virtual simulator to improve understanding of the concepts of direct current electrical circuits was designed to be implemented in twenty fifty-minute sessions, which had to be adapted to be carried out in a computer laboratory. Each of these sessions was designed based on a constructivist theoretical approach, placing the student as the protagonist of the session and responsible for the construction of their own knowledge.

In each of the sessions, the student was able to improve his understanding of the concepts of direct current electrical circuits, as well as his ability to solve numerical problems by designing electrical circuits, where he used his creative capacity, verifying the laws studied by observing under which conditions his circuits worked correctly and under which conditions they did not; verifying the results obtained in problem solving, measuring directly in the circuit to corroborate the result, designing and experimenting freely in the virtual simulator.

The students found the use of the virtual simulator an attractive strategy that allowed them to develop their creativity and collaborative work without neglecting their learning. Because they were able to model concepts seen in class, solve problems to verify the results in the simulator and check the physical laws in circuits designed by them.

The design of contextualized activities combined with the use of the virtual simulator (which was a novel strategy for the students in their training and allowed them to develop their creativity) increased the students' attention, attracted their attention to the subject, to the scientific explanation of phenomena and to scientific experimentation through the use of virtual laboratories.

For the implementation of the project and the study of DC electrical circuits in baccalaureate, a basic use of applications that handle forms and graphics, as well as knowledge of algebra and unit conversion, are required as prior knowledge.

The scope of this learning alternative allows for an improvement in the learning of the subject. After its application, an improvement was observed in the understanding of electrical circuit concepts, greater interest in the subject, greater participation in class, willingness to work collaboratively, an increase in the creativity of the designs, interest in observing and experimenting with the simulator, looking for what else could be done on it in addition to the proposed activities.

There were also special cases of students who sought more than what was intended by the alternative. One student tried to implement all the components of the simulator in an electrical circuit, one student proposed to represent all the electrical elements in his room and one student wanted to experiment more and built the same physical circuit that she designed in the simulator.

Therefore, the main result is that the virtual laboratory has to be used in activities that cover the contents of direct current electrical circuits seen in the syllabus of the high school physics subject; the activities have to be focused on the development of the student's creativity, as well as on the construction of their own learning; thus achieving the improvement of their learning, in relation to the subject treated.

V. CONCLUSION

The teaching of physics involves theoretical concepts, problem solving and experimental practice. The project presented contributes to improving the understanding of concepts in the subject it was designed for.

The project's contribution to the field of education is to provide a teaching strategy that can be used in schools that, due to their context, lack the infrastructure to carry out experimental practices on electrical circuits. It is thus an alternative for teaching science in physics subjects that involve learning concepts, problem solving and experimental practices.

The project provides a solution to the problem of teaching direct current electrical circuits; however, in the teaching profession with regard to the teaching of physics, there are still learning problems for students related to this science. For this reason, based on the success obtained through the alternative, the search for virtual simulators that allow experimental practices to be carried out on other subjects that present learning problems for students of physics subjects is motivated.

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