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Analogy among electrical potential difference and gravitational potential difference on the teaching of physics

Analogía entre diferencia de potencial eléctrico y diferencia de potencial gravitacional en la enseñanza de la física

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Abstract

This paper proposes to create a strategy that enables solid learning of the topic of electrical potential, through an analogy between electrical and gravitational potentials. The proposed activity conceives the use of low-cost materials with the objective of bringing physical knowledge closer to the students' daily lives. This is because a certain lack of interest in Physics has been perceived in the focus population of this study, which in some way is contradictory, since the presence of this science in our daily lives is manifested in the various activities that we carry out in the context in which we are inserted as well as in the widespread use of new information and communication technologies to which the human species has been having access in recent years. The methodology includes a review of the available literature on the subject and has a qualitative-quantitative tendency, referring to the collected data's analysis during the experience. The results shows that there were better students performances during the second stage of the research process, which allows us to conclude that teaching Physics through analogies developed by the teachers of this subject enables better learning of this science to the extent that scientific and everyday knowledge are linked.

Keywords

Education, Inclusion, Significant Learning, Pedagogical Innovation, Academic Thinking.

Resumen

Con el presente trabajo se pretende crear una estrategia que posibilite un aprendizaje sólido del tema de potencial eléctrico, a través de una analogía entre los potenciales eléctrico y gravitacional. La actividad que se propone concibe el uso de materiales de bajo costo con el objetivo de aproximar el conocimiento físico al común de los estudiantes. Esto porque se ha percibido en la población foco de este estudio, un cierto desinterés por la física, lo que de alguna forma resulta contradictorio, una vez que la presencia de esta ciencia, en nuestro día a día, se manifiesta en las diversas actividades que desenvolvemos en el contexto en que estamos insertados, así como en el uso extendido de las nuevas tecnologías de información y comunicación (TIC) a que la especie humana ha venido teniendo acceso en los últimos años. Por su parte, para la creación de la citada estrategia se ha considerado el uso de una metodología que concibe una revisión de la bibliografía disponible sobre el tema y tiene una tendencia cualitativa-cuantitativa, siendo esta referida al análisis de los datos que serán colectados durante la experiencia. Los resultados muestran que hubo un mejor desempeño de los estudiantes durante la segunda etapa del proceso investigativo. Esto nos permite concluir que la enseñanza de la física a través de analogías elaboradas por los profesores de esta asignatura posibilita un mejor aprendizaje de esta ciencia en la medida en que se vinculan conocimientos científicos y cotidianos.

Palabras clave

Educación, inclusión, aprendizaje significativo, innovación pedagógica, pensamiento académico.

Introduction

According to Pinheiro, Silveira e Bazzo (2007), the teaching of science in recent decades has become a very important topic. On the one hand, this movement has concentrated mainly on research and actions that, governed by educational instruments, require significant attention to these issues. Thus, this approach, like that of experimentation in the teaching of physics, constitute trends on which researchers committed to this area have focused their interests with more emphasis in recent years. This has been favored by the recent conceptions proposed by the Common National Curricular Base (BNCC, 2018), in which skills and competencies are more in line with the human being that is intended to be formed with the aim that he coexists better with the environmental demands and technologies of the 21st century.

In this way, such trends constitute a way of approaching physical and scientific knowledge, in general, to students. No longer from a teaching of physics steeped in classic Skinnerian traditionalism, where the approach of the different topics of this science is reduced to the ultrapast stimulus-response format. Today new visions are projected for teaching the contents of physics in secondary education; so that critical and reflective positions on the topics studied are potentialized, once these are reflected in our daily life. Consequently, space is opened to possible understandings and interpretations of nature that are more in line with the structure of science. So that common perceptions built from individual experiences and systematized observations are left aside, but not permeated by a deductive logic regarding the events that happen around us.

This research conceives this discussion in a particular way from the establishment of an analogy between the electric and gravitational potential. This is because it has been perceived, during the teaching of physics through the Pedagogical Residency (RP) and University for All (UPT) programs, promoted by the University of the Southwest of the State of Bahia, in the municipality of Itapetinga-Brazil, that students who are part of these programs present difficulties in understanding and interpreting the concept of "electrical potential", both from its most abstract form and from its visualization in power outlets and electrical equipment.

Once the problem has been identified, it should be noted that this study aims to create a strategy that allows a solid learning of the topic of electrical potential, through an analogy between this and the "gravitational potential". For this purpose, the use of low-cost materials is considered, since as cited in the governing documents of Brazilian education, in particular the BNCC (2018), with respect to science teaching in middle school, it is thought that:

> The area of Nature Sciences and its technologies proposes to deepen in the subjects Matter and Energy, Life, Evolution, Earth and Universe. The conceptual knowledge associated with these topics constitutes a basis that allows students to investigate, analyze and discuss problem-situations that emerge from different sociocultural contexts, in addition to understanding and interpreting laws, theories and models, applying

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them to the resolution of individual, social and environmental problems (p. 548).

In this sense, the use of low-cost materials for experimentation or as didactic resources in the teaching of physics, aims at the recycling and use of raw materials in order to enable different positions and behaviors of students towards the environment. In addition, it allows a different view of scientific teaching when other possibilities for teaching the subject are shown to extend scientific (physical) education to all social layers of this immense country.

In the midst of desertification, rising global temperatures, forest fires in the Amazon, the recent floods in Rio Grande do Sul and the successive neglect of the environment, we see an irrational and unsustainable behavior on the part of man. Thus, the evolution of changes in favor of a sustained improvement of life on Earth gains a solid basis in the teaching of scientific disciplines that, traditionally, have been adopted giving great weight to memoristic and repetitive learning of equations. Thus, it is necessary to highlight the fundamental role of the teaching of physics in this process of scientific inclusion of society. Physics opens doors to learning that starts from the creation of strategies that lead to critical thinking.

It is necessary to be aware that the traditional teaching of that science has created negative perceptions about it; mistakes about its own nature, echoing the complacency against inductive interpretations related to phenomena that happen around us. This is evident when it is limited to the resolution of exercise lists, when topics close to the daily life of students are not addressed or simply when they are not topics about which we usually do not stop to think critically. In this study, issues of a certain social impact are highlighted, which in many cases are discarded by teachers.

When considering the set of topics dealt with during middle school in the teaching of physics, the issue of electrical phenomena gains relevance, once the current humanity is constituted, in some way, dependent on such events. Whether in the use of electronic equipment and appliances, in companies and industries, theaters, cinemas, in the lighting of the house or the streets and avenues of our cities, such events are present. However, as such a subject is taught, opinions stand out in students that reveal a lack of understanding of phenomena of this nature. Difficulty that manifests itself in the interpretation that is offered to the voltage with which the equipments work at home. For example, the potential difference commonly found in 110 V or 220 V consumers is often called current. This shows a certain lack of knowledge on the part not only of the

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students, but also of ordinary people inside and outside academic institutions. In this sense, in the study by Dias et al. (2009), the author states that:

> It is possible to observe that some students claim that they did not understand the contents taught by the teacher, believing that there are various difficulties. Students consider that they have difficulties in interpreting the contents taught by the teacher, some even observe that the knowledge is very abstract, which makes it difficult for them to understand (p. 112).

Events such as the one mentioned above show that many students have difficulties in establishing clear relationships between the principles worked during the study of the electric field and their daily life. This perception is manifested when they are asked about aspects related to the subject. At that time, there are explicit negative weightings referring to the classes, where the latent difficulty in understanding and establishing relationships that show the application of such knowledge in the day to day is highlighted. So the concepts, at this level, abstract, are left without support with the reality of the students, as interpreted by Dias et al. (2009, p. 114), when referring to the answers offered in interview with the disciples.

The lack of concrete representations has been displaced from the natural events that are studied in physics courses, to the point that this impacts on the non-concretization of competences and skills traced by the guiding documents of education in Brazil. What is not limited, as one might think, to topics of modern, contemporary and quantum physics, but also to topics that are addressed in classical physics. Classical physics stands out because even though the phenomena described in it constitute macroscopic events, the treatment offered does not cease to be abstract for the students. This lack of representation or modeling of the phenomena that are studied in secondary education also happens due to the lack of continuous and adequate training of physics teachers, who are responsible for teaching such knowledge in a solid way. This article aims to create a strategy that allows a solid learning of the topic of electrical potential, through an analogy between the electrical and gravitational potentials. This strategy has been built so that a meaningful learning of the issue that is addressed can be achieved.

Likewise, the research presented here conceives an experimental methodology, since it considers groping and direct contact with the low-cost materials proposed, a direct way for learning and interpretation with the event, as suggested by Piaget (1967). On the other hand, during the treatment offered to the theoretical foundations of the study, it is considered the

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use of an approach with a historical perspective on the electric current, so that another of the current trends of the teaching of science (physics), is revealed. During the presentation of the results, a description is made considering the responses of the students to the questionnaire. Then, the conclusions show the considerations obtained as a result of the investigation.

Electricity from the teaching of physics

A treatment is proposed on topics related to the topic of electricity considering elements related to the teaching of physics in middle school. Traveling from historical elements, passing through definitions related to the subject in question, in search of that they are approached in a firmer way previously cited elements. In this way, it is intended to analyze those aspects related to the role of experimentation in the teaching of physics, once this would be the means by which, in this study, the idea of a more finished and profound understanding of the electrical potential is defended.

A brief historical electric current

Electric current is a concept that plays a fundamental role in our daily lives. Its rich history shows more systematic signs of its study by the 16th century and makes clear, even today, the contributions and discoveries made by several scientists who dedicated themselves to this field of physics. It is worth noting that until the 17th century little was known about electricity. The author cites that the knowledge collected more carefully and systematically on this matter was built by Cardano, when he was interested in the medicinal properties of amber. Although it is necessary to recognize that such properties were already known by the Greeks by 600 BC, when philosophers like Thales de Mileto already knew that, by causing friction between a piece of this material and a piece of wool or skin, amber attracted small pieces of straw, according to Oka (2000).

Knowing the existence of static electricity or as known, electrostatic electricity in the 17th century, scientists such as Otto von Guericke and Stephen Gray conducted experiments with electricity that demonstrated their ability to attract objects. Such discoveries and experiments laid the foundation for our current understanding of these events and served as the foundation for advances in studies in this area. Likewise, Benjamin Franklin's works stand out with his experiences on electricity in the 18th century, which contributed significantly to a better understanding of electrical principles. It is worth noting that in several texts, such

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as the physics textbooks aimed at his teaching here in Brazil, narratives are used about the experiment in which this researcher employs a key tied to a kite by means of a damp silk thread and thrown into the air in the middle of an electrical storm. The objective was to verify if electricity was present in the clouds during the storm once it was from it that the rays that it managed to visualize sprouted. The fact of approaching the tip of the fingers and perceiving, consequently, that an electric spark was sprouting towards its fingers, demonstrated the presence of electricity in the clouds during the storm.

This episode may seem very simple in the eyes of people who are beginners in scientific subjects or whose daily activities are not directly related to this form of knowledge construction. Thus, it is likely that individuals will be left with a wrong perception about the construction of scientific knowledge and science in particular. It is a vision about physics that neglects the path by which men and women go around to construct such principles and statements, on which the operation of many of the technological devices with which we live is based. That is the risk that is run by introducing a brief history of science in physics classes in order to comply with what is disseminated in the documents that guide scientific education in Brazil. The idea that is pursued with this type of approach or tendency for the teaching of physics is to eliminate the tendency to idealize events and characters linked to the principles and laws that are studied in this subject. For this reason, this point is made once it is generally disregarded that scientists and their theories are permeated by philosophical conceptions and inserted in historical contexts that often have their driving forces in questions of a political, economic, social, cultural within other factors. Therefore, there should be no doubt that such aspects usually influence gnoseological constructions relating to the field of electricity. In this sense, Pimentel and Silva (2006) declare:

> That discovery did not happen suddenly after the realization of an experiment, in that case the experience of the papalote proposed in 1752, as the didactic books lead us to create. At various times, Franklin expressed his ideas about the electrical nature of lightning. This occurred well before he proposed the kite experiment, as may be noted in his correspondence (p. 5).

Franklin's experiment enabled a more elaborate explanation to be given to thunder and lightning, which were either seen as unexplained phenomena or attributed to the sovereign power of the gods. In his explanation of lightning, Franklin suggested that lightning constituted electric

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shocks that occurred due to the difference in potential that is established in a certain region, between clouds and Earth. Thunder, on the other hand, refers to a phenomenon of a mechanical nature and, therefore, is related to the propagation of the sound produced by the aforementioned electric shocks. In addition, this experiment allowed electricity to be understood as a natural phenomenon and not only as an event observed in laboratories.

And since experimentation is mentioned, alluding to laboratories, it is worth referring to the contributions of Michael Faraday, who left a legacy that endures to this day. His systematic studies, often the result of curiosity, led him to construct and introduce quite relevant concepts related to the electric and magnetic fields, in his theory. Conceptualizations that are widely linked to the directed and ordered movement of electric charges through a conductor: electric current, a subject on which Andrè Marie Ampère had already published his works since 1825. The understanding of the relationship between the electric and magnetic fields, which Faraday reached through experimentation, had as a direct consequence the discovery of the phenomenon of "electromagnetic induction", in 1831. Its social impacts are still visible today, as this discovery opened the way for the construction of electric current generating machines. It is worth noting that the first of these machines was built by Faraday himself and was known as a disk dynamo. In this way, he opened paths for the construction of power generating machines by man, which nowadays are used in hospitals, *shopping malls*, cinemas, thus showing a diverse range of applications.

In order to finish this historical journey on the electric current and being aware that what is described is nothing more than a fairly small summary, it is necessary that the contributions of James Clerk Maxwell are addressed. His great contribution to science is reflected in the fact that he managed to unify electrical and magnetic events in the same theory. Maxwell proposed that these two fields were interconnected and that changes in one of them may undergo influence or induce variations in the other. Maxwell thus formalizes in four differential equations the dynamic description of the electric and magnetic fields: the Gaussian law of the electric field, the Gaussian law of the magnetic field, the Faraday law of induction, and the Ampère–Maxwell law. These equations describe the behavior of electric charges and currents when they are influenced by the above-mentioned fields.

By analyzing historically and critically the course of scientific advances in this field of physics, the elaboration of principles and laws that govern the operation of electrical appliances or household appliances that

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we have at home, we perceive that historical and philosophical foundations are present. The knowledge to which such scientists arrived is based on philosophical perceptions or paradigms that govern scientific thought in a certain context. Thoughts and ideas that respond to questions of a political, economic, social, cultural nature and that seek to solve a demand or problem of humanity at a specific time. Considering such elements it is possible to appreciate the importance of history and philosophy in the development of physics and the products of this science. It is a way to understand the influence and impacts of obycles faced by scientists when trying to assimilate and respond to a certain social demand. Difficulties that do not remain in the scope of their technological applications, but weigh heavily on the resistance or opposition that we often make to change our way of thinking about a certain event. This is discernible in physics classes when we continue to manifest the power of the common census in our interpretations of day-to-day electrical phenomena. In a very significant way, how do we decode the knowledge related to the difference of electric potential or as popularly known: the voltage.

The difference in electrical potential from a science, technology and society approach

The perspective of science, technology and society (STS) is a way that allows significant approaches regarding the difference in potential, as a focus of our study. According to Pinheiro et al. (2007), the relevance of the STS strategy in the context of secondary education enables contextualized views of the knowledge taught in physics classes, in particular. Its impact extrapolates the classrooms and classes of this subject, from the moment in which the application of such knowledge is recognized in the cultural, social, political and economic context of any current population. The STS approach in the teaching of science, has as its axis in the dissemination and scientific literacy (CA) of individuals. Literacy has at its core the goal of forming critical, thoughtful citizens who are positioned in the face of the various situations that affect life on the planet.

The non-understanding of the concept of potential difference, such as the electrical energy difference between two or more points of a conductor at which moving (current) electric charges pass, by much of the lay public in science and even by those within the academy, can be reflected in accidents that happen with some frequency. Fires caused by energy imbalances in the lines that conduct the fluid; burning of cables; appliances that are lost due to misuse or failure to understand the labels

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that describe how the consumption and manipulation of them should be. The frequent fact of not knowing how to interpret what the voltage with which a certain appliance works, be it 110 V or 220 V, and frequently calling such magnitudes as "current", makes clear the scientific illiteracy to which it was previously alluded. In this sense, the development of the STS approach is important in the current proposals of science teaching. There is an urgent need to prepare trained teachers to develop up-to-date visions in the teaching of physics. Visions that contemplate the technology, so widely used and disseminated in our days, so that it is placed within the reach of people, the possibility of thinking critically about the impact that some of these have on the environment and society.

Likewise, there must be a conscious distancing from the repetitive teaching of "formulas", which do not represent or do not translate into something beneficial and meaningful for students. According to Chassot (2006), scientific literacy—including the STS approach here—is a powerful tool for any country seeking research education. As well as a scientific education that has the intention of forming citizens who do not limit themselves to repeating what they hear, or give absolute veracity to the knowledge coming from the common environment.

The role of abstraction in the topic of electric current: difficulties

Students' difficulty in understanding concepts related to electrical potential difference, as well as other topics related to electricity and linking them to everyday life, can be due to a number of complex factors. Within these, abstraction can be cited as one of the main challenges, since it seems that it is inherent to these concepts. Note that electricity conceives phenomena that are not visually perceptible, once it deals with moving electrons, variable electric fields and electric charges, to the point that the student is required a certain level of abstraction, which will allow him to understand the content taught by the teacher. The lack of concrete representations can make it difficult for students to visualize and therefore understand these abstract concepts (*cf.* Dias et al. 2009, p. 112).

Many students show difficulties in establishing clear connections between the principles of electricity, proportional relationships between magnitudes that appear in Ohm's law, and their applications in daily life. Generally, when asked about the negative aspects of the approach given to the subject by the teacher, in their answers emerges the difficulty of establishing relationships between abstract concepts and the reality in which they are inserted (Dias et al. 2009, p. 114). The lack of these con-

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nections may result in disinterest in the subject, reinforcing attitudes that go against the educational foundations established in the BNCC for the training of the Brazilian citizen of the 21st century. The latter is reflected in Santos and Dickman (2019):

> The teaching of physics should stop focusing on the simple memorization of formulas or the automated repetition of procedures, in artificial or excessively abstract situations, thus contributing to the classes being uninteresting for the student, resulting in a low performance (p. 34).

The complexity of the mathematical calculations involved in the electricity issue can also be a major obstacle. As reported by Dias et al. (2009) scholars observed in student surveys that difficulty interpreting texts and solving mathematical problems are mentioned as factors that represent learning challenges. Ohm's law, for example, relating voltage, current, and resistance, requires advanced mathematical skills, which students often do not develop due to the lack of preparation of some professionals who act in the area of physics teaching, because they lack a degree in this discipline. This can lead to a sense of insurmountable challenge, frustration on the part of students in understanding electricity as an everyday event, leading to conflicts, repulsive states about the subject and of physics itself.

Another problem to be considered is the lack of opportunities for experimentation in the teaching processes of science, in particular physics. Electricity as a scientific or study topic is an area in which experimentation is a fundamental element for constructing knowledge, as seen in the previous subtopic, regarding the discovery of Faraday. However, many schools may not have adequate resources to conduct experiments, limiting students' ability to visualize and apply electricity concepts in practice.

The fear of failure, the pressure that some teachers create on students with respect to this subject, thus manifesting their traditional conceptions of education; the devaluation of error in experimentation, as a possibility of transforming it into the construction of knowledge in middle school, are additional concerns observed in the teaching of physics. In particular, electricity as a subject of study is often perceived as a difficult topic and this perception can generate anxiety and insecurity among students, negatively affecting their motivation to study the subject.

In order to help students overcome these difficulties, it is important that educators adopt more practical, contextualized and interactive teaching approaches. In addition, it is essential to create an encouraging and supportive environment where students feel comfortable asking

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questions and seeking help when needed. The combination of up-to-date teaching methods and practical resources can make a significant difference in understanding these.

From experimentation to critical thinking in the teaching of physics

When analyzing the Brazilian educational organization, it is possible to observe that it presents problems in different perspectives and approaches that impact on secondary education. These issues are reflected in the structures of public schools, in the content taught and in the group of teachers responsible for teaching the subject, since the continuous training of professionals is not a priority. This is seen in the reports and documents that reach the National Institute of Educational Studies and Research Anísio Teixeira (INEP) and the Ministry of Education and Culture (MEC). Likewise, the aforementioned statutes highlight that the educational system has presented, in recent years, inconsistencies and challenges, which must be difficult to solve in the medium term. These problems include problems such as lack of materials, poorly structured schools, educational institutions lacking laboratories and teachers unprepared to immerse experimentation in the teaching of physics with constructivist approaches.

It is worth noting that in the official documents cited above, reference is made to the lack of continuity in the preparation of Physics teachers when they state, in our interpretation, that:

> In Brazil, there is currently a very small number of teachers trained in the specific subject of physics and, according to the data collected, this number is not enough to meet the demand for teachers for this subject. We found problems related to the small number of first-year students and, of these, a small number of graduates, indicating that few teachers have been trained with specific qualifications to teach the subject of physics.

Still in the same direction, we find the ideas of (Pacca and Villani, 2018) who after conducting a study on the subject of training of Physics teachers, they declared that:

> The continuous training of the Physics teacher comes, even in our days, to show no effective procedures and no adequate results. The (continuous training) had its origins effectively in the 1960s when physicists from this country perceived that the teaching of that science was not being successful. Its objective was to train teachers to know how to use

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> the physics teaching projects that were developed. Subsequently, it was perceived that this training should be understood as updating teachers, however, this still persists as a matter without final resolution. Moreover, it is now a problem which is only increasing (p. 1).

This means that the subject is taught by teachers who are not trained in the area, worsening the situation since the training of specialized teachers is essential to ensure the quality of the teaching of physics in schools. The absence of an adequate number of teachers with specific qualifications compromises student learning, harming the development of skills and understanding in this area of knowledge.

In this sense, both the educational system and teachers must provide training that opens space to the creativity of professionals and the welfare state of these. Also, must consider the hours of classes compatible with the demands and guidelines disclosed in the governing documents of secondary education in the country in the preparation and continuous training of professionals, in specialization courses, master's degrees and doctorates. All this while responding to the lack of equipment, teaching resources and materials for experimentation, necessary for developing didactic experiences that make increasingly significant the physical knowledge that is taught.

Hence, it is necessary to make explicit that, among the specific competences of the graduate in Physics, is that he is able to elaborate or adapt teaching materials to the different teaching situations. In this way, the teacher must identify the objects that contribute to a proper training of students, to strengthen the learning and scientific education of individuals, based on a participatory perception and with a critical view about their environment. In this regard, the National Council for Education (CNE/CES 1.304/2001, p. 3) reflects as one of its objectives to make students think critically, thus creating an environment for reflection on the daily life of each of them.

In support of such judgments Freire (1996) describes this process of methodological rigor and its distancing from banking knowledge:

> The democratic educator cannot deny the duty, in his teaching practice, to reinforce the critical capacity of the student, his curiosity, his insubordination. One of the main tasks is to work with students on the methodical rigor with which they must "approach" knowable objects. And this methodical rigor has nothing to do with a "banking" discourse that is limited to transferring the profile of the object or content. It is precisely in this sense that teaching is not limited to the "treatment" of the object

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> or content, done superficially, but extends to the production of the conditions in which critical learning is possible. And these conditions involve or require the presence of creative, instigating, restless, rigorously curious, humble, and persistent educators and students (p. 13).

In this sense, Freire (1996) describes conditions that enable critical learning, considering that it is necessary that the teacher, in addition to possessing specific knowledge, can transmit it in an appropriate and coherent way with the context in which the student is involved. From this perspective, the renowned intellectual insists on the need for students to be active entities in the construction of their knowledge. Thus, we can say that the active participation of the student in the construction of their learning is fundamental, especially in the discipline of physics, where many concepts can be explored through practical activities, providing a more tangible and attractive understanding.

Therefore, although there are obstacles and precarious conditions in Brazilian education, it is necessary to continue looking for the possibility of offering decent and quality education for all. In reference to the latter, the Federal Constitution (Brazil, 1988) and the Law on Guidelines and Bases of National Education (Brazil, 1996) affirm that education is the duty of the State and the family, with a view to the integral development of the student. Therefore, to ensure full compliance with legal requirements and keep up with the technological advances of the 21st century, society needs to adapt to the new times and that is also the responsibility of scientific education.

Therefore, a path in which education is transmitted in a double way; the first of these is the one where the student learns with the mediation of the teacher; the other, in which the professional acquires knowledge through his performance in the classroom. Thus, the teacher, fundamentally the physics teacher, can use different resources to make the contents viable in order to ensure meaningful learning by the students. Fiasca (2021) emphasizes that "teaching is not transmitting knowledge, but creating the possibilities for its production or construction".

With the aim on this production and construction of knowledge, this work focuses on experimentation as a trend on which the teaching of physics is based to achieve more robust results in terms of learning. For such it is considered that this trend can be used to mediate difficulties in relation to certain specific topics of the discipline since they involve abstract content and little understanding (Araujo and Abib, 2003).

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A content that is relevant for such an approach is the topic related to the Difference of Electric Potential, since it is an accessible topic from the point of view of its presence in the daily life of any subject. According to Piassi (1995) experimentation is fundamental to truly understand physical concepts, allowing students to discover the laws of nature and internalize fundamental principles. Thus, the aforementioned author emphasizes that "improvised devices and assemblies, made with the most modest laboratory resources, should be considered not as an emergency solution, but on the contrary, as a new desirable technique to develop the constructive and inventive capabilities of the student" (p. 6).

Highlighting the relevance of using improvised equipment and components in educational laboratories, this approach is considered not only a temporary or emergency solution, but also a desirable new technology. The central idea is to "encourage" students to develop their constructive and inventive skills using simple, improvised resources. This view holds that some educational institutions may have limited access to sophisticated instruments and well-equipped laboratories due to monetary or infrastructure restrictions, which unfortunately extend to all regions of the country.

Methodology

The proposed analogy between the difference in electric potential and the difference in gravitational potential is based on the idea that electricity can be understood by comparing events of a gravitational nature. This idea arises, as said at the beginning of the work, by the need for visual representation that the teaching of physics lacks. Regarding this research, it is considered that visual perception; experimentation; social interaction between subjects; recognition of previous knowledge in which the new knowledge is anchored to rise to higher stages, psychologically speaking, are elements, among others, that favor the understanding of content in the teaching of physics. Thus, this study starts from the idea that such aspects reinforce the processes of knowledge construction, as well as known epistemological theories (Piaget, 1967; Moreira, 2015; Vygotsky in Ledesma Ayora, 2014). To do this, we must consider the role that these theories offer us, the continuous training of physics teachers, with the intention of modeling the teaching-learning processes in a way that aims at obtaining increasingly encouraging results.

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In this way, such aspects allow teachers to be able to establish relationships and analogies between the various contents taught. Therefore, just as the difference in height determines the gravitational potential energy of a system in vertical motion, in the subject of electricity the difference in potential is related to the electrical energy stored in a region of the system. On this basis, it is possible to establish a relationship with the fluidity of water within a hose and of electrons in a metal conductor, as Ewald George von Kleist did in 1745, by observing that electricity flowed from body to body like water in the stream of a river with wide flow. The analogy becomes physically possible, because as Aguiar, Faraco and Texeira (2022) point out, we have to:

> Although these forces have different natures, both laws describe interaction forces between particles that have common characteristics: they are related to the product of an intrinsic property of the particles involved in the process (charge in one case, mass in the other) and have a dependence that varies with the inverse of the square of the distance that separates them (p. 1).

In other words, the analogy becomes physically possible when we consider the fact that two forces are related to central interactions governed by the same law. Central forces are those that act along the line that joins two or more particles in a system and that also depend only on the distance between them.

In this perspective, a simple experimental activity was proposed, in which low-cost materials such as: hose, plastic wells, hot glue and water are used. The idea of using low-cost or alternative materials, in addition to being based on our belief that they enable a way to bring this experience to any educational context in which the subject is being treated, favors a vision of reuse and preservation of the environment. In this way, access to scientific knowledge is also made possible in a way that stimulates the active participation of students in the construction of knowledge related to the subject that is presented, taking into account the STS perspective, previously addressed.

This study considers the bibliographic research, once a review of articles and texts that deal with the difference of electric potential and the establishment of analogies with gravitational potential was carried out. Below, we selected a low-cost materials and the assembly of the experimental system using the cited materials, as represented below:

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Figure 1
Materials selected for the experiment
(personal collection)

Population and sample

This article includes as a sample the students of the third year of secondary education of the educational programs and trainers "University for all" and "Pedagogical Residence" of the municipality of Itapetinga, in the southwestern region of the State of Bahia, in Brazil. In particular, reference will be made to a group of 22 volunteers from the school belonging to the state of Bahia: Alfredo Dultra, located in the city of Itapetinga.

The experimental assembly was commanded by the students, with the clear intention of promoting their active participation from the beginning of the activities. In this way, encouraged by the didactic perspective that points to research teaching, the students gathered both vessels through the limbs of the transparent hose. Once this connection was made through the side holes of the containers, hot glue was placed in order to fix the hose to the wells. Water was incorporated into the system, containing tiny pieces of polyfoam, representing the moving electrical charges within the fluid. Such polyfoam particles were previously colored red, in order to increase the visualization of these particles in the displacement described by the water fluid inside the transparent hose. In this

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way, the latter symbolizes the electrical conductor through which moving electrons circulate (electric current):

Figure 2
Student-mounted experimental system
(personal collection)

Figure shows the experimental system mounted by students in the classroom. During the assembly process we perceived that the students were more involved, curious and committed to the fact of working, and being able to activate the materials that were available.

For collecting the data, a questionnaire was used to diagnose the level of knowledge that the students had on the subject. Once this idea was conceived, such an instrument was applied in two different stages to the disciples. The first of these moments, prior to experimentation, while the second was applied *a posteriori*. The ten questions they formed for this technique were:

- What are the particles that make up an atom?
- What are the so-called free electrons?
- What does electrodynamics study?
- What is the cause of the electron movement?
- What is the difference in electrical potential?
- What is electric current?
- What is the unit of measurement of the electrical voltage?
- How to get the average electric current intensity?
- What is electrical resistance?
- Which devices cause the electrical potential difference?

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The questionnaire as a data collection technique in a scientific research consists of the elaboration, by the interested parties, of a set of questions that are intended to understand, estimate or perceive ideas and opinions of the participants regarding a specific topic. As García says (2003) it is an instrument that must be prepared systematically and carefully, on the facts and aspects that interest in an investigation or evaluation, and that can be applied in various forms, among which stand out its administration to specific groups of people or its mailing to volunteers.

After this stage, a brainstorming was promoted, so that some questions were discussed in groups, allowing the exchange of experiences among them, thus favoring the socialization of knowledge.

This research conceives the empirical element and the action on objects as a fundamental element in the construction of scientific knowledge regarding the content that has been declared. In the application of this teaching perspective, the focus was the resolution of a problem related to the daily life of students, in a cooperative and participatory way. In this way, it was intended that the conceptual inconsistencies initially detected be clarified, at least at a first level, and that such a resolution be verified later through the application of the aforementioned instrument. Thus and as a conclusion of the activity, the same questionnaire was placed for the second time, so that the initial answers could be compared with those found at the end of the process. In this way, the validity of the proposal and the methodology used would be checked, under the conditions in which it was applied.

The data collected were analyzed in a qualitative and quantitative way, understanding that the qualitative research focuses on the study of the characteristics of the sample, according to Godoy (1995, p. 21). This type of scientific research occupies a recognized place among the various possibilities in which phenomena relating to human beings can be studied. In this way, the analysis derived from this type of methodology involves the interpretation of data and the search to understand the perceptions, opinions and experiences of the subjects that are part of the public object of the investigation.

For its part, quantitative research compares statistical data, equations, as well as the mathematical processing to understand the problem in question. This involves obtaining data from techniques and instruments that are closely related to this type of methodological perspective. They make up the aforementioned data: notes, scores in tests and/or evaluations, graphs that denote the temporal behavior of meteorological variables, for example, during a certain period.

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As far as our work is concerned, the collection and analysis of these data can provide information on the performance of students against the activity that is proposed. For Galvão and Bastos (2007), using the quantitative approach:

> When you have numerical data there seems to be a correct and obvious answer, but there is another aspect that should be considered. Quantitative research only makes sense when there is a very well-defined problem, there is information and theory about the object of knowledge, understood here as the focus of research and/or that which is to be studied (p. 3).

In this case, the fact of using a methodology such as the proposal contributes to Godoy's (1995, p. 21), to the reflexive and critical analysis of a phenomenon that can be better understood in the context in which it occurs and of which it is part in the construction of that knowledge. An integrative perspective in which the performance of the students before and after the intervention is compared with the proposed teaching approach is important.

Results and discussion

During this study an approach was adopted in which the trends: "science, technology and society", "history and philosophy of science", "teaching by research" and "experimentation in science", constitute the didactic platform on which the proposal presented here was based. In essence, the fact of creating a strategy that allows a solid learning of the topic of electrical potential, through an analogy between the electrical and gravitational potentials, seeks in itself to potentialize the scientific literacy of students from that content. The graph below shows the behavior of the data that was collected in the classroom during the experimental activity that was proposed. It is worth noting that the first intervention of the questionnaire was carried out prior to the experimental assembly conducted by the students, while the second intervention was after the representation of the phenomenon.

The results show that there has been a greater performance of students taking into consideration the greater number of true answers in the second stage of the application of the questionnaire. The analysis of the collected data was developed through the frequency distribution of the responses, which enabled the data to be represented by means of a bar graph to better explain the results and thus visualize the behavior of

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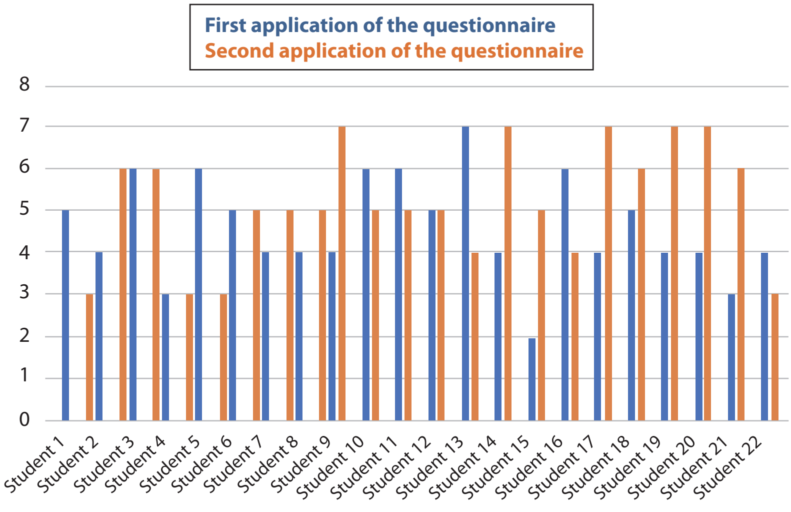
the responses, according to Hernández (2012). In this way, it was possible to verify, in principle, that there was a certain understanding of the phenomenon studied during the proposal. It is worth noting that the questionnaire applied focused their questions on the electrodynamics of the particle, so that students could perceive the relationship of the subject related to the experimental assembly with the sequence of questions asked.

During the analysis of the responses, it was verified that out of the 22 students who composed the sample group, 16 did not know the concept of electric potential difference in the first stage of application. However, 11 (50%) of them responded better to that questionnaire question at the second stage. For those who remained at the same level, we can say, according to the analysis of the responses, that there were 4 students with this characteristic, a value that represents 18.1% of the participants. Of the total, 7 students, or 31.8%, were better off in the first stage than in the second:

Figure 3
Frequency chart of students' responses to the questionnaire



With this research it is possible to affirm that the students managed to better understand the concept of electric potential difference. In this sense, it must be mentioned the behavior of the answers for the seventh question in which 86.3% of the 22 participants, equivalent to 19 successful answers, achieved a better performance.

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It should be explicit that by introducing this methodology during the study we perceive how enriching it was to see the active participation of the students in front of the proposal. They were interested, participatory, promoting a renewed learning environment and stimulating reflective and critical thoughts on the subject. In this way, it opened the way for strengthening a scientific literacy based on the integration of scientific concepts and the understanding of the world, in this case related to the electrical phenomena of the day to day. Through the strategy, students not only acquired theoretical knowledge, but also practical knowledge through experimental assembly. This provided them moments of exchange, so that they experienced, through the discussions, an opening for different positions and points of view on the subject. In this way, they were also able to relate the concepts treated under the lens of science, leaving delimited conceptions and scientific definitions of those elaborated through the common census.

Under these principles, this work coincides with the four pillars of education defined by UNESCO: *learn to know*, *learn to do*, *learn to live together* and *learn to be*. Within the scope of *learning to know,* it is highlighted that students gained a better understanding of scientific concepts, developed skills to evaluate the information provided in a critical and reflective way, thus strengthening their ability to integrate and apply scientific concepts to understand the world around them. With regard to *learning to do*, the disciples applied theoretical knowledge in practical situations and projects, they were also able to identify, analyze and solve problems that would have previously been seen as complex. In this way, they were able to understand the relevance and practical application of scientific concepts to everyday life. The *learning to coexist* is observed during experimental practice, where students developed the experience by putting teamwork into practice. During that time and afterwards, they were able to value cooperation and the exchange of ideas, a reality achieved thanks to a participatory learning environment, where respect and collaboration were fostered. The *learning to be* manifested when it is conceived that the activity promoted a greater confidence in themselves and encouraged them to learn as a result of the active participation in the process.

Conclusions

It is expected that this work will contribute to the opening of ideas for improving pedagogical practices in the teaching of science and physics

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in a particular way. With respect to concepts related to the electric field, it was perceived that the application of the teaching strategy offered ways to deal with the subject, which is believed to be extended to issues with a certain level of complexity in the teaching of physics. In general, this strategy is an innovative, meaningful and accessible way for knowledge to be constructed in a way that transforms erroneous visions permeated by the common census.

Finally, taking into account the results obtained, it is necessary to mention that it was possible to verify how positive the teaching of this topic was through the analogy already mentioned. It is worth underlining that the methodology applied is effective once a greater number of certain answers are verified during the application of the second stage of the questionnaire. In this way, the reader interested in the subject can be invited to think about strategies like this that can be applied to other topics related to the teaching of this science, in order to promote more meaningful learning. Therefore, the invitation to use the proper contextualization of the topics studied, having as a focus the relevance of each content, so that it is possible to form more active and reflective human beings through the teaching of physics.

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