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# USE OF ELECTRICAL CIRCUIT SIMULATORS IN PHYSICS EDUCATION WITH ACTIVE LEARNING METHODOLOGIES

## *USO DE SIMULADORES DE CIRCUITOS ELÉTRICOS NO ENSINO DE FÍSICA COM METODOLOGIAS ATIVAS*

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## ABSTRACT

This paper explores the application of virtual simulators in the teaching of electrical circuits, focusing on using active methodologies to promote more effective and engaging learning. The theoretical framework covers the importance of information and communication technologies (ICTs) in education, highlighting the evolution of pedagogical practices and the impact of tools such as Tinkercad and PhET Colorado. The proposal includes the integration of virtual simulators in physics classes, aiming to enhance the understanding of electricity and magnetism concepts through practical and investigative activities. The research is based on a critical analysis of active methodologies and their applications, with a special focus on the flipped classroom methodology and the use of simulators as support for remote teaching. This study seeks to contribute to developing innovative and effective pedagogical practices in teaching electrical circuits.

**Keywords:** Virtual Simulators, Electrical Circuit Teaching, Active Methodologies, Active Learning, Information and Communication Technologies (ICTs).

**RESUMO**

Este trabalho explora a aplicação de simuladores virtuais no ensino de circuitos elétricos, com foco na utilização de metodologias ativas para promover uma aprendizagem mais efetiva e engajadora. O referencial teórico abrange a importância das tecnologias de informação e comunicação (TICs) na educação, destacando a evolução das práticas pedagógicas e o impacto de ferramentas como Tinkercad e PhET Colorado. A proposta inclui a integração de simuladores virtuais nas aulas de física, visando melhorar a compreensão dos conceitos de eletricidade e magnetismo através de atividades práticas e investigativas. A pesquisa é fundamentada em uma análise crítica das metodologias ativas e suas aplicações, com um enfoque especial na metodologia de sala de aula invertida e no uso de simuladores como suporte ao ensino remoto. Este estudo busca contribuir para o desenvolvimento de práticas pedagógicas inovadoras e eficazes no ensino de circuitos elétricos.

**Palavras-chave:** Simuladores Virtuais, Ensino de Circuitos Elétricos, Metodologias Ativas, Aprendizagem Ativa, Tecnologias de Informação e Comunicação (TICs).

## Background

In the context of contemporary education, information and communication technologies (ICTs) have proven to be powerful didactic tools to assist both teachers and students in the pursuit of a more dynamic and effective learning process (Andrade; Buffon; Junior, 2018). Physics education, in particular, is essential for understanding the scientific discoveries that impact everyday life (Queiroz *et al*., 2023). As a field dedicated to the study of natural phenomena, physics provides a solid foundation for analyzing the causes and effects of interactions in nature, fostering critical development regarding the transformations faced by humanity (Tonet; Leonel, 2019).

However, when examining the teaching of physics in schools, especially at the high school level, a significant gap becomes apparent between the true purpose of the subject and what students actually assimilate (Queiroz *et al*., 2023). Often, physics education follows a traditional and content-driven model focused on expository and mathematical methodologies, leading students to memorize equations without sufficient emphasis on the observation and analysis of phenomena (Santos; Dickman, 2019).

More dynamic and creative methodologies have the potential to help students reason more clearly about physics content (Domingues; Carvalho; Philippsen, 2021). However, integrating technology into the school environment to enhance the effectiveness of teaching still faces significant challenges, such as inadequate preparation in initial teacher training, the lack of appropriate resources in institutions, and the limited time allocated for technological activities (Andrade; Buffon; Junior, 2018).

In the context of teaching electric circuits, students often face difficulties in understanding the physical phenomena involved (Domingues; Carvalho; Philippsen, 2021). Tools such as PhET (Physics Educational Technology) and Tinkercad have proven to be effective in enhancing the understanding of these electrical systems through dynamic representations (Arantes; Miranda; Studart, 2010). PhET offers a wide range of simulations that allow students to interact with physical models, facilitating the comprehension of concepts, laws, and theories through direct observation and manipulation (Arantes; Miranda; Studart, 2010). Tinkercad is a free web application that provides tools for 3D design, electronics, and coding, fostering students' confidence through a practical and engaging approach (Autodesk, 2024).

According to the BNCC (Brazilian National Common Curriculum), computing and programming unfold in various aspects, including the use of digital tools for learning and production; the application of technological resources to develop, publish, and test products; and the mastery of languages and algorithms to solve specific problems (Brazil, 2018).

An approach that has shown great potential to overcome the limitations of traditional teaching is inquiry-based learning. This pedagogical method engages students in activities that promote the exploration and discovery of scientific concepts through active investigation (Araújo *et al*., 2023). Rather than passively receiving information, students are encouraged to formulate questions, conduct experiments, and analyze data, developing critical skills and a deeper understanding of the content (Oliveira, 2015). Inquiry-based learning not only stimulates students' curiosity but also prepares them to tackle real-world problems, fostering problem-solving skills and critical thinking (Reis, 2024).

According to Carvalho *et al*. (2014), an activity is considered investigative when it creates situations that provoke questioning and discussion, leading to problem-solving and the introduction and analysis of concepts. This type of teaching aims to develop skills related to scientific culture, bringing students closer to fundamental aspects of scientific practice, such as hypothesis formulation and the systematization of knowledge using scientific language (Carvalho *et al*., 2014).

In this context, the use of virtual simulators has proven to be highly effective in physics education, particularly in the area of electronic circuits. Tools such as PhET and Tinkercad offer interactive resources that transform the teaching-learning process. These tools facilitate the understanding of concepts and perfectly align with the inquiry-based teaching approach, allowing students to formulate hypotheses, conduct virtual experiments, and analyze results in a controlled environment.

In this paper, we will employ the integrative review methodology to explore the importance of using virtual simulators in physics education, with an emphasis on the application of active learning methodologies, particularly inquiry-based learning. The analysis will be conducted through a theoretical and qualitative discussion.

## Literature review

In educational literature, information and communication technologies (ICTs) have increasingly been integrated into teaching strategies. ICTs, such as computers, educational software, and online platforms, provide new perspectives for science education and facilitate the creation of more interactive and engaging learning environments (Rigotti *et al*., 2020). In particular, the use of computational simulations allows students to explore scientific concepts in a dynamic and visual manner, aiding in the acquisition of a deeper understanding of the phenomena being studied (Rigotti *et al*., 2020).

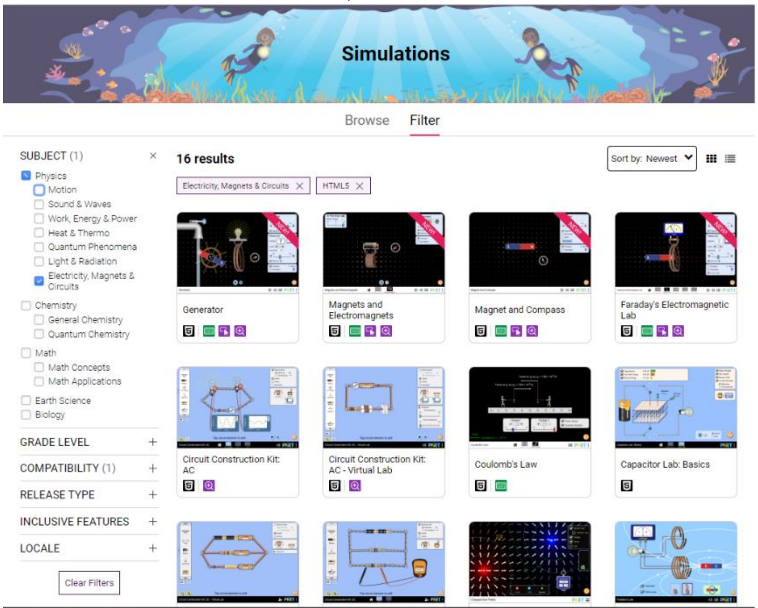
The global educational system faced unprecedented challenges due to the COVID-19 pandemic. Emergency Remote Teaching (ERT) became imperative with the suspension of in-person classes to ensure social distancing and public health. Virtual Learning Objects (VLOs) and Virtual Learning Environments (VLEs) exemplify how ICTs have played a crucial role in transforming educational strategies in this new context (Queiroz *et al*., 2023).

Students have the opportunity to explore scientific concepts visually and dynamically through interactive simulations offered by the PhET platform. These virtual environments provide a means to conduct experiments that would be impractical or hazardous in a traditional classroom setting (Queiroz *et al*., 2023). They can also be used in locations with limited infrastructure.

Physics education is an area that greatly benefits from the use of educational technologies, particularly in understanding physical phenomena (Macêdo; Dickman; Andrade, 2012). Virtual simulators are among the most widely used technological resources in physics education, due to their clear advantage as a bridge between traditional methods of studying phenomena (such as using a chalkboard) and laboratory experiments. They allow results to be observed clearly and repeatedly, with many variables involved. (Coelho, 2002).

PhET (Physics Education Technology) is a platform developed by researchers Carl Wieman, Eric Allin Cornell, and Wolfgang Ketterle from the University of Colorado, USA. PhET provides interactive and free simulations for mathematics and other sciences students, as illustrated in Figure 1. A comprehensive educational study involved students participating in an intuitive learning environment where discovery and exploration are the primary means of acquiring knowledge (Cristo et al., 2024).

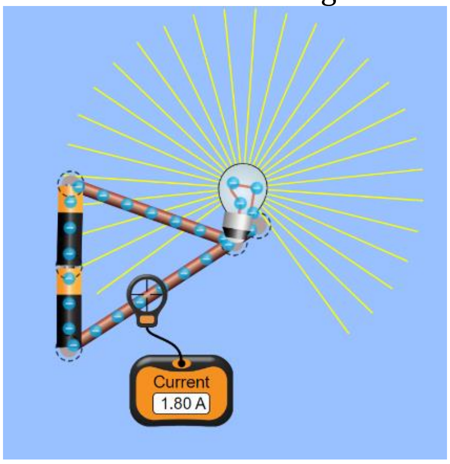
Figure 1 – PhET Simulations Interface, with results focused on Electrical Circuits




Source: PhET-Simulations (2024).

A research project was conducted as part of the physics curriculum internship for a third-year high school class at a public state school (Maia; Levinski, 2021). It was observed that students were solving exercises without understanding the connection between them and the concepts of physics. The study aimed to determine how the dialogic problematizing approach, which combines problem-solving with computational simulations, could contribute to the development of scientific thinking. Under the supervision of the school's teachers, 24 classes on DC and AC circuits, Ohm's laws, and generators were conducted. PhET Interactive Simulations, a tool developed by the University of Colorado Boulder that offers free and accessible simulations online, was utilized. Figure 2 illustrates the use of PhET Colorado, as proposed by Maia and Levinski (2021).

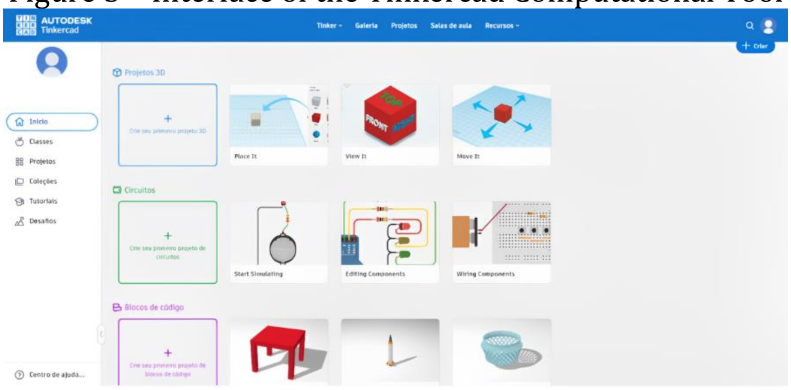
Figure 2 – Simple circuit assembled using PhET Colorado Software




Source: Adapted from Maia and Levinski (2021).

In the basic electricity and electronics course, practical experiments, although integrated with theory, are conducted in groups and constrained by the available time. In this context, the use of virtual laboratories such as TinkerCAD, illustrated in Figure 3, provides an interface similar to that of a real laboratory, allowing students to replicate and deepen the practices conducted in person. This approach facilitates the autonomous and collaborative exploration of concepts such as current, voltage, and electrical resistance, as well as the use of measurement instruments. The extracurricular activities proposed with TinkerCAD complement the theory, providing a learning environment that gives meaning to practical knowledge and encourages both discussion and student autonomy (Miguez *et al*., 2022).

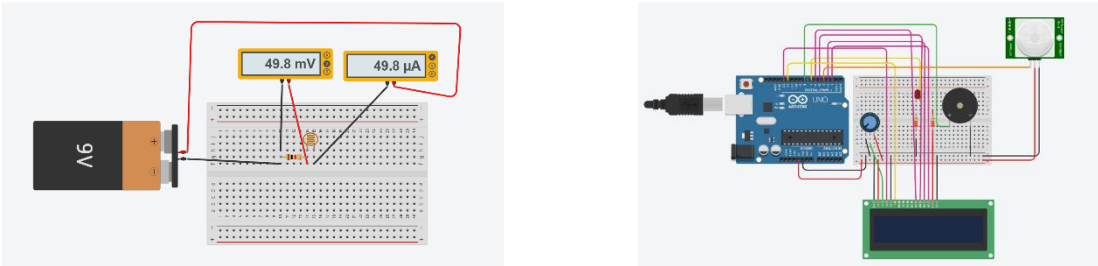
Figure 3 – Interface of the Tinkercad Computational Tool




Source: The Authors.

The Tinkercad computational tool was utilized for remote teaching of electrical circuits, applying the flipped classroom methodology (Santos & Santos, 2023). The qualitative research followed the participant observation method, with researchers actively engaging in remote activities, planning, and making adjustments as needed (Bogdan & Biklen, 1994). Students interacted with the tool by assembling circuits, testing their functionality, and formulating hypotheses. As shown in Figure 4a and Figure 4b, the practicality and flexibility of using the Tinkercad platform are evident.

Figure 4 – a) Circuit for measuring light intensity in an environment. b) Burglar alarm in Tinkercad




a) b)

Source: The Authors.

Technological advancement, especially in the field of robotics, is increasingly present in basic education, despite the gap between the rapid evolution of technologies and the training provided in schools (Azeredo & Filete, 2020). An example of an efficient and accessible application is the robotics workshop based on the Arduino platform, conducted virtually via Google Classroom and implemented using the Tinkercad software. The project proposed by Azeredo and Filete (2020) enabled teachers and students to learn how to create circuits with virtual components and program in both graphical and textual languages, all within a low-cost environment accessible to various education levels, from basic education to postgraduate studies. The proposal showed significant interest, suggesting that technologies like Arduino, when integrated with accessible tools such as Tinkercad, are valuable for the ongoing professional development of teachers across different fields.

Tinkercad was used to construct a traffic light with 5th-grade students in Votorantim — SP, as part of the project "Educational Robotics: a proposal for Elementary School I," demonstrating the effectiveness of technology in basic education (Mondini *et al*., 2023). The Tinkercad platform was chosen for its intuitive interface and cost-effectiveness, allowing students to explore concepts of electrical circuits and programming interactively. The virtual construction of the traffic light enabled students to experiment with and understand the logic of light control and electronic components, fostering skills development. This project not only introduced students to the world of technology but also contributed to digital inclusion and educational equity, aligning with affirmative actions aimed at combating inequalities and providing opportunities to students from less privileged backgrounds (Mondini *et al*., 2023).

**Active Methodologies in Physics Education**

Physics education has often been dominated by traditional teaching methods, where the teacher plays a central role and students are seen as passive recipients of knowledge, frequently limited to memorization and repetition (Barbosa *et al*., 2023). Despite the introduction of the Base Nacional Comum Curricular (BNCC) in 2018, which proposed a more dynamic and student-centered approach, many curricula still prioritize technical aspects and face challenges related to inadequate resources and teacher preparation. These factors have contributed to a growing disinterest among students in the subject (Barbosa *et al*., 2023).

Active Learning Methodologies (ALM) emerge as an innovative approach aimed at increasing student engagement and stimulating sensory/motor, affective/emotional, and cognitive aspects of learning (Nascimento & Coutinho, 2016). These methodologies offer a solution to transform the teaching and learning process in Physics, aligning with the principles of the BNCC and promoting an environment where students are protagonists of their educational journey (Barbosa *et al*., 2023).

The application of active learning methodologies plays an important role in education, especially in Brazil, where the sector requires substantial transformations. It is necessary not only to invest in quality content but also to recognize that improving the methods used for teaching is crucial when considering the holistic development of individuals. This is essential for providing fair, inclusive, and emancipatory education for present and future generations (Batista & Cunha, 2021).

However, the implementation of these methodologies faces challenges, primarily due to the need for mathematical understanding for problem-solving and the difficulty of adaptation by teachers (Barbosa *et al*., 2023). The lack of teacher preparation and limited school support are significant obstacles. Despite these challenges, the benefits of active learning methodologies are evident. They promote greater student engagement, stimulate teamwork, and develop critical, creative, and scientific skills, as well as cognitive and socio-emotional competencies, preparing students for a conscious role in society (Araújo & Araújo, 2023).

These methodologies allow students to adopt a proactive stance, choosing activities and facing challenges to solve problems and find practical solutions (Nascimento & Coutinho, 2016). Moreover, they promote student autonomy by encouraging curiosity and decision-making, both individually and collectively, based on essential activities in social practice and the students' context (Borges & Alencar, 2014).

Teacher preparation is essential for achieving the specific objectives that each active learning methodology provides for teaching physics. Thus, a crucial step in implementing these methodologies is to have clearly defined goals. For example, if a teacher aims for students to develop problem-solving skills, they must incorporate activities in their lessons that involve such situations. Similarly, if the teacher's goal is to foster creativity, task delegation, and collaboration among students, they need to engage students in situations that stimulate these qualities (Silva *et al*., 2023).

The use of technologies can support the planning, monitoring, and assessment of challenges and activities, enabling the mobilization of intellectual, emotional, personal, and communicative skills. Educators must refine their teaching practices by creating an environment that engages and challenges students to seek knowledge, learn from their mistakes, and apply their ideas meaningfully within a social context (Morán *et al*., 2015).

## Inquiry-Based Teaching in Physics Education

Student engagement in classroom activities is crucial for effective learning (Oliveira, Veit, & Araujo, 2015; Santos & Sasaki, 2015). In teaching electrical circuits, a traditional approach involves practical experimental activities, where students construct circuits in a laboratory using materials such as wires, bulbs, and batteries (Andrade, Buffon, & Junior, 2018). This hands-on practice provides valuable experiential learning. However, a modern alternative is the use of virtual simulations, which allow for digital experimentation without the need for physical laboratories or specific materials (Paludo, 2014).

Virtual simulations offer significant advantages, such as ease and speed of access and a safe digital environment to explore various scenarios involving resistors, capacitors, and bulbs. This risk-free environment for experimentation and interaction expands opportunities for experimentation and learning (Andrade, Buffon, & Junior, 2018).

Inquiry-based teaching is a methodology that differs by directing teaching activities toward the construction of knowledge through problem-solving rather than merely transmitting information (Barbosa & Moura, 2013). This method enables students to develop argumentation skills, engage in discussions with the teacher and peers, formulate and test hypotheses, and transition from every day to scientific language (Carvalho & Sasseron, 2015). When applied to circuit simulations, inquiry-based teaching allows students to use technology to solve proposed problems, promoting active and investigative learning (Faria & Vaz, 2019).

Inquiry-based teaching is characterized by presenting problematizing situations that foster questioning and discussion, involving problem-solving and concept analysis (Carvalho & Sasseron, 2015). The goal is to cultivate a scientific culture among students, bringing them closer to the essential elements of scientific work, such as hypothesis formulation and systematic knowledge using scientific language (Carvalho *et al*., 2014).

Computational simulations can be an effective tool for creating inquiry-based teaching sequences, provided they are designed to stimulate investigation. In more complex simulations, the ability to modify variables and observe outcomes enables students to test their hypotheses, aligning with the desired investigative nature (Arantes, Miranda, & Studart, 2010). As Sá (2009) emphasizes:

> Activities should be accompanied by problematizing, questioning, and dialogic situations that lead students to solve problems and introduce concepts for them to construct their knowledge. The student's action is fundamental in this type of strategy. They should not be limited to mere manipulation or observation. Instead, they must reflect, discuss, explain, and report, applying their knowledge to new situations (Sá, 2009, p.44).

Thus, while technological tools such as virtual simulations are extremely useful, they do not fully replace the fundamental pedagogical needs required to develop effective investigative activities. The creation and implementation of such activities remain significant challenges for educators (Andrade, Buffon, & Junior, 2018).

In the context of laboratory investigative activities, variation in student engagement can be influenced by various factors, including the clarity of instructions, task complexity, and support provided during the execution of the activities. Studies such as Faria and Vaz (2019) highlight that student engagement is often contingent upon the activities' ability to promote active and reflective participation, making it essential to adjust pedagogical strategies to meet different needs and levels of student competence.

In the work conducted by Andrade, Buffon, and Junior (2018), students used a simulation program to build and explore physical situations involving electrical circuits, employing the investigative approach of the POE (Predict, Observe, and Explain) Method. The results indicated that the activities significantly promoted student participation and engagement with the subject matter, demonstrating that

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students effectively grasped concepts related to simple electrical circuits. This methodological approach proved to be effective in engaging students actively and reflectively, facilitating the understanding and practical application of concepts interactively.

The adoption of investigative methodologies, both in traditional laboratory settings and through virtual simulations, has proven to be a promising approach for teaching physics, particularly in complex topics such as electrical circuits (Conceição, 2016). Investigative activities allow students to actively engage in the learning process, developing essential skills such as hypothesis formulation and testing and autonomous knowledge construction (Bernardino & Santos, 2023). Virtual simulations, in particular, provide a valuable alternative to physical laboratory environments, offering a safe and accessible space for exploring scientific concepts (Alfonso, 2024).

However, these activities must be well-planned and implemented to ensure effective and meaningful student engagement. The effectiveness of virtual simulations and investigative activities depends on the design of the activities, the clarity of instructions, and the support provided during execution. Studies demonstrate that the ability of activities to promote active and reflective participation is essential for successful learning (Faria & Vaz, 2019). Therefore, educators must continue to innovate and adjust their pedagogical strategies to meet the diverse needs and levels of student competence, ensuring that technological tools complement and enhance existing educational practices (Andrade, Buffon, & Junior, 2018).

Continuous progress in research and pedagogical practice is fundamental to improving the impact of investigative methodologies in physics education, ensuring that students not only understand scientific concepts but also develop critical and investigative skills essential for their future academic and professional success.

**Integrative Review Methodology**

Integrative review is a research method aimed at analyzing existing knowledge about the use of computational simulators in physics education. This method allows for the synthesis of multiple published studies, facilitating the creation of new insights based on previous research findings.

The concept of an "integrative" approach arises from the combination of different perspectives, ideas, or concepts obtained from the research applied to the method. This is where the potential for scientific knowledge advancement becomes evident (Whittemore & Knafl, 2005). By contributing to theoretical development, a well-executed integrative review presents the current state of knowledge on a given topic, such as environmental education. This methodological approach allows for the inclusion of studies employing different methodologies, including experimental and non-experimental designs.

To ensure that the integrative review is effective, researchers must exercise great care throughout its execution. At any stage of the review, a lack of explicit and systematic methods can result in a significant rate of errors. For instance, if relevant primary sources are not considered, the initial bibliographic search phase may be compromised. Additionally, there is a risk that data from these primary sources could be collected or interpreted incorrectly (Whittemore & Knafl, 2005).

In this study, we adopted the integrative literature review as the method for conducting the bibliographic review on the use of computational simulators in physics education, focusing on their contribution to the active learning process. This approach was selected for its ability to synthesize and analyze existing scientific knowledge on the subject (Cooper, 1984; Ganong, 1987; Broome *et al*., 2000; Beyea & Nicholl, 1998; Stetler *et al*., 1998).

Given this description, the stages of the integrative review process are delineated and organized in a clear and systematic flow to ensure the quality and validity of the review. These stages are essential to ensure that the integrative review is conducted rigorously and comprehensively, resulting in meaningful

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insights and contributions to the advancement of knowledge in the field of physics education.

The integrative review process follows a series of well-defined stages. These stages are represented in Table 1 and will be described in detail below.

Table 1 – Description Used as Classification of the Stages Applied in the Integrative Review Process

| INTEGRATIVE REVIEW | | | | | |
|---|---|---|---|---|---|
| 1ª Stage | 2ª Stage | 3ª Stage | 4ª Stage | 5ª Stage | 6ª Stage |
| Identification of the Topic and Selection of the Research Question. | Establishment of Inclusion and Exclusion Criteria. | Identification of Pre-Selected and Selected Studies. | Categorization of Selected Studies. | Analysis and Interpretation of Results. | Presentation of the Review/Synthesis of Knowledge. |
| Definition of the problem. Formulation of a research question. Definition of descriptors. Definition of databases. | Use of databases. Search for studies based on inclusion and exclusion criteria. | Reading the abstract, keywords, and title of publications. Organization of pre-selected studies. Identification of selected studies. | Development and use of the Synthesis Matrix. Categorization and analysis of information. Formation of an individual library. Critical analysis of the selected studies. | Discussion of the results. | Creation of a document detailing the review. Proposals for future research. |

Source: The Authors.

## Integration of Inquiry-Based Teaching

Inquiry-based teaching is an educational method that prioritizes students and offers activities centered around them, helping them learn to solve problems and make decisions (Sá *et al*., 2007). Inquiry-based teaching involves, among other aspects, active student participation in the teaching and learning process, granting them greater control over their learning (Clement, Custódio, & Filho, 2015).

In this context, inquiry-based teaching requires the formulation of a problem that not only piques the students' curiosity but is also suitable for addressing the content to be taught. The primary purpose of this pedagogical approach is to "make students reflect, discuss, justify their ideas, and apply their knowledge to new situations using theoretical and mathematical concepts" (Santos, 2012).

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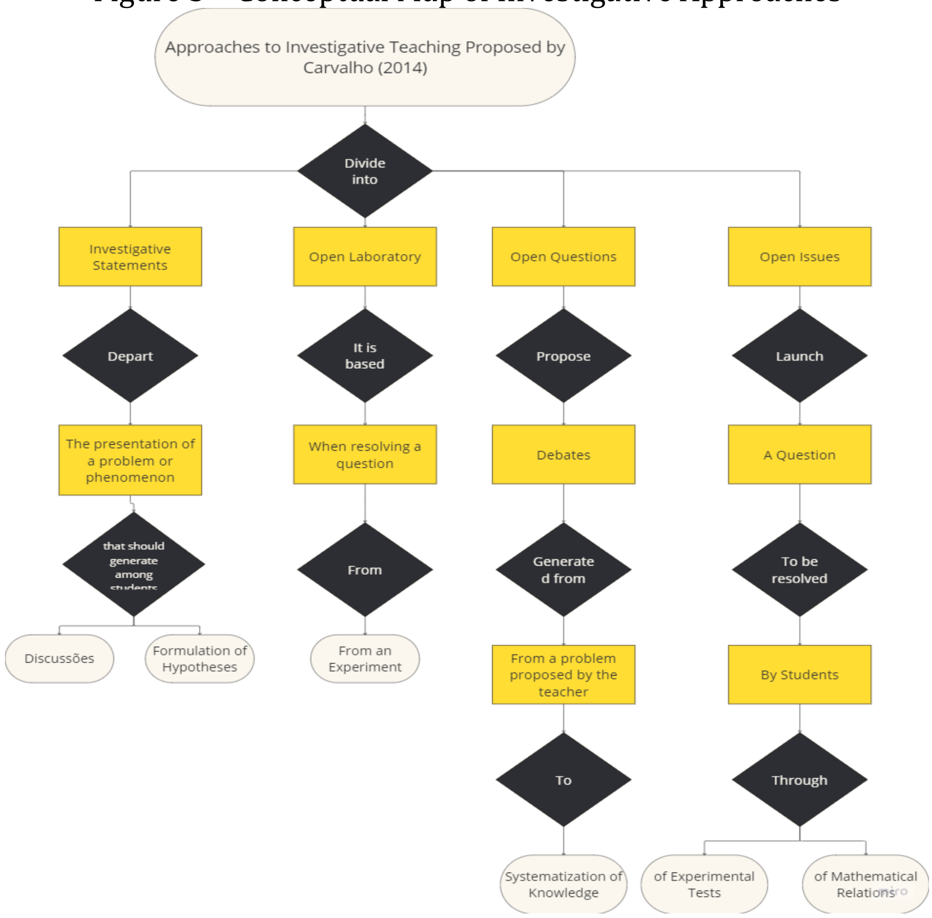
Activities in inquiry-based teaching allow the lesson to be shaped according to the students' progress. Consequently, such activities do not need to follow rigid scripts, permitting students to intervene or make modifications (Oliveira, 2010). The author also emphasizes that due to its more flexible nature, the stages of these lessons can be defined during discussions and adjusted as new discoveries are made or answers are re-evaluated (Mourão & Sales, 2018).

According to Carvalho (2014), an activity can only be considered investigative if it is accompanied by situations that promote problematization, questioning, and dialogue, involving problem-solving and the introduction of concepts. Carvalho (2014) suggests four ways to apply investigative approaches: investigative demonstrations, open laboratories, open questions, and open problems. These different approaches are concisely outlined in a conceptual map demonstrated in Figure 5.

Figure 5 – Conceptual Map of Investigative Approaches




Source: Adapted from Mourão and Sales (2018).

**Integration of Inquiry-Based Teaching**

Investigative demonstrations refer to activities that begin with the presentation of a phenomenon or problem to be explored, leading students to investigate the phenomenon in question (Santos, 2012). Carvalho (2014) notes that, in general, experimental demonstrations in the sciences are conducted with the intention of illustrating a theory, whether it has already been addressed or is in the process of study.

**Investigative Demonstrations**

In classroom demonstrations, the starting point is always a problem (Figure 5) proposed by the teacher, who, through questioning students, seeks to identify the type of thinking they have about the topic, whether it is intuitive or based on common sense. This can be exemplified by the following citation:

> Firstly, it is essential to know how to formulate problems. And, no matter what is said, in scientific life, problems do not spontaneously formulate themselves. It is precisely this sense of the problem that characterizes the true scientific spirit. For the scientific spirit, all knowledge is a response to a question. If there is no question, there can be no scientific knowledge. Nothing is self-evident. Nothing is free. Everything is constructed (Bachelard, 2021, p. 22).

In this context, the teacher plays a role in guiding students through the transition from everyday knowledge to scientific knowledge through investigation and questioning about the phenomenon.

Azevedo (2012, p. 27) highlights several contributions of investigative demonstrations in physics teaching, such as enhancing student interaction with the subject matter, creating cognitive conflicts in the classroom, understanding students' spontaneous conceptions through their participation in various stages of problem-solving, and emphasizing the learning of attitudes in addition to content.

**Open Laboratory**

As illustrated in the Conceptual Map (Figure 5), this approach involves an experimental investigation where students, organized in groups, are challenged to solve a problem through practical experimentation (Santos, 2012; Carvalho et al., 2014).

Azevedo (2012, pp. 28-29) outlines that this search for a solution can be structured into six stages: the formulation of the problem (presenting a broad, non-specific question designed to stimulate scientific curiosity and promote extensive discussion); hypothesis generation (conducted by the students under the teacher's guidance); development of a work plan (deciding on the methodology to be used in the experiment); setup and data collection (practical stage where students manipulate materials and begin collecting data); data analysis (including graph construction and hypothesis testing); and, finally, conclusion (formulating a response to the initial problem and discussing the validity of the proposed hypotheses).

The importance of the teacher emphasizing that this analysis is crucial in scientific work lies in the fact that such activities significantly contribute to the development of student's cognitive skills, such as analysis, comparison, interpretation, and evaluation, which are essential for strengthening critical thinking (Borrajo, 2017).

**Open Questions**

This approach involves presenting real-life situations related to concepts previously discussed in class. As depicted in the conceptual map (Figure 5), based on Carvalho (2014), the teacher should propose scenarios that encourage student participation, allowing them to develop reflection skills, organize their thoughts to systematize knowledge, and use scientific language appropriately. Carvalho (2014, pp. 90-91) suggests three ways to work with open questions: in large groups, in pairs, or in small groups of three or four students, as well as through tests and assessments. Regardless of the format, students need to record their answers in writing. The teacher should then facilitate a discussion based on the responses, highlighting which answer aligns most closely with the scientific viewpoint.

**Open Problems**

In open problems, the solution does not occur immediately or automatically. Students are presented with general and broad situations that must be resolved through a process of reflection and decision-making. Unlike open questions, an open problem (Figure 5) requires the results to be expressed mathematically. In an open-ended problem, the solver needs to conduct a qualitative study of the situation, formulate hypotheses, and develop solution strategies based on theoretical knowledge (Peduzzi and Peduzzi, 2001).

Carvalho (2014) adds that the problem situation should be engaging for the student and preferably related to their everyday life. This investigative approach stimulates students' creativity and encourages them to organize their thoughts, as they will need to formulate hypotheses and set boundaries for a real situation. As with open questions, students must document the entire process in writing.

**Conclusion**

This study qualitatively explored the application of virtual simulators in teaching electrical circuits within the State-of-the-art framework, with a particular focus on active methodologies, such as flipped classrooms and the use of technological tools. The primary aim was, through the use of the integrative review methodology, to identify works that promote more engaged and effective learning, emphasizing the significance of information and communication technologies (ICTs) in the educational environment.

The research demonstrated that integrating virtual simulators can significantly enhance students' understanding of electrical circuits. These simulators offer a practical and investigative approach, allowing students to experiment with and visualize concepts that are often abstract when addressed theoretically. The active methodology proved particularly effective in fostering dynamic and autonomous learning, encouraging students to engage more deeply with the content and develop problem-solving skills.

The flipped classroom methodology, based on the studies reviewed, emerged as an effective approach for maximizing classroom time for practical activities and discussions. The theoretical study presented highlighted the crucial role of ICTs in facilitating remote teaching, especially during the COVID-19 pandemic. Tools such as Tinkercad, according to the referenced authors, were particularly useful for constructing and simulating electrical circuits, providing a richer and more interactive learning experience and enabling better visualization and understanding of concepts.

The research underscored the importance of adapting pedagogical practices to students' needs and preferences, emphasizing the necessity for innovative methodologies that can meet the demands of contemporary teaching. The adoption of virtual simulators and active methodologies can serve as a model for other areas of physics education, offering a solid foundation for future investigations and pedagogical practices.

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