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ARTIFICIAL INTELLIGENCE IN PHYSICS TEACHING: TOOLS FOR EDUCATIONAL INNOVATION

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ABSTRACT

This research aims to analyze how Artificial Intelligence (AI) and other educational technologies, such as recommendation systems, active methodologies and virtual simulators, can be used in a complementary way to modernize the teaching of Physics, promoting a more dynamic, personalized and meaningful learning. Theoretically based on authors such as Nogueira (2023), Moreira (2018) and Bardin (2011), qualitative research is based on case analysis to identify advantages, challenges and perspectives of these innovations. Research reveals that AI can personalize learning and optimize teaching, overcoming challenges such as teacher training and technological infrastructure. Active methodologies, such as Problem-Based Learning (PBL) and the Flipped Classroom, have proven effective in engaging students and developing critical skills, while tools such as Easy YouTube (EYT) and virtual simulators, such as Physics Education Technology (PhET), diversify content and facilitate the understanding of complex concepts. The text is structured in four main parts: the first presents the concepts of AI and active methodologies; the second discusses the role of recommendation systems and the effectiveness of virtual simulators; the third analyzes the possible transformations in the teaching of Physics based on the technologies explored; and, finally, the fourth part discusses the necessary conditions for the effective implementation of these tools, with emphasis on teacher training and school infrastructure. It is concluded that the integration between technological innovation and pedagogical practices configures a promising path to transform the teaching of Physics in the twenty-first century.

Keywords: Artificial Intelligence (AI). Active Methodologies. Teaching of Physics.

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INTRODUCTION

The teaching of Physics has been faced with structural and methodological challenges that make it difficult for students to approach the concepts and practices of the discipline. Despite the immense importance of Physics in the formation of citizens and in the understanding of the world around us, traditional methodologies, centered on the passive transmission of knowledge, often result in disinterest on the part of students (Moreira, 2018). In this context, the incorporation of educational technologies, such as AI, recommendation systems, and virtual simulators, has proven to be a promising strategy to innovate teaching and engage students in a more effective and personalized way.

AI, in particular, has shown great potential to transform the way content is approached and how students interact with learning. As highlighted by Nogueira (2023), it can be used to personalize teaching, adapting to the pace and needs of each student, providing continuous and individualized learning. However, the effective implementation of AI-based tools depends not only on the technological infrastructure of schools, but also on a continuous process of training teachers, who need to adapt to the new pedagogical demands brought about by these technologies.

In addition, active methodologies, such as PBL and the Flipped Classroom, perfectly complement the use of this combo in Physics teaching. These approaches have as their main objective to promote the student's protagonism and stimulate the development of critical skills, such as logical reasoning and problem solving, which are essential in the study of Physics.

PBL, for example, challenges students to solve real or hypothetical questions, encouraging the application of physical concepts in a practical and meaningful way. The Flipped Classroom, on the other hand, allows students to have access to theoretical content outside the classroom, leaving class time for discussion and active practice of concepts. The combination of these methodologies with emerging technologies has the power to transform the dynamics of learning, making it more collaborative, interactive, and aligned with the demands of the twenty-first century.

The use of recommendation systems, such as EYT, arises as a response to one of the main difficulties of teachers in the digital educational context: the search and selection of relevant educational content. As pointed out by Pinheiro et al. (2018), the automated recommendation of videos and teaching materials can save time and provide quick access to quality resources, which are essential for building richer and more diverse learning.

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These systems operate through collaborative filtering algorithms and content-based recommendation, adjusting to users' preferences and needs to suggest materials that complement teaching in a more efficient and personalized way. Simultaneously, virtual simulators present an innovative alternative for teaching Physics, offering students the opportunity to interact with phenomena that would be difficult to observe or experience otherwise. The PhET platform is an example of a resource that allows you to simulate complex physical situations, providing more visual and practical learning. According to Lopes, Silva, and Souza (2023), these tools help overcome the limitations of traditional teaching, allowing students to visualize abstract concepts in a concrete and interactive way.

The incorporation of educational simulators also meets a growing demand for quick and immediate feedback, which is key to maintaining student interest and motivation in the digital age. However, the implementation of these technologies faces significant challenges, especially in relation to infrastructure in schools and the lack of specific teacher training. Despite the potential of technologies, many teachers are still not prepared to use them effectively, which can compromise the quality of teaching. In addition, the need for a pedagogical approach that values the conscious and integrated use of technologies is essential for them to become tools for real transformation in the educational process. As noted by Lopes, Silva, and Souza (2023), continuing education is a crucial element to ensure that the use of simulators and AI is done in a way that complements and enriches the learning experience, and does not replace the role of the educator.

Therefore, this work proposes to investigate how AI can favor the improvement in the teaching-learning process of Physics in High School. It is based on a qualitative bibliographic research, which is based on the analysis of articles, dissertations and specialized journals, according to the principles of content analysis of Bardin (2011). The general objective of the research is to analyze the contributions of AI and educational technologies in the teaching of Physics and, as specific objectives, to identify methodological strategies, discuss the challenges for their implementation and evaluate the pedagogical benefits provided by these innovations.

The text is organized into four main parts: the first presents the concepts of AI and active methodologies; the second addresses *chatbots*, recommendation systems and virtual simulators; the third analyzes the potential transformations in the teaching of Physics; and the fourth discusses the conditions for implementation, with emphasis on teacher training and school infrastructure.

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Thus, the integration between AI, active methodologies and digital tools is a promising way to transform the teaching of Physics in the twenty-first century, promoting a more dynamic, collaborative learning aligned with the demands of contemporary society.

METHODOLOGY

This study aims to analyze how AI can be used in a complementary way in the teaching of Physics in High School, exploring its main advantages, challenges and perspectives in the educational context. Bibliographic research was chosen as a methodology because it is fundamental for the theoretical basis and structuring of studies of this nature. This approach not only provides a systematic and organized survey of relevant information, but also enables the construction of a memory rich in records and notes, essential for the writing of the work and for the deepening of the theme.

> Bibliographic research is the necessary and basic basis for carrying out monographic studies, with the exception that the bibliographic survey is the essence of the exploratory study, and must be accompanied by notes, records, class notes, as well as notes that are related to the theme of interest, in order to constitute an important memory for the registration and writing of the work (Soares, Picolli and Casagrande, 2018, p.3).

Although AI has significant potential to transform teaching, the analysis of academic articles and bibliographic research has highlighted a scarcity of studies that directly address its application in the teaching of Physics. This gap has been pointed out by several authors, such as Nogueira (2023), who highlights the need for interdisciplinary research that unites Education, Physics, and Technology to explore the possibilities of integrating these areas. This absence of literature reflects both the novelty of the topic and the challenges inherent in the practical application of technological tools in specific educational contexts.

To overcome this limitation, this study refined the keywords used in searches carried out on Google Scholar and in databases such as Scopus and SciELO, using terms such as "Active Methodologies in Physics" and "Artificial Intelligence in High School". This strategy allowed to broaden the search spectrum and identify more comprehensive and up-to-date materials in digital libraries, ensuring greater depth in bibliographic research and a more robust analysis of the applications of AI in the teaching of Physics.

Methodological rigor is not established only by the attribution of a specific name, but by the detailed explanation of the steps followed in carrying out the research, with a clear

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and precise description of the path adopted to achieve the objectives. In this study, the bibliographic research was planned in a systematic way, with a focus on ensuring the validity and relevance of the sources analyzed. The research is based on the analysis of dissertations, scientific articles and specialized journals that address AI, Physics teaching methodologies and technological applications in the educational environment. Gil (2010, p. 43) defines bibliographic research as "a set of theoretical procedures that aim to identify the knowledge available in the literature on a given subject". Thus, sources such as dissertations have provided a solid theoretical basis, essential to deepen concepts and theories, while articles from specialized journals have brought recent contributions and empirical data that allow an updated and relevant analysis of the theme.

Although the work presents AI as a promising tool, it is necessary to explore in greater depth the practical impact of this technology on the teaching of Physics. As in the case of intelligent tutoring systems, educational data analysis and tools such as interactive simulators can transform classroom teaching. Furthermore, the research benefited from a broader discussion about the challenges and limitations of active methodologies in the teaching of Physics. Despite their potential, there are significant barriers, such as teacher resistance, the need for specific training, and the adequacy of school infrastructure to implement these approaches. Aspects such as the lack of time to plan interactive activities or the difficulty in balancing theory and practice are also challenges that deserve to be highlighted.

The active methodologies are detailed as to their application in the teaching of Physics. In an illustrative way, PBL can be structured in a way that connects real problems of students' daily lives with physical concepts, promoting both engagement and deeper understanding. Other strategies, such as the use of virtual laboratories, interactive simulators and augmented reality, can also be used as complementary tools to the teaching of Physics.

The integration of Information and Communication Technologies (ICT) is another relevant point. Tools such as the PhET virtual lab exemplify how interactive simulations can facilitate the understanding of complex concepts, but it would be interesting to expand this analysis, discussing how *simulation software*, augmented reality, and adaptive teaching platforms can enrich learning. As an example, how can AI be used to analyze students' responses and propose customized activities to overcome specific difficulties?

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The selection of sources followed strict inclusion and exclusion criteria, ensuring the reliability and relevance of the materials analyzed. The qualitative bibliographic research was structured with the aim of systematically exploring the use of AI and active methodologies in the teaching of Physics, with a particular focus on High School. The selection of the works was carried out based on rigorous criteria, prioritizing studies that specifically addressed the use of AI in the teaching of Physics and the innovative pedagogical practices that have gained prominence, such as active methodologies. The analysis of these sources followed the content analysis methodology proposed by Bardin (2011), which is characterized by the segmentation and organization of data in order to facilitate the understanding of the topics addressed. This approach allowed a detailed analysis, organized into two main categories: Artificial Intelligence in Physics Teaching and Active Methodologies in Physics Teaching.

The first category, focused on Artificial Intelligence in Physics Teaching, included studies that explore the use of AI as a tool to improve the teaching-learning process of Physics. Among the most relevant works for this category are the studies by Dantas et al. (2019), which discuss the use of AI-based *chatbots* to aid the teaching of Physics, providing a more personalized and efficient interaction in the learning process. Another important study was that of Nogueira (2023), who investigated the perception of students in the Physics course at the Federal University of Ceará about the use of AI as an educational tool. In addition, the work of Tavares, Meira, and Amaral (2020) presents a more comprehensive analysis of the use of AI in education, discussing its implications for science teaching and its advantages in the educational context.

The second category, focused on Active Methodologies in Physics Teaching, includes studies on pedagogical practices that seek to make the student the protagonist of their learning, using technologies such as simulators, games and project-based learning. The work of Lovato, Michelotti and Da Silva Loreto (2018) was one of the main references for this analysis, as it presents a critical review of active methodologies. Gomes, Franco and Rocha (2020) also contribute significantly to the understanding of the use of simulators as tools to enhance the learning of Physics, bringing examples of how these technologies can be incorporated into everyday school life to make teaching more dynamic and effective. The analysis by Goulart, Pastorio, and Vidmar (2023) was important to understand the impact of digital technologies on Physics teaching, especially in the context

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of emergency remote teaching, when the use of technologies intensified due to the pandemic.

The work of Darroz, Rosa, and Ghiggi (2015), in turn, offered a comparative analysis between traditional methodologies and meaningful learning methodologies, exploring how these approaches impact teacher teaching and training.

The segmentation of the texts followed the proposal of Bardin (2011), who guides the reading of the works with the objective of identifying the units of registration, that is, the excerpts of the texts that address the central aspects of the categories in question. From this reading, the information was grouped according to the most recurrent themes and the main ideas presented by the authors. The categorization process involved the identification of sub-themes, such as the personalization of teaching through AI, the use of digital tools for remote teaching, and the application of active methodologies to improve student engagement in Physics classes.

The critical analysis of the works revealed that both active methodologies and AI-based tools have the potential to transform the teaching of Physics, making it more interactive and adapted to the needs of students. Digital technologies, such as *chatbots* and simulators, allow for a more personalised and effective approach, while active methodologies, such as project-based learning, promote student autonomy and encourage critical thinking and collaboration. The integration of these approaches in the educational context can provide more meaningful learning, in addition to preparing students for the challenges of an increasingly digital and interconnected world.

In short, the bibliographic research allowed us to understand the contributions of digital technologies and active methodologies in the teaching of Physics, especially in High School, and how they complement each other to improve the teaching-learning process. Content analysis, according to Bardin's (2011) methodology, was fundamental to organize the information and provide a clear and in-depth view of the topics addressed, highlighting the most relevant works for each of the categories and offering a solid basis for future investigations and pedagogical practices.

As proposed by Fink (2019), this research was planned with a clear definition of the theme and the central research issues. The guiding question "How can AI favor the improvement in the teaching-learning process of Physics?" guided all stages of the research, from the initial search to the synthesis of the data. Thus, the study presents a

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consistent and grounded methodological path, contributing to a critical analysis of the use of AI in the teaching of Physics.

Thus, the methodology presented here is based on the rigorous analysis of reliable academic sources, such as university repositories and specialized journals, ensuring a robust qualitative approach to support the objectives of this work.

AI IN THE EDUCATIONAL CONTEXT

This chapter draws on the literature research described in the methodology to discuss how AI has been approached in the educational context. The analyzed works were selected based on criteria of relevance and topicality, following the principles of content analysis by Bardin (2011). From this research, the main contributions, challenges, and trends related to the use of AI in education were identified.

Bates (2015) characterizes artificial intelligence as the representation in software of the mental processes involved in human learning. The author notes that attempts to replicate teaching through AI began in the 1980s, initially focusing on the teaching of arithmetic. Despite the various studies on this tool in education over the last three decades, the results obtained have not been satisfactory.

The difficulty of machines in dealing with the wide range of ways in which students learn (or face difficulties learning) has proved to be a significant challenge. However, we have begun to notice more significant advances recently, especially with regard to adaptive learning.

According to Tavares, Meira, and Amaral (2020), the use of artificial intelligence in education, known in English as *Artificial Intelligence in Education* (AIED), is a controversial topic. This is mainly due to factors such as insufficient technological infrastructure, lack of teacher training, and ethical issues surrounding the use of student data. The application of AI can be seen as a form of substitution of human tasks, and, from an objectivist perspective, which focuses on quantitative and measurable results without considering the particularities of the teaching context (Garrison, Anderson and Archer, 2001), it can lead to the mistaken idea that the machine could replace the teacher. However, there is great potential for using AI as a valuable support in learning activities, both from the perspective of students and educators.

Applications can be found in the daily lives of teachers and students. By way of illustration, intelligent tutoring systems adapt the content to the learning pace of each student, providing a personalized experience.

On the other hand, the analysis of educational data allows educators to identify performance patterns, facilitating targeted interventions. *Chatbots* are another interesting tool. They are AI systems designed to simulate conversations with users, being able to answer questions in real-time and offer ongoing support outside of school hours. This definition is based on authors such as McTear (2017), who details how they operate using natural language processing techniques to interact with students.

In addition, adaptive learning platforms use algorithms to create tailored learning paths, increasing student engagement. These tools show how AI can enrich teaching, making it more accessible and centered on the needs of students. Throughout the 1980s to the present day, one of the main challenges faced by AI in education has been its difficulty in dealing with the diversity of ways students learn. Each individual learns in a unique way, influenced by cultural, emotional, and cognitive factors. Early initiatives, such as arithmetic-focused tutoring systems in the 1980s, had limitations in that they were unable to adapt to this variability. An example of this was PLATO (*Programmed Logic for Automatic Teaching Operations*), which emerged in the 1970s and had greater prominence in the 1980s. Although innovative for the time, the system did not have the necessary flexibility to adjust to the different ways of learning of students. In addition, the lack of sufficient data and the less advanced technology of the time made it difficult to develop effective solutions. However, recent advances, driven by deep learning algorithms and large volumes of data, have overcome some of these barriers.

Another point that generates discussions is the ethical and pedagogical impact of the adoption of AI in education. The personalization promoted by these technologies, while appealing, raises concerns about student privacy and data protection. In an environment where algorithms analyze personal information to create tailored learning paths, there is a risk of exposure or inappropriate use of this data. Thus, it is essential that robust security policies accompany the implementation of these tools, ensuring that the benefits do not come at the expense of privacy.

Equally, it is essential to prepare teachers for the effective use of artificial intelligence in teaching. Many educators are still unaware of the potential of these tools or face difficulties in integrating them into their practices. Offering training that teaches not only technical use, but also strategies to combine available tools with traditional pedagogical methodologies, can be the key to maximizing benefits.

In this sense, AI should not be seen as a replacement, but as an extension of the teacher's skills, allowing them to focus on activities that require human sensitivity and critical judgment.

Finally, the balance between the use of technology and human interaction in the educational process must be carefully evaluated. While adaptive learning platforms offer personalized trajectories and increase engagement, the figure of the teacher remains indispensable. He is the mediator who interprets the data provided, makes adjustments based on the context, and offers emotional support that no machine can replicate. Thus, the greatest potential of AI lies in enriching teaching practice, making teaching more dynamic, accessible, and efficient, without losing the human essence of education.

PHYSICS LEARNING

The discussion presented in this chapter is based on the literature review described in the methodology, which included relevant works on the teaching of Physics and innovative pedagogical strategies. The analysis of the materials followed the guidelines of Bardin (2011), allowing the categorization of the results into two main axes: active methodologies and specific methodologies for teaching Physics. These axes structure the subsequent topics and are supported by central authors, such as Lovato, Michelotti and Da Silva Loreto (2018) and Nogueira (2023).

Moreira (2018) points out that the teaching of Physics in Brazil had a significant growth in the 1980s, driven by advances in research, the creation of graduate programs, the holding of national meetings, and international recognition. However, despite being a consolidated research area, in recent years it has faced challenges, such as the reduction of the workload, the shortage of professors and the lack of adequate environments for practical classes. Similarly, much content is still taught by traditional methods, which may not meet the current needs of students. The result of this type of teaching is that students, instead of developing a predisposition to learn Physics, as would be desirable for meaningful learning, end up generating such an intense aversion that they even state, metaphorically, that they "hate" (emphasis added) Physics.

It is important to note that few students complete high school with a clear understanding of the concepts of Physics. This is because the discipline is often taught

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only as a set of formulas and information, without taking into account the students' perspectives on the world and experiences. This approach limits learning to only what has been taught in the classroom, not enabling them to understand the world in which they live.

According to Leite (2023), Physics is integrated into our daily lives, influencing everything from simple actions, such as hearing and seeing, to more complex activities, such as running, building things, and predicting phenomena. It plays a crucial role in the technologies and structure of modern society. Thus, learning Physics is not only a human right that frees us from simplistic interpretations and common sense; It is also a fundamental tool to stimulate critical thinking.

The resistance of many teachers to adopt innovative teaching methods in Physics can be attributed to a combination of individual and political factors, as pointed out by Santos, Beato and Aragão (2010). At the individual level, issues such as lack of time, reluctance to try new approaches and insecurity resulting from inadequate training contribute to the maintenance of traditional education. Moreover, the lack of adequate materials and environments for the practice of teaching can discourage educators from exploring new methodologies, limiting the quality of student learning.

In the field of school policies, the situation is equally challenging. The lack of access to resources, such as *outdated hardware* and inadequate software, along with the absence of environments conducive to the implementation of educational technologies, reinforces teachers' resistance to innovating.

Santos, Beato and Aragão (2010) highlight that institutional reorganization is essential to facilitate this transition, allowing teachers to integrate ICT into their practices, which could result in a more dynamic teaching that is aligned with the current needs of students provided for by the National Common Curricular Base (BNCC) (Brasil, 2018).

> Initially, the Base establishes the following thematic units for the area of knowledge in question, in High School: Matter and Energy; and Life, Earth and Cosmos. In the first, the focus appears on the interactions between matter and energy, as the name suggests, highlighting the use of more abstract models (without mentioning which ones) that allow a better understanding of phenomena that involve knowledge of the curricular components of this area. In the second unit, it is established that the proposal is that students can understand the complexity of the emergence of life, especially human life, on Earth, so that they need more advanced models to study processes such as nuclear reactions, the emergence of stars, the formation of matter, among other subjects that involve the interaction between human existence and the environment in which they live (Arruda, 2022, p.47).

The BNCC (Brazil, 2018) establishes specific guidelines for the teaching of Physics that seek to promote a deeper understanding of natural phenomena. Among the objectives

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is the elaboration of explanations and predictions about the movements of objects, using the analysis of gravitational interactions, with or without the aid of digital devices, such as simulation software and virtual reality.

It also emphasizes the importance of analyzing stellar evolution, relating it to the origin and distribution of chemical elements in the universe, as well as investigating and understanding the functioning of electrical and electronic equipment to evaluate contemporary technologies and their social, cultural and environmental impacts, etc. The competencies for the area of Natural Sciences are three in total and are listed below:

> Specific Competencies of Natural Sciences and their Technologies for High School 1. Analyze natural phenomena and technological processes, based on the interactions and relationships between matter and energy, to propose individual and collective actions that improve production processes, minimize socio-environmental impacts, and improve living conditions at the local, regional, and global levels. 2. Analyze and use interpretations of the dynamics of Life, the Earth and the Cosmos to elaborate arguments, make predictions about the functioning and evolution of living beings and the Universe, and support and defend ethical and responsible decisions. 3. Investigate problem situations and evaluate applications of scientific and technological knowledge and their implications in the world, using procedures and languages specific to the Natural Sciences, to propose solutions that consider local, regional and/or global demands, and communicate their findings and conclusions to varied audiences, in different contexts and through different media and digital information and communication technologies (DICT) (Brazil, 2018, p. 553).

The first two specific competencies, directly linked to the thematic units, can be enriched with the use of technological resources.

AI can contribute to the deployment of these skills by offering tools that allow you to customize learning according to the needs and rhythms of students, facilitating the construction of specific skills in a more efficient and engaging way.

In addition, technologies such as virtual simulators, intelligent tutoring systems, and educational data analysis can help contextualize content in a more dynamic way, providing learning experiences that connect theory to practice, especially in local and global contexts (Tavares, 2020).

In the case of the third competency, which seeks to integrate the contextualization of scientific knowledge, AI can act as a mediator between academic knowledge and everyday issues, allowing students to explore local and global problems in an interactive and contextualized way. The use of tools such as *chatbots*, simulation platforms, and analysis of large volumes of data can broaden the understanding of how scientific knowledge applies to the real world, promoting a deeper reflection on the implications of global issues,

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such as climate change and social inequality, while connecting these topics to local realities (Leite *et al*., 2017).

Through AI, it would be possible not only to teach "what should be done" with scientific knowledge, but also to engage students in active and contextualized learning, which allows them to reflect on how to apply this knowledge in different scenarios. The combination of emerging technologies with innovative pedagogical practices can thus contribute significantly to achieving the proposed teaching and learning objectives.

Darroz, Rosa and Ghiggi (2015) state that the current teaching model, which focuses only on the development of content with an emphasis on solving exercises, can lead to good results in quantitative assessments. However, this approach is inadequate for understanding and exploring new content.

Zanatta and Neves (2016) complement this idea by highlighting that the competencies required for the teaching of Physics in the contemporary era, as established by the BNCC (Brasil, 2018), cannot be fully met by the traditional model. Students demonstrate a growing interest in more engaging and interactive methods, surpassing conventional lectures.

ACTIVE METHODOLOGIES

The active methodologies analyzed in this work were organized based on a thematic categorization that included strategies such as PBL, the Flipped Classroom and Project-Based Learning. These methods were evaluated considering their practical applications in the teaching of Physics and the potential to engage students, as described by authors such as Morán (2015) and Lovato, Michelotti and Da Silva Loreto (2018).

Morán (2015) informs that, currently, schools face uncertainties in the midst of the great changes that occur in society. Institutions need to adapt to provide a comprehensive education to students, offering an intentional education and helping them to realize the importance of their presence in this environment. In the face of so many evolutions, the need to adapt the forms of teaching is evident, since the traditional model is no longer able to provide all the necessary and expected tools for students in their education in the twenty-first century.

Traditional teaching methods, which prioritized the transmission of information by teachers, were appropriate in times when access to information was limited. However, with

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the popularization of the internet and the availability of various courses and materials, we can now learn anywhere, anytime and with different people.

This new reality is complex, necessary and, in a way, frightening, as we do not have previously established models that are effective for flexible learning in a highly connected society (Valente, Almeida and Geraldini, 2017).

Morán (2015) highlights that current technology promotes an integration of spaces and times, creating a constant interconnection between the physical and digital worlds. In this context, teaching and learning become hybrid, taking place not only within the classroom, but also in various daily environments, including digital ones. For this integration to be effective, it is necessary to balance face-to-face communication and digital interaction, using mobile technologies to enrich the educational experience. However, as Avilés and Galembeck (2021) point out, the success of this strategy depends not only on access to technologies, but on a broad and integrated process of technological literacy for teachers and students. In this way, the incorporation of hybrid methods requires planning and continuing education, ensuring that the school opens up to the digital world in an accessible and effective way, expanding the possibilities of didactic experimentation and democratizing access to technological tools.

> For the opportunities it offers in the process of democratization and expansion of access to didactic experimentation, being conceptualized as didactic strategies that expand the possibilities of access and manipulation of real experiments from access to the internet. Nevertheless, the success of the implementation of this strategy will depend not only on access to technologies, but also on a broad and integrated process of technological literacy for teachers and their students (Avilés and Galembeck, 2021, p. 214).

Morán (2015) clarifies that despite structural deficiencies, there is a growing search for alternatives in the educational sector, both public and private, in response to children's rejection of authoritarian and uniform teaching models.

Institutions are dividing into two paths: a more gradual one, which maintains the disciplinary curriculum, but adopts active methodologies such as project-based teaching and flipped classrooms; and another more innovative, which proposes the elimination of traditional subjects in favor of models based on practical and collaborative activities, allowing students to learn at their own pace and in interaction with others under the guidance of teachers.

> Active methodologies, in general, aspire to the formation of the human being in an integral way, in addition to technical and theoretical knowledge, to the formation of

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> individuals with a global vision of reality, preparing them to always seek knowledge that they do not yet have, making them learn by "getting their hands dirty" (Urias and De Azeredo, 2017, p.80).

Lovato, Michelotti and Da Silva Loreto (2018) provide an explanation of the most well-known active methodologies, among them, Team-Based Learning (TBL) is a collaborative method that involves dividing the class into groups of 5 to 8 students, maintaining heterogeneity between them. The teams are composed in such a way that their composition remains constant throughout the course, and students are encouraged to carry out previous readings on the topic to be discussed. This approach values students' prior knowledge, promoting interaction and the exchange of ideas. After discussing the issues raised, the groups present their answers to the class, reviewing the main points of the subject.

TBL is not limited only to the transmission of content, but also uses concepts from the discipline for problem solving, providing students with both conceptual and procedural knowledge.

Another methodology highlighted is Peer *Instruction*, developed by Eric Mazur, which aims to involve all students during classes. In this method, students are encouraged to explain the concepts to each other, promoting active learning. The teacher circulates around the room, stimulating discussions and guiding the students' thinking, who at the end receive the correct explanation from the teacher and can move on to new questions or topics (Lovato, Michelotti and Da Silva Loreto, 2018).

The *Flipped Classroom* also stands out as a pedagogical innovation, where students watch videos with the theoretical content before class and use the time in the classroom to apply what they have learned. This approach was initially created to serve students who missed classes due to sports commitments, but evolved into a widely applied teaching methodology, focusing on hands-on interaction during meetings (Lovato, Michelotti, and Da Silva Loreto, 2018).

The *Jigsaw methodology*, developed by Elliot Aronson, involves groups of students who become "experts" in different parts of a topic and then teach what they have learned to their peers. This technique encourages individual responsibility and collaboration, fostering an environment in which each member is essential to the group's success (Lovato, Michelotti, and Da Silva Loreto, 2018).

Another approach, the Division of Students into Teams for Success (STAD), was developed by Robert Slavin and emphasizes individual responsibility within collaborative groups. Each student contributes to collective success, and the performance of the groups is evaluated through individual tests, where the best results are rewarded.

This methodology is especially beneficial for students with special educational needs, showing positive results in their learning and behavior (Lovato, Michelotti, and Da Silva Loreto, 2018).

The Team Game Tournaments (TGT) method, developed by David Devries and Keith Edwards, is also based on cooperation, promoting interaction between students of different levels of performance. In this approach, teams compete in games based on academic issues, providing a playful way to learn (Lovato, Michelotti, and Da Silva Loreto, 2018).

In addition to the active methodologies mentioned, it is important to distinguish between collaborative and cooperative learning. Collaboration entails working together in which members share leadership and trust each other, while cooperation may involve more hierarchical relationships. Both approaches aim to solve problems as a group, but collaboration tends to be more open and active. APB and problematization are also relevant approaches, in which students identify and solve real problems, developing critical and reflective reasoning.

APB, originated at McMaster University, allows students to become responsible for their learning, while problematization involves the observation and analysis of reality for the formulation of questions and solutions (Lovato, Michelotti and Da Silva Loreto, 2018).

Project-Based Learning is a methodology that encourages students to solve complex and authentic problems through research and group work, promoting dynamic and active learning. This approach, advocated by John Dewey, seeks to develop not only academic knowledge, but also emotional and social skills (Lovato, Michelotti, and Da Silva Loreto, 2018).

These active methodologies have the potential to arouse students' curiosity and interest, integrating them into the teaching-learning process in a more effective and collaborative way. With a variety of approaches available, it is essential to choose the ones that best suit the educational context and the needs of students, ensuring meaningful and lasting learning.

TEACHING METHODOLOGIES IN PHYSICS

The literature review identified specific strategies for teaching Physics that integrate theoretical concepts with innovative pedagogical practices. These strategies were analyzed considering their relevance for the development of competencies proposed by the BNCC (Brasil, 2018) and for the promotion of meaningful learning, based on authors such as Gonçalves *et al*. (2020).

According to Gonçalves *et al.* (2020), PBL is a methodology that was initially applied in medical schools, but which is now widely used in different areas of knowledge, including in the teaching of Physics. A practical example of its application could be the study of the movement of projectiles, where the teacher presents a problem-situation: calculating the ideal angle of throwing a ball so that it reaches a certain distance, as in a soccer game. In this activity, students should identify and apply kinematics principles, such as the laws of motion and the decomposition of velocity vectors, to solve the problem.

This approach, in addition to engaging students in the practical application of physical concepts, also promotes the characteristics described by Almeida (2015) for active methodologies, such as problem solving, argumentation, and the performance of high-level mental tasks, including analysis, synthesis, and evaluation. By investigating, discussing and testing hypotheses, students actively engage with the learning process, reflecting in a reasoned way on the actions carried out, which is in line with the principles of active methodologies that seek to integrate thinking and doing.

> [...] The student must read, write, ask, discuss, argue, oppose, through problem solving and the development of study plans and/or projects. In addition, the student must perform high-level mental tasks such as analysis, synthesis, and evaluation. In this sense, methodologies that promote active learning can be defined as a set of activities, properly grounded and articulated, that occupy the student in doing something and, at the same time, lead him to think in a reasoned way about the things he is doing (Almeida, 2015, p. 27).

This process not only increases the understanding of theoretical content, but also develops important skills such as problem-solving, teamwork, and critical thinking.

Valente, Almeida and Geraldini (2017) argue that, in an era of abundance of information and rapid technological advances, it is essential to adopt active methodologies in teaching. This means going beyond the traditional limitations of classroom time and space, incorporating new environments for knowledge construction, such as laboratories and digital spaces, and exploring diverse cultural contexts and ways of knowing.

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According to Nogueira (2023), ensuring that schools have adequate access to the internet is essential for the implementation of ICT in the educational environment. These technologies, combined with active teaching methodologies, have the potential to enrich the learning experience and raise the quality of education.

Soares, Tarouco and Silva (2021) report the seriousness of the students' contact with experiments and practical classes. One practical possibility is to incorporate virtual labs into the curriculum, such as the PhET Interactive Simulations platform, a project of the University of Colorado at Boulder. This resource, which is free and accessible online, provides teachers with several tools to enrich their lesson plans with interactive simulations that depict real-world situations, allowing students to explore and experiment with scientific concepts in a practical and visually appealing way.

AI IN PHYSICS TEACHING

According to Mello, Vallini and Vieira (2022), ICT is almost always based on common sense about innovation in teaching and learning. It is assumed that the simple use of these technologies generates new methodologies and ways of teaching, learning and thinking. This suggests that these tools, on their own, would possess inherent values, regardless of how they are used or the social and human contexts involved.

In this sense, it is essential to discuss the role of technologies in the classroom, as it cannot be assumed that their use, by itself, generates major educational impacts. It is necessary for teachers to use them intentionally, associating them with coherent pedagogical practices so that, in fact, they promote a positive impact on student learning.

This chapter explores the practical applications of AI in the teaching of Physics, based on the bibliographic research presented in the methodology chapter. The analysis of the materials followed the principles of content analysis by Bardin (2011), organizing the results into three main categories: *chatbots*, recommendation systems and simulators. The choice of these axes was based on the relevance of these technologies to the educational context, as discussed by authors such as Dantas *et al.* (2019) and Lopes, Silva e Souza (2023).

In this context, Goulart, Pastorio, and Vidmar (2023) point out that changes in the classroom, especially during the pandemic, have highlighted the importance of training strategies that include constructivist approaches, such as the investigative focus and the resolution of real problems. These approaches are particularly effective when integrated with the use of ICT in a planned and intentional way, allowing technologies to become tools that expand the potential of contextualized and investigative teaching.

Thus, teachers can strengthen their training and apply pedagogical strategies that take advantage of ICT not as an end in itself, but as a means to promote meaningful learning aligned with the needs of students.

> The changes in the classroom, associated with the pandemic. recommend the development of teacher training strategies with alternative, constructivist teaching approaches, such as, for example, the investigative focus and the resolution of real problems, which favor learning based on the school context, in addition to techniques, procedures and application of protocols. Teachers perceived, in the pandemic and during social distancing, a moment to strengthen their training in approaches and new strategies that generate support and important contributions in the act of teaching Science (Goulart, Pastorio and Vidmar, 2023, p. 24).

The theory of distributed cognition, which originated in the 1990s, is cited by Nogueira (2023) as a relevant theoretical support. This theory proposes that knowledge is built not only internally, but through interactions with the environment and cognitive artifacts (tools that increase human performance), such as smartphones and digital platforms. Unlike the traditional view, which sees knowledge as something individually embodied, distributed cognition suggests that it emerges from the interaction between people and technology.

Jho (2020) informs that in the teaching of Physics, technology has changed educational practice: where students used to solve calculations manually, today they can use digital tools to facilitate learning. In this context, Nogueira (2023) states that the role of the teacher is transformed from a transmitter of information to an advisor in the use of digital resources.

According to Silva and Lima (2018), this change requires the revision of curricula and pedagogical practices so that the teacher acts as a mediator, promoting interaction with new tools and knowledge resources.

The integration of AI in the teaching of Physics brings a significant advance to education, offering new possibilities to improve the teaching and learning process. With AI, it is possible to personalize the experience of teachers and students, enabling more effective pedagogical approaches adapted to individual needs (Nogueira, 2023).

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CHATBOTS

The analysis of materials related to *chatbots* in the teaching of Physics considered studies that explore their practical implementation, benefits and challenges. The categorization included aspects such as usability, personalization potential, and impact on student engagement, as highlighted by Dantas *et al.* (2019).

A *chatbot* is a computer program designed to simulate a human conversation in an interactive and natural way, either through text or voice. Its origin dates back to 1966, when researcher Weizenbaum developed ELIZA, one of the first, with the purpose of carrying out simple dialogues. Currently, they are widely used in various contexts of daily life, especially on digital communication platforms, such as WhatsApp, Telegram and Facebook Messenger (*Dantas et al*., 2019).

These tools have become popular among users of different age groups, becoming an integral part of the daily routine. As a result, the familiarity and accessibility of these platforms paved the way for the inclusion of advanced functionalities, especially aimed at education. This reflects a strategic investment, since these technologies are already deeply rooted in the behavior of the general public and offer great potential to enrich the educational experience (Dantas *et al*., 2019).

The use of AI and Natural Language Processing has significantly expanded the possibilities of applying *chatbots* in different areas of daily life. These technologies allow interaction with the system to occur through audio, text, images, or a combination of these formats, and are widely used in automated telephony systems, educational support, and e-commerce platforms.

In education, *AI-based and* NLP-based chatbots offer innovative features, such as searching for content on platforms such as YouTube and Wikipedia, receiving news, and supporting productivity through alerts and reminders. These tools act as interactive and dynamic personal assistants, providing personalized and relevant information to students, promoting greater engagement in the learning process.

However, the discipline of Physics is often perceived as abstract and difficult to understand by students. This is partly due to the gap between student goals and traditional teaching methodologies, which often result in memorizing concepts and formulas without a deep understanding of physical phenomena. Despite attempts to innovate in teaching methods, students' experience with the discipline often remains demotivating and unengaging, highlighting the need for more effective and attractive approaches in the teaching of Physics (Dantas *et al.,* 2019).

Based on the difficulties faced by teachers in making the discipline of Physics more attractive, Dantas *et al.* (2019), developed a *chatbot* using AI and NLP techniques to assist in the teaching-learning process. The tool was created using *Python*, an efficient and easy-to-learn programming language, ideal for interactive applications. In addition, a cloud architecture was implemented, ensuring accessibility and continuous operation on different platforms, such as WhatsApp, Facebook Messenger and Telegram.

The development of the *chatbot* included the construction of specific modules, such as database, AI, and NLP, with distributed functionalities to ensure efficient performance. Using Dialogflow, a Google technology, it was possible to create interactive and customizable conversation models. Teachers and tutors contributed to the elaboration of the basic dialogues and didactic content, aimed at high school, allowing him to be trained with specific knowledge of the discipline (Dantas *et al*., 2019).

During use, the *chatbot* interacts with students in a dynamic way, using multimedia resources, such as images, audio, and videos. It is able to answer questions about Physics and store ununderstood questions in a database for later analysis by the teaching staff. If necessary, new content is added and it is reconfigured to provide more complete answers.

In addition to promoting interaction with students, the tool generates detailed reports on the most questioned content, response time and number of questions. This information provides teachers with valuable insights to adjust their lessons and teaching strategies, making learning more efficient and tailored to students' needs (Dantas *et al*., 2019).

Dantas *et al*. (2019) carried out a study to evaluate the application of a *chatbot* with artificial intelligence in the teaching of Physics, following the ethical standards of the Federal University of Uberlândia. The experiment involved four classes of the first year of high school, totaling 25 students. For four weeks, students were instructed to use it to solve exercises outside the classroom. This stage had as its main objective to assist in the students' activities and identify frequently asked questions through the use of technology.

During this period, the device received 72 questions, with the main intentions processed related to vectors (25.0%), uniformly varied movement (18.75%), trajectory (15.63%), general help request (14.6%) and variables (9.38%). This information helped the teacher to improve his lesson plan, prioritizing the topics with the highest number of

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doubts. In the second stage, the feasibility of the tool and the students' expectations were evaluated through a questionnaire with eight questions. The answers were categorized into five levels of agreement, allowing the analysis of the participants' perceptions of the experience.

The results confirmed that the use of this resource, as indicated in the literature, can contribute significantly to the teaching-learning process. In addition, the survey of the main doubts contributed to the planning of the classes. In future studies, the authors intend to investigate the impact of *chatbots* on students' academic performance and explore possible limitations of this approach (Dantas *et al.,* 2019).

ChatGPT

According to Leite (2023), ChatGPT is a generative AI tool that can be applied in several areas, including customer service, content creation, and language translation. While the answers he provides are generally cohesive and understandable, they are not perfect. This is because the model collects information from a variety of sources, such as the internet, online books, and social media, and uses this information to generate responses. The performance of the resource depends on the databases from which this information is extracted, and while the answers may be coherent most of the time, they may not be entirely accurate.

ChatGPT is powered by a reinforcement learning model with human *feedback*, which allows it to improve its responses over time, but there are still limitations in its ability to offer completely correct or accurate information.

The research carried out by Leite (2023) aimed to evaluate the potentialities and limitations of ChatGPT in the context of teaching chemical concepts. To this end, the study was developed in three main stages. In the first step, it was necessary to create a profile on the platform, as it was a closed tool, requiring registration to gain access to its features. The second stage consisted of the elaboration of questions on five specific chemical concepts: atom, chemical bond, chemical equilibrium, isomeric and acid-base. These questions were submitted to the *chat*, which provided answers to each of the concepts. The system was then asked to improve the definitions provided, with the aim of evaluating the evolution of the responses in terms of clarity and precision.

Finally, in the third step, the responses generated by ChatGPT were analyzed and compared with the definitions contained in the IUPAC Compendium of Chemical

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Terminology, a widely recognized source in the field of chemistry for the definition of terms. To ensure that the answers were original, plagiarism checker tools were used to confirm the authenticity of the content generated by it. The analysis of the responses allowed us to understand the limitations of AI in defining chemical concepts and helped to identify areas in which the tool could be useful or inappropriate in the educational context.

Leite (2023) highlights that, although ChatGPT has the ability to generate answers to a variety of questions, it does not specialize in chemistry. This implies that the answers provided need to be carefully checked, especially when it comes to complex or critical topics.

Even so, the tool offers a valuable contribution by enabling an initial approach to learning and teaching chemical concepts, especially when used as a complementary resource, and not as a substitute for human expertise.

In the article by Leite (2023), the author explores the use of ChatGPT in Chemistry teaching, especially to answer questions about chemical concepts. Although the device provides coherent answers in many cases, it has limitations, such as incomplete or erroneous information, which requires caution on the part of teachers to ensure that students recognize possible flaws. The article argues that, beyond simply questioning and answering, it is necessary for teaching to promote deeper discussions and debates, something that AI, with its limitation in logic and abstraction, cannot adequately offer. It should be seen as an auxiliary tool, not a substitute for teaching, with the teacher acting as a mediator to guide students in the critical analysis of the information provided. Instead of prohibiting the use of ChatGPT, the recommendation is that the professor teach students how to select, analyze and critique the answers, stimulating advanced cognitive skills and promoting more meaningful learning. The integration of technology in the teaching of Natural Sciences can open up new educational possibilities, especially when aligned with methodologies that value student-centered learning. The responsible and reflective use of these technologies can contribute to a more transformative educational process, in line with the perspectives of educators such as Seymour Papert and Paulo Freire.

RECOMMENDATION SYSTEMS

The recommendation systems research focused on identifying how these tools can facilitate access to relevant and personalized educational materials. Collaborative filtering

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and content-based recommendation methods were considered, following the work of Nogueira (2023) and Pinheiro *et al.* (2018).

According to Nogueira (2023), recommendation systems (SR) use algorithms to suggest relevant content to users, based on their past interactions or those of individuals with similar interests. In today's digital context, these tools are essential, especially on platforms with large volumes of content, such as YouTube, where more than 720 thousand hours of videos are uploaded daily. Without proper systems, the choice of content can become confusing and frustrating, negatively impacting the user experience.

In the educational field, SRs also play an important role, especially in recommending quality materials. A significant example is the EYT, created to recommend educational videos with proven didactic value (Pinheiro *et al*., 2018). This system seeks to deal with the difficulty of selecting content in a digital environment where publication is accessible to everyone, regardless of technical or pedagogical knowledge.

SRs operate mainly with two methods. The first, called collaborative filtering, is based on the preference patterns shared between users with similar interests. This approach allows you to create two-way recommendations, where one user's choices positively influence suggestions for others with similar tastes. The second method is content-based recommendation, which analyzes the characteristics of the items consumed by the user, suggesting those that have the most similarity.

In addition, these recommendations can be refined with personal data, such as age, gender, and location, to make them even more accurate (Nogueira, 2023).

The application of SRs, such as the EYT, has benefits not only for students but also for teachers. According to Moreira (2018), teachers often spend a lot of time looking for complementary study materials. Systems like these facilitate access to relevant content, optimizing class preparation time and contributing to more effective teaching. Thus, these systems represent a promising tool for teaching Physics and learning in the digital environment.

SIMULATORS

The analysis of virtual simulators was based on the evaluation of their potential to enrich the teaching of Physics, promoting interactive and practical experiences. The categorization included the types of simulators available, their applications in the

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classroom, and the challenges faced by teachers, as discussed by Lopes, Silva, and Souza (2023).

The teaching of Physics in Brazil faces significant challenges, despite the modernization opportunities that arise from the adoption of new methodologies and technologies. Lopes, Silva, and Souza (2023) highlight that, although the possibilities for modernization are present, not all schools or professionals are adapted to these changes.

Many students, instead of being interested in physics, develop an aversion to it, often due to the traditional, teacher-centered approach that is adopted in most institutions. As stated by Moreira (2018), this traditional teaching approach contributes to students' lack of interest in the subject.

Traditional pedagogy, characterized by expository classes and without the active participation of students, prevents the development of essential skills, such as problem-solving, logical reasoning and social skills. According to Saviani (2021), this teaching model focuses on the transmission of knowledge in a unidirectional way, without promoting the necessary interaction between student and content. As a result, students end up becoming passive spectators of their own learning.

Furthermore, the introduction of technologies in the teaching of Physics could, theoretically, increase the interest of students. However, Lopes, Silva, and Souza (2023) point out that the lack of use of these technological tools in the classroom contributes to the even greater distancing of Physics students. The research carried out by these authors revealed that the lack of context in the teaching of Physics is seen as one of the biggest obstacles to learning, with issues related to the lack of equipment and experimental laboratories, the training of teachers in the use of technologies and the curriculum, also being mentioned.

However, the use of virtual simulators, as defended by Lopes, Silva and Souza (2023), presents an interesting alternative to overcome these difficulties. They allow the simulation of everyday situations that would be difficult to reproduce physically, such as slow thermal processes or experiments involving magnetic and electric fields, making learning more dynamic and closer to the students' reality.

However, the use of simulators faces obstacles, such as teachers' lack of knowledge to handle these applications, the need for electronic equipment, and the restriction of the internet in schools, which hinder their effective implementation.

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Virtual simulators are *software* developed to emulate real equipment and situations, with the aim of facilitating experimentation and training. These simulators allow students to practice concepts in an interactive way, as in Microsoft Flight Simulator, which simulates flights and aerial maneuvers in a similar way to reality. In physics education, virtual simulators can be used to represent everyday situations that would be difficult or expensive to reproduce in the laboratory, allowing for safe and effective practice.

According to Lopes, Silva and Souza (2023), many students have an immediatist profile, influenced by the speed of information in the digital age. To maintain students' interest and motivation, it is necessary to provide quick feedback, and simulators meet this demand. In addition, educational simulators have game characteristics, incorporating elements of gamification, a methodology that uses aspects of games in non-playful contexts to engage, motivate, and promote learning (Silva and Sales, 2017).

With regard to research on the use of virtual simulators in Physics teaching, Lopes, Silva and Souza (2023) conducted a study with Science teachers, including questions about the use of simulators in their classes. The questions addressed the experience of the teachers, such as the use of simulators and the conditions in which this occurred, in addition to exploring how they learned to use these tools. The study revealed that most professionals did not receive specific training on the use of simulators, which hinders their implementation in pedagogical practices.

The introduction of virtual simulators is a promising alternative, and several digital platforms are available to assist in the teaching of Physics. Lopes, Silva, and Souza (2023) mention platforms such as Physics at School and PhET, which are valuable resources to promote students' interaction with physical concepts in a practical and visual way. The PhET platform, for example, is widely used due to its simplicity, free access, and interface in Portuguese, which facilitates its use by teachers and students.

On the other hand, teachers can even build their own simulators, as exemplified by the PhET project and the creation of the "Simulation" simulator, which has been tested and evaluated for its effectiveness in teaching mechanical energy concepts.

However, creating simulators requires a multidisciplinary team and can be a complex and time-consuming process. Although the use of simulators has shown positive results in the learning of Physics, it is essential that the teacher keeps the focus on the physical concepts, using the simulators as a tool to facilitate understanding, and not as the center of the class. This was confirmed by experiments, such as Ribeiro's (2020), which showed the efficiency of simulators in the teaching of Physics.

FINAL CONSIDERATIONS

AI has shown great potential to personalize learning and offer ongoing support to students, but its implementation still faces barriers, such as a lack of teacher training and data privacy concerns.

For training to be effective, teachers need to develop specific skills, such as mastering AI tools, integrating active methodologies with technological support, and managing digital platforms in the educational context. These competencies are essential for the conscious and planned use of these technologies in the classroom.

However, in addition to training, school infrastructure is a determining factor for the success of this integration. This includes high-speed internet access, adequate technological equipment, virtual labs, and ongoing technical support for teachers and students. The lack of these resources in many schools, especially in disadvantaged regions, is a challenge that needs to be addressed to ensure equitable and effective implementation.

When applied well, AI can be a valuable extension of teaching practice, helping to create more dynamic and accessible learning experiences. However, it is necessary to consider the challenges, such as resistance on the part of some educators, high implementation costs, and regional inequalities in access to technology.

To overcome these barriers, it is essential to adopt public policies that prioritize investments in infrastructure and teacher training, as well as partnerships with technology companies to make these solutions more accessible.

Active methodologies, such as PBL and the flipped classroom, have been shown to be effective in promoting more engaged and collaborative learning, essential for the formation of critical skills in an increasingly connected world. These approaches, along with the use of technologies such as virtual simulators, can transform the teaching of Physics, making it more practical and closer to the students' reality. As a result, virtual simulators have the potential to overcome the limitations of traditional teaching, offering immersive and practical experiences.

The introduction of AI and other digital technologies in the teaching of Physics represents a significant opportunity for transformation in pedagogical practices, aligning

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with a global movement of educational innovation. The analysis of different technological tools, such as *chatbots*, recommendation systems and simulators, reveals considerable potential to improve students' interaction with content and the personalization of teaching. *Chatbots*, in particular, have been shown to be effective solutions in aiding physics learning, making it easier to resolve questions outside of the school environment, and providing continuous feedback.

In the context of ChatGPT, the tool stands out for its potential to generate quick and contextualized responses, but it makes it clear that AI still needs human mediation, especially when it comes to the accuracy and depth of information. Thus, the role of the teacher remains central, ensuring the critical analysis of the answers provided by AI. The integration of ChatGPT as a complementary tool, and not a substitute, in the teaching of Natural Sciences is aligned with a pedagogical approach that values the student's protagonism and the conscious use of technology.

Recommendation systems, such as EYT, are equally promising in optimizing the search for educational content, allowing access to high-quality materials in a practical way. This approach can increase the diversity and personalization of learning, saving time and offering content that is more aligned with the needs of students.

Future research could explore how to overcome challenges related to the implementation of educational technologies in different contexts. Research that addresses the long-term impacts of these tools, as well as strategies to mitigate regional and economic inequalities, are essential to amplify the benefits of technological innovations.

Therefore, the integration of AI and other technologies in the teaching of Physics is not a magic solution, but represents an important step in the modernization of the educational process. For these tools to be effective, it is necessary to use them consciously and planned, which considers the specificities of the discipline, the needs of the students, and the continuous training of teachers. The path to a more innovative and transformative education depends on the collaboration between technology and pedagogy, with the teacher playing the role of mediator and facilitator of learning.

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