

USING ARTIFICIAL INTELLIGENCE AND OTHER DIGITAL TOOLS TO TRANSFORM PHYSICS EDUCATION

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Abstract

This paper explores the transformative potential of artificial intelligence (AI) in reshaping physics education. Traditional methods, often reliant on lecture-based instruction and rote memorization, are increasingly inadequate for meeting the diverse needs of today's learners. By contrast, AI offers adaptive, personalized learning experiences that can improve students' engagement and comprehension. Tools such as chatbots, large language models (LLM), and AI-driven simulations facilitate inquiry-based learning, support real-time feedback, and enable dynamic visualization of complex concepts. By integrating AI tools, educators can tailor their instruction to meet the diverse needs of learners, ultimately fostering a deeper understanding of complex concepts. This approach not only promotes active participation but also empowers students to take ownership of their learning. As a result, classrooms become dynamic environments where collaboration and critical thinking thrive, preparing students for the challenges of the future. By prioritizing individualized learning pathways, educators can help students discover their passions and strengths, leading to more meaningful educational experiences. As students engage more deeply with their learning, they become empowered to take ownership of their education. This empowerment not only builds confidence but also prepares them for future challenges, both academically and in their personal lives.

Keywords: Artificial Intelligence; Physics education; Personalized learning

Introduction

Physics serves as the groundwork for all natural occurrences and technological progress. Numerous areas within this field are vital for the advancement of our contemporary society, representing an essential foundation upon which future generations will build their knowledge. In the past hundred years, the teaching of physics has undergone significant transformations that have moved away from the conventional lecture-based and instructor-focused approach to a more engaging, learner-centered model (Muhammad et al., 2025). There are structural and methodological issues in physics education that make it hard for students to understand the discipline's ideas and procedures. Traditional approaches, which focus on the passive transmission of knowledge, frequently lead to students' disinterest in physics despite its enormous importance in the development of citizens and in understanding the world around us (Jalilova & Musayeva, 2025). In this regard, using educational technology like artificial intelligence (AI), recommendation engines, and virtual simulators has shown promise as a way to creatively teach and engage students in a more efficient and customized manner.

Concerns about algorithmic discrimination, data privacy, human reluctance to adaption, and equality issues pose significant obstacles to the incorporation of AI in physics education. Students' critical thinking skills may be hampered by an over-

reliance on AI tools, even though these tools improve grasp of concepts and provide better answers for hard problems, but they fall short of the intricacy of scientific problems, which call for human-like reasoning (Muhammad et al., 2025).

Table 1: Evolution of Artificial Intelligence in Education (AIED): Key Developments, Technologies, and Impacts (Muhammad et al., 2025).

Time Period	Key Developments	Technologies	Impact/Outcomes	References
1950s-1960s	Early exploration of computers for personalized instruction	B.F. Skinner’s teaching machines	Laid the groundwork for AI-driven educational tools by providing immediate feedback	(Skinner, 1958)
1970s-1980s	Emergence of Intelligent Tutoring Systems (ITS).	SCHOLAR, Basic Instructional Program (BIP)	Simulated one-on-one tutoring, adapted to individual learners’ needs, and improved learning outcomes	(Ashley et al., 1982; Carbonell, 1970)
1990s-2000s	Rise of adaptive learning systems and data-driven approaches.	Carnegie Learning’s Cognitive Tutor, data mining, and learning analytics.	Personalized feedback, improved problem solving support, and early identification of at-risk students.	(Baker et al., 2009; Koedinger et al., 1997)
Recent Years	Expansion of AI capabilities in education, particularly in Science, Technology, Engineering, and Mathematics (STEM) fields	Physics Education Technology (PhET) Interactive Simulations, virtual labs, AI-driven simulations, automated grading.	Enhanced engagement through interactive, visual, and gamified learning experiences.	(Koedinger et al., 1997)
2010s	Breakthroughs in machine learning (ML) and natural language processing (NLP).	IBM’s (International Business Machines) Watson Tutor, chatbots, automated essay scoring, virtual learning assistants	Enabled real-time feedback, automated grading, and more sophisticated AI tools for education.	(Rajeshwari et al., 2020)
COVID19 Pandemic	Accelerated adoption of AI in education due to the shift to online learning.	Zoom’s AI-driven transcription, Google’s AI-based classroom management tools.	Bridged gaps in traditional education systems, improved accessibility, and supported remote learning.	(Pantelimon et al., 2021)

The emergence of AI in physics education

Artificial intelligence (AI) in physics education has been acknowledged as one of the most effective developments in the fight against some of the long-standing issues in teaching and learning of physics (Verawati & Nisrina, 2024). AI in education, and specifically in physics education, has been widely studied, exploring its impact on

learning outcomes, student engagement, and teaching effectiveness (Mahligawati et al., 2023). Through adaptive learning platforms, virtual labs, and intelligent tutoring systems, artificial intelligence has completely changed the way that physics is taught at the elementary, secondary, and university levels. The application of artificial intelligence (AI) in physics education remarkably dates back to the 1980s and 1990s, when preliminary research was done to examine how AI might improve physics education through computer-based systems. Complex information system management is becoming more and more dependent on quantum computing due to its capacity to effectively handle exponential data expansion (Rashid et al., 2013). One of the first uses at the time was the ITS/ICT, which was intended to serve as a one-on-one tutor for physics principles. For instance, students enrolled in introductory physics courses received personalized feedback and assistance with problem-solving via Andes, an intelligent tutoring system created in the late 1990s. Research showed that the Andes system put students ahead of students taking the same courses in traditional classrooms (VanLehn et al., 2005). First adaptive learning systems that nearly matched physics education were developed in the last years of the 20th century. They used AI algorithms to evaluate student results and automatically detected the need to adapt the level and type of teaching materials presented. For instance, through Carnegie Mellon University Cognitive Tutor Authoring Tools (CTAT), some authors promoted a more individualized learning environment by enabling real-time engagement with a tutor who gave prompt feedback and/or hints based on student input. (Aravind et al., 2017).

Methodology

The bibliographic research for this study was organized methodically, with an emphasis on guaranteeing the reliability and applicability of the materials examined. Dissertations, scientific articles, and educational journals that discuss AI, physics teaching strategies, and technological applications in school formed the frame of the study. Bibliographic research is 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.

Artificial intelligence (AI) in physics

AI tools provide a totally personalized experience with the potential to modify in line with the demands of the students, resulting in improved understanding and retention. Studies have established the viability of the AI characteristics, which overstepped the usual limitations of physics instruction and improved students' interactions with physics-related items (Mahligawati et al., 2023). As in the more traditional physics class, such an approach would heavily rely on the student memorizing rules for manipulating equations, making it for some students difficult to relate to adding together to a calculus equation.

One breakthrough application of AI in physics education is symbolic regression, which uses learning algorithms to encode physics problem answers as equations connecting variables.

Designed to personalize learning tool that allows the students to model the equations and connect them with the mathematical relations in physics. It increases their

computational skills and bridges the gap between the theoretical and practical applications (Zhu et al., 2024). AI, along with other emergent technologies, stands to profoundly alter conventional educational systems through a shift toward more technology-based methodologies in teaching (Lee et al., 2021).

Moreover, the rapid and targeted feedback that AI offers helps students rectify errors and enhance their problem solving abilities (Mustofa et al., 2024). AI has increasingly transformed evaluation through rapid scoring and immediate primary feedback. AI language models, specifically ChatGPT, are indeed changing physics for the better by offering instant tutors, step-by-step reasoning based on its training, and dynamic clarifications based on student criticisms. As a support for independent learners, ChatGPT fills the gap between traditional instruction and autonomous learning through the benefits of an interactive dialogue (Liang et al., 2023).

Recent advancements in Machine Learning (ML) and Deep Learning (DL) have enabled physicists to tackle complex problems in quantum mechanics, astrophysics, condensed matter physics, and high-energy physics (Adeola et al., 2025). AI has had a big effect on quantum computing and quantum mechanics. Quantum (NISQ) devices. Particle physics experiments, such as those at CERN's Large Hadron Collider (LHC), generate vast datasets requiring AI-driven analysis.

Chatbots

A chatbot is a computer software that can have a conversation with a person in a natural and engaging fashion, either by voice or text. Its origin dates back to 1966, when researcher Weizenbaum developed ELIZA, one of the first, with the purpose of carrying out simple dialogues. At present, they are utilised frequently in many areas of everyday life, especially on digital communication platforms like WhatsApp, Telegram, and Facebook Messenger (Rodolpho 2025). AI and Natural Language Processing have made it possible to deploy chatbots in many more 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 ecommerce platforms.

However, students frequently see Physics as abstract and difficult to comprehend. Based on the difficulties faced by teachers in making the discipline of Physics more attractive, chatbot using AI and Natural Language Processing (NLP) techniques to assist in the teaching-learning process was developed. 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.

Challenges and limitations of AI in physics education

AI has shown great potential to personalize learning and offer ongoing support to students, but its implementation still faces barriers, such as:

- (1) A lack of teacher training,
- (2) data privacy concerns and
- (3) the lack of structured ways of infusing AI into the curricular practice.

There is need for clearer strategies on how to incorporate AI tools and traditional teaching methods so that meaningful improvements are made in education (Mustofa et al., 2024). While using tools like ChatGPT in support of problem-solving, Ding

(2023) notes that students sometimes question the accuracy, which creates mistrust in AI as a resource for learning. Such shyness might greatly restrain the widespread use of AI in education, where consistency is of utmost importance. Furthermore, though AI simulations and adaptive learning platforms stand to personalize education, their capacity to accommodate varying learning styles is still debatable. More studies should be conducted to enhance AI adaptiveness to ensure it will incorporate varied student needs. Such targeted studies will go a long way to enhancing the reliability, effectiveness, and orderly introduction of AI in physics education (Liu et al., 2021).

Conclusion

When considering potential teaching and learning transformations, AI integration in physics education has shown enormous promise. AI-powered Chatbots and machine learning algorithms help students in rural or resource-poor places by giving an independently paced learning opportunity with feedback in virtually real time. Such advances help enhance student engagement and understanding, yet, at the same time, cut down the administrative burden on teachers and allow them to focus on personalized instruction. There are problems with fair access, data protection, and the requirement for teacher training before AI can reach its full potential. Policymakers must invest in infrastructure and create ethical rules, which educators must accept as complimentary instruments.

On the other hand, researchers need to look into ways to make AI work better in different settings with good learning outcomes and think about the long-term effects and by working together researcher can harness the transformational potential of AI to create a comprehensive, engaging, and successful physics education that prepares students for the intricate issues of the 21st century.

Recommendation

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.

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.

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