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ADVANTAGES AND CHALLENGES OF USING ARTIFICIAL INTELLIGENCE TECHNOLOGIES IN TEACHING PHYSICS

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Abstract: The rapid integration of artificial intelligence (AI) into education has opened new opportunities for transforming how physics is taught and learned. This article examines the pedagogical benefits and the accompanying difficulties of applying AI technologies in physics instruction. Drawing on recent developments in intelligent tutoring systems, adaptive learning platforms, virtual laboratories, and generative language models, the study argues that AI can substantially enhance the individualisation of learning, the visualisation of abstract phenomena, and the efficiency of assessment. At the same time, the analysis highlights persistent obstacles, including the risk of superficial understanding, unequal access to digital infrastructure, the reliability of AI-generated explanations, and the shifting role of the teacher. The paper concludes that AI is most productive when treated as a supporting instrument that augments rather than replaces the pedagogical judgement of the physics educator, and it outlines the conditions under which the technology can be introduced responsibly.

Keywords: artificial intelligence, physics education, adaptive learning, intelligent tutoring systems, virtual laboratory, digital pedagogy.

1. Introduction

Physics occupies a distinctive place among the natural sciences because it combines abstract mathematical reasoning with concrete experimental observation. For many learners, this dual nature is precisely what makes the subject difficult: concepts such as electromagnetic fields, quantum states, or relativistic motion cannot be perceived directly and must be reconstructed mentally from equations and idealised diagrams. Traditional classroom instruction, constrained by fixed timetables and large groups, often struggles to accommodate the varied pace at which students build these mental models. Against this background, artificial intelligence has emerged as a technology that promises to reshape the methodology of teaching physics.

Over the past decade, AI-driven tools have moved from experimental prototypes to widely available applications. Adaptive learning environments now tailor problem sets to the demonstrated competence of each student, while conversational language models can generate explanations, derive formulas step by step, and answer questions at any hour. Simultaneously, machine-learning algorithms support the analysis of laboratory data and the simulation of physical processes that would be impossible or unsafe to reproduce in a school setting. These capabilities raise a fundamental pedagogical question: to what extent, and under what conditions, does the use of AI genuinely improve the understanding of physics rather than merely accelerating the delivery of answers?

The present article addresses this question by examining both the advantages and the problems associated with introducing AI technologies into physics education. Rather than treating the technology as inherently beneficial or harmful, the discussion adopts a balanced perspective,

recognising that the educational value of any tool depends on the way it is embedded in a coherent teaching strategy. The aim is to provide teachers, methodologists, and curriculum designers with a structured overview that can inform practical decisions about the responsible adoption of AI in the physics classroom.

2. Advantages of Using Artificial Intelligence in Teaching Physics

The potential benefits of AI in physics education can be grouped into several interrelated areas, each corresponding to a long-standing difficulty in conventional teaching.

2.1. Individualisation of the learning trajectory

Perhaps the most significant advantage is the capacity of AI systems to adapt instruction to the individual learner. Adaptive platforms continuously monitor a student's responses, identify recurring errors, and adjust the difficulty and sequence of tasks accordingly. In physics, where a gap in an early concept such as vector addition can undermine the understanding of every subsequent topic, this diagnostic precision is especially valuable. A well-designed system can detect that a learner consistently confuses velocity with acceleration and can respond with targeted exercises, thereby offering a degree of personal attention that a single teacher managing thirty students cannot realistically provide.

2.2. Visualisation of abstract phenomena

A second advantage lies in the visualisation and simulation of processes that are inaccessible to direct observation. AI-enhanced simulations allow students to manipulate variables in a virtual environment and to observe the consequences immediately, for instance by altering the mass of a planet and watching the resulting change in orbital motion, or by adjusting the frequency of a wave and seeing the interference pattern evolve. Such interactive models transform passive reception into active experimentation and help learners construct intuitive mental representations of phenomena that equations alone rarely convey.

2.3. Access to virtual laboratories and safe experimentation

Closely related is the contribution of AI to laboratory work. Many schools lack the equipment, materials, or safety provisions required for certain experiments, and some phenomena, such as nuclear decay or high-voltage discharge, cannot be reproduced safely in a classroom at all. Intelligent virtual laboratories reconstruct these experiments with realistic behaviour, enabling students to design procedures, collect simulated measurements, and analyse results. Although a virtual experiment cannot fully replace the tactile experience of handling apparatus, it broadens the range of accessible investigations and lowers the barrier to inquiry-based learning.

2.4. Efficient assessment and feedback

AI also increases the efficiency of assessment. Automated systems can grade quantitative problems, recognise the structure of a derivation, and provide immediate feedback that indicates not only whether an answer is correct but where the reasoning has gone astray. Immediate, formative feedback is known to strengthen learning far more effectively than delayed marking, and by relieving teachers of routine grading it frees time for the higher-order guidance that only a human educator can offer.

2.5. Support for teachers and continuous availability

Finally, AI tools support the teacher directly. They can generate varied problem sets, propose lesson materials, and summarise the progress of a class, reducing the preparatory workload. For students, conversational assistants provide a form of continuous availability, answering questions outside lesson hours and offering explanations in alternative wordings until a concept becomes clear. This constant accessibility can be particularly beneficial for learners who are hesitant to ask questions in front of their peers.

3. Problems and Challenges

The advantages outlined above are counterbalanced by a set of serious difficulties. Ignoring these problems risks turning a promising instrument into a source of new pedagogical shortcomings.

3.1. The risk of superficial understanding

The foremost concern is that ready access to AI-generated solutions may encourage superficial learning. When a student can obtain a complete, correctly formatted derivation in seconds, the temptation to bypass the effortful process of reasoning becomes strong. Yet it is precisely that effort, the struggle to set up a problem and to recover from mistakes, that builds durable understanding in physics. If AI is used as a shortcut to the final answer rather than as a guide through the reasoning, it may produce learners who can reproduce solutions but cannot construct them independently.

3.2. Reliability and correctness of AI-generated content

A second problem concerns the accuracy of the information that AI systems provide. Generative language models are known to produce plausible but incorrect statements, and in physics such errors can be subtle: a misapplied sign convention, an invalid approximation, or a conceptually flawed explanation may pass unnoticed by a novice. Because these tools present their output with uniform confidence, students often lack the means to distinguish a sound explanation from a mistaken one, which places an additional verification burden on the teacher.

3.3. Unequal access and the digital divide

The benefits of AI are not distributed evenly. Effective use presupposes reliable internet connectivity, adequate devices, and, in many cases, paid subscriptions. Schools in economically disadvantaged regions may be unable to provide these resources, so that a technology introduced to widen educational opportunity can paradoxically deepen existing inequalities. Any strategy for adopting AI in physics teaching must therefore address questions of infrastructure and equity from the outset.

3.4. The changing role and workload of the teacher

The integration of AI also transforms the professional role of the physics teacher. Educators are required to acquire new competencies, to evaluate the quality of AI tools critically, and to redesign lessons so that technology supports rather than dictates the learning process. This transition demands time and training that are frequently unavailable. There is, moreover, a legitimate concern that an over-reliance on automated systems could gradually erode the pedagogical initiative of teachers and diminish the human relationship that lies at the heart of effective instruction.

3.5. Data privacy, ethics, and dependence

Finally, the use of AI raises ethical and practical concerns that extend beyond the classroom. Adaptive platforms collect detailed data on student behaviour, which prompts questions about privacy, consent, and the security of sensitive information about minors. In parallel, habitual dependence on intelligent assistance may weaken students' capacity for independent problem solving and critical thinking, the very qualities that physics education is meant to cultivate.

4. Discussion: Toward a Balanced Pedagogical Model

The juxtaposition of advantages and problems suggests that the value of AI in physics education is not intrinsic to the technology itself but arises from the manner of its use. A recurring theme across the preceding sections is the distinction between AI as a substitute for cognitive effort and AI as a scaffold that supports it. When a tool simply supplies answers, it undermines the constructive struggle that learning physics requires; when the same tool is configured to reveal reasoning gradually, to pose guiding questions, and to withhold the final result until the learner has engaged, it reinforces rather than replaces active thinking.

This observation points to a set of practical conditions for responsible adoption. First, AI should be integrated within a clearly defined methodological framework in which the teacher determines the pedagogical objective and the technology serves that objective. Second, learners should be taught to treat AI output critically, verifying results against established principles and recognising that fluency of presentation is not a guarantee of correctness. Third, institutions should ensure equitable access and provide teachers with the training needed to evaluate and deploy these tools competently. Under such conditions, the documented advantages, individualisation, visualisation, and efficient feedback, can be realised while the associated risks are contained.

It is also important to recognise the limits of the present analysis. The field is developing rapidly, and empirical evidence on the long-term effects of AI-supported physics instruction remains limited. Much of the current literature reports short-term gains in engagement or performance, but the durability of conceptual understanding and the transfer of skills to novel situations require longitudinal investigation. Future research should therefore examine not only whether AI improves immediate outcomes but whether it strengthens the deeper competencies that define scientific literacy.

5. Conclusion

Artificial intelligence offers physics education a powerful set of instruments capable of individualising instruction, visualising abstract phenomena, extending laboratory practice, and accelerating feedback. These advantages address genuine and long-standing limitations of conventional teaching. At the same time, the technology brings substantial challenges, among them the risk of superficial learning, the fallibility of AI-generated content, unequal access, the evolving demands on teachers, and unresolved questions of ethics and dependence.

The evidence and arguments assembled here support a measured conclusion: AI is neither a panacea nor a threat to be avoided, but a supporting instrument whose educational worth depends on thoughtful integration. When it is embedded within a sound methodology, guided by the professional judgement of the teacher, and accompanied by attention to equity and critical evaluation, artificial intelligence can meaningfully enhance the teaching and learning of physics. Realising this potential will require continued research, teacher preparation, and a clear understanding that technology is most effective when it amplifies, rather than replaces, the human dimension of education.

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