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Role of Artificial Intelligence in Enhancing Conceptual Understanding in Physics

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Abstract

Artificial Intelligence (AI) plays a significant role in enhancing conceptual understanding in Physics by enabling personalized and interactive learning experiences. AI-powered tools such as intelligent tutoring systems, simulations, and data-driven visualisations help students grasp abstract and complex physical concepts more effectively. By analysing learner performance, AI adapts instructional content to individual needs, provides instant feedback, and supports self-paced learning. These applications improve problem-solving skills, conceptual clarity, and student engagement in Physics education. This paper discusses how AI-based approaches contribute to deeper conceptual understanding and align with the objectives of NEP-2020 in transforming Physics education.

Keywords: Artificial Intelligence, Physics Education, Conceptual Understanding, AI in Learning, Intelligent Tutoring Systems.

Introduction

The integration of Artificial Intelligence (AI) into the educational landscape has marked a significant shift in how complex scientific subjects are taught and understood. In Physics, AI plays a pivotal role in enhancing conceptual understanding by moving beyond traditional, static methodologies toward personalized and interactive learning experiences. This transition from lecture-based instruction to dynamic intervention allows for a more nuanced approach to pedagogy, where abstract and complex physical concepts become more accessible through data-driven analysis.

The central thesis of this research is that AI facilitates the mastery of these concepts by continuously analyzing learner performance and adapting instructional content to meet individual requirements. The objective of this research is to discuss how AI-based approaches contribute to deeper conceptual clarity, support self-paced learning, and align with modern educational frameworks.

Methodology

The methodological framework for integrating AI into Physics education centers on data-driven instruction and the establishment of a continuous, adaptive learning cycle. This approach is structured around three primary pillars:

Analyzing Learner Performance through Formative Assessment

AI systems are employed to monitor student progress in real time, functioning as a continuous mode of formative assessment. By evaluating how a student interacts with physics problems and theoretical material, the AI identifies specific cognitive gaps or misconceptions. This data allows the system to adapt instructional content dynamically, ensuring that the level of challenge remains within the student's zone of proximal development.

Instant Feedback and the Self-Paced Cycle

A critical component of the AI framework is the provision of instant, automated feedback. As students engage with complex physics exercises, AI-driven responses provide immediate corrections and pedagogical scaffolding. This mechanism supports a robust self-paced learning cycle, allowing students to recognize and rectify misconceptions at the point of origin, thereby reinforcing correct conceptual mental models without the delays inherent in manual grading.

Implementation of AI-Powered Vehicles

The methodology utilizes specific AI-powered tools as the primary vehicles for inquiry-based learning:

- Intelligent Tutoring Systems (ITS): Digital mentors that simulate one-on-one human tutoring by guiding students through logical problem-solving steps.

- Simulations: Virtual laboratories that provide inquiry-based environments where physical variables (e.g., mass, velocity, friction) can be manipulated to observe theoretical outcomes in real time.
- Data-Driven Visualizations: Systems that convert abstract mathematical data into intuitive visual representations to aid in the comprehension of fundamental physical laws.

Discussion

AI-Powered Tools and Their Educational Impact

The deployment of AI tools has a direct correlation with the depth of a student's grasp of physical phenomena. As illustrated in Table 1, the specific impacts of these tools are multifaceted.

Table 1: AI-Powered Tools and Their Educational Impact

AI Tool/Application	Impact on Conceptual Understanding
Intelligent Tutoring Systems	Personalizes learning by analyzing performance and adapting content to individual student needs.
Simulations	Enables students to grasp abstract and complex physical concepts through interactive, inquiry-based experimentation.
Data-Driven Visualizations	Enhances conceptual clarity by transforming theoretical and mathematical data into accessible visual formats.

Personalized Pedagogy and Alignment with NEP-2020

The application of AI in Physics education is inherently aligned with the objectives of NEP-2020. The policy emphasizes a radical transformation of the educational system through technology-driven insights and personalized learning pathways. AI-based approaches fulfill these goals by shifting the focus away from rote memorization and toward a system that values competency-based learning and deep conceptual clarity.

By bridging the gap between abstract theory and tangible understanding, AI-enhanced simulations and visualizations allow students to "see" and interact with phenomena that are otherwise purely mathematical. This creates a tailored environment that fosters high levels of engagement and improves advanced problem-solving skills. The transition from abstract theory to conceptual clarity becomes a seamless process when learners can manipulate variables and receive instant data-driven feedback, making the study of Physics an intuitive and inquiry-driven pursuit.

Conclusion

Artificial Intelligence serves as a transformative force in Physics education, making the subject more effective, accessible, and intellectually engaging. Through the deployment of intelligent tutoring systems, simulations, and visualizations, AI-based interventions lead to superior problem-solving skills and a more profound understanding of the physical world. As global educational demands evolve, the necessity of aligning technological advancements with frameworks such as NEP-2020 becomes paramount. Embracing AI is not merely an auxiliary improvement but a fundamental requirement for the future of Physics pedagogy, ensuring that instructional methods remain as dynamic and precise as the science they represent.

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