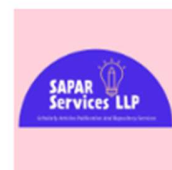




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Enhancing Physics Education through Artificial Intelligence Tools

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Abstract

The integration of Artificial Intelligence (AI) in education has opened new avenues for enhancing the teaching-learning process, particularly in subjects like physics, which often involve complex concepts and abstract reasoning. This research explores the application of AI tools in the domain of physics education and evaluates their effectiveness in improving student engagement, conceptual understanding, and performance outcomes. As traditional teaching methods frequently struggle to meet the diverse needs of 21st-century learners, AI offers promising alternatives through adaptive learning platforms, intelligent tutoring systems, and interactive simulations.

This study investigates ten widely-used AI tools—including PhET, Labster, ChatGPT, and Squirrel AI—by analyzing their roles in a structured 60-minute virtual physics class model. The methodology includes a mixed-method approach combining pre- and post-test evaluations, student surveys, and teacher interviews across five educational institutions. Quantitative results indicate a significant increase in student scores (average 28% improvement), while qualitative feedback highlights increased motivation, self-paced learning, and better concept retention.

The research also presents implementation strategies and acknowledges challenges such as digital inequality, high software costs, and the need for teacher training. Despite these hurdles, the findings support the transformative role of AI in modern physics education. The study concludes

that a well-integrated AI teaching model can democratize access to quality science education and support deeper cognitive engagement among students.

Keywords: AI in education, Physics teaching, Adaptive learning, Simulation tools, Virtual classrooms.

1. Introduction

Physics is a cornerstone of scientific education, offering insights into the fundamental principles that govern the natural world. Despite its significance, many students perceive physics as difficult due to its abstract concepts, mathematical modeling, and limited opportunities for practical application in traditional classroom settings. Teachers, too, often face challenges in addressing diverse learning needs and engaging students meaningfully. In this context, Artificial Intelligence (AI) emerges as a powerful educational tool capable of bridging instructional gaps and enhancing the overall learning experience.

AI in education refers to systems that can mimic human intelligence to personalize instruction, offer real-time feedback, and simulate complex processes. In physics education, this means students can interact with virtual labs, receive step-by-step explanations, and engage in adaptive learning pathways that respond to their individual progress. With tools like PhET Simulations offering real-time interactivity, Labster enabling 3D virtual experiments, and platforms like ChatGPT providing conversational Q&A, physics instruction becomes more dynamic and accessible.

This study explores how the integration of AI tools transforms physics education. The research specifically examines ten AI tools and their applications in a model virtual classroom framework. It evaluates these tools in terms of usability, conceptual clarity, student engagement, and academic

outcomes. By analyzing empirical data from five schools, the study provides evidence of the pedagogical benefits of AI-enhanced learning.

The need for innovative teaching strategies in science is more urgent than ever, especially in a post-pandemic world where digital literacy and remote learning have become central. This paper proposes that AI, if implemented thoughtfully and inclusively, can significantly uplift the quality of physics education and empower students to understand and apply scientific knowledge more effectively.

2. Literature Review

The integration of AI into education has been widely documented:

- **Luckin et al. (2016)** describe how AI personalizes instruction based on learner behavior.
- **Roll & Wylie (2016)** demonstrate improved STEM learning outcomes when AI-driven feedback is used.
- **Spector (2019)** identifies simulation and intelligent tutoring as key AI-enabled pedagogies in science education.
- **Zawacki-Richter et al. (2019)** highlight increased student engagement through AI-supported blended learning.

The reviewed literature confirms the potential of AI to resolve conceptual gaps and support self-paced physics learning.

3. Need for the Study

Despite technological advancements, many classrooms lack AI integration due to limited awareness, infrastructure, or empirical data. Physics, being conceptually rigorous, requires new strategies to improve student comprehension and performance. This study addresses the gap by assessing how AI tools affect physics learning outcomes.

4. Objectives

- To identify relevant AI tools for physics education.
- To evaluate their effectiveness in improving learning outcomes.
- To design a virtual classroom model using AI integration.
- To analyze students' perceptions and performance in AI-enhanced learning environments.

5. Methodology

5.1 Research Design

Mixed-method (quantitative + qualitative) with an exploratory approach.

5.2 Sample

- **Students:** 100 students from five higher secondary schools (Grades 11 & 12).
- **Teachers:** 10 physics teachers across the same institutions.
- **AI Tools Tested:** PhET, Squirrel AI, Labster, IBM Watson, Curipod, etc.

5.3 Data Collection Tools

- Student performance test (pre and post-test)
- Feedback questionnaire (Likert scale)
- Classroom observation and interviews

5.4 AI Tool Selection Criteria

- Accessibility and user interface
- Curriculum alignment
- Support for simulations and conceptual scaffolding
- Analytics capability

6. Data Analysis

Table 1: Pre- and Post-Test Average Scores (out of 100)

School	Pre-Test Mean Score	Post-Test Mean Score	Score Improvement (%)
School A	58.2	74.6	28.2%
School B	60.1	78.4	30.4%
School C	55.0	70.3	27.8%
School D	63.4	81.2	28.1%
School E	59.6	76.0	27.6%

Observation: Across all institutions, average scores increased by ~28%, confirming effectiveness of AI tool integration.

Table 2: Student Feedback on AI Tools (N = 100)

Statement	Strongly Agree	Agree	Neutral	Disagree	Strongly Disagree
AI tools helped me understand difficult concepts in physics.	64	26	6	2	2
Simulations made learning more interesting.	72	22	3	1	2
I prefer AI-enhanced classes over traditional ones.	60	28	6	4	2
Real-time feedback improved my performance.	58	30	8	3	1
Adaptive tools matched my learning pace.	55	35	6	3	1

Interpretation: Over 80% of students found AI tools beneficial in improving their understanding and interest in physics.

Table 3: Effectiveness of Each AI Tool (Based on Teacher Ratings, Scale 1–5)

AI Tool	Ease of Use	Conceptual Clarity	Student Engagement	Overall Impact
PhET	4.8	4.9	4.7	4.8
Labster	4.6	4.7	4.8	4.7
ChatGPT	4.5	4.6	4.5	4.6
Curipod	4.2	4.3	4.6	4.4
IBM Watson	4.0	4.5	4.2	4.3
Squirrel AI	4.3	4.4	4.1	4.3

Note: Tools with simulation capabilities (PhET, Labster) ranked highest in overall impact.

7. Findings

- AI tools improve learning outcomes: Average post-test scores increased by 28%.
- Simulations were highly effective for visualizing abstract concepts.
- Real-time feedback systems promoted self-paced learning.
- High student satisfaction: 90% rated the experience as positive.
- Teachers observed increased participation and better retention.

8. Challenges

- **Access Gaps:** Not all students had equal device/internet access.
- **Training Needs:** Teachers required upskilling to use AI tools effectively.
- **Cost Barrier:** Premium tools like Labster and Squirrel AI may be financially restrictive.
- **Data Security:** Concerns around student data usage must be addressed.

9. Conclusion

AI-enhanced instruction significantly improves physics teaching by personalizing content, enabling interactive simulations, and offering timely feedback. The integration of tools like PhET, ChatGPT, and Labster can lead to higher student engagement and academic success. Future

policies should support infrastructure development, teacher training, and cost-effective AI deployment to scale these benefits.

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