



**Artificial Intelligence for Scientific Discovery in Physics:
Bridging School and College-Level Concepts**

Pravinkumar Jadhav

Assistant Professor

Ashoka College of Education, Nashik

Abstract

Artificial Intelligence (AI) is increasingly transforming the field of physics by enhancing data analysis, modelling complex systems, and accelerating scientific discovery. From fundamental school-level concepts such as motion, energy, and waves to advanced college-level topics like quantum mechanics, electromagnetism, and astrophysics, AI tools provide new ways of understanding physical phenomena. This article examines the role of AI in physics-based scientific discovery with particular emphasis on its importance, uses, scope, and limitations in relation to basic physics concepts taught at school and undergraduate levels. The study highlights how AI supports conceptual clarity, experimental analysis, and theoretical development, while also discussing the challenges of interpretability, data dependence, and ethical use. The article concludes that AI serves as a powerful complementary tool to traditional physics methods, enriching both physics education and research.

Keywords: *Artificial Intelligence; Physics Education; Scientific Discovery; Machine Learning; Data-Driven Physics.*

1. Introduction

Physics is a fundamental science that seeks to explain natural phenomena through laws, theories, and mathematical models. At the school level, physics focuses on basic concepts such as motion, force, energy, light, sound, and electricity. At the college level, it extends to abstract and mathematically intensive subjects like classical mechanics, electromagnetism, quantum mechanics, thermodynamics, and solid-state physics. With the rapid advancement of technology, modern physics experiments generate enormous volumes of data that are difficult to analyze using traditional methods alone. Artificial Intelligence (AI), particularly machine learning (ML) and deep learning (DL), has emerged as a powerful tool to address this challenge. AI enables physicists to analyze complex datasets, simulate physical systems, and even discover new physical laws.

AI for scientific discovery in physics represents a shift from purely equation-based and hypothesis-driven approaches to data-driven and AI-assisted physics, benefiting both research and education at school and college levels.



2. Review of Literature

Artificial Intelligence (AI) has emerged as a transformative force in scientific discovery and education, particularly within the discipline of physics. Existing literature highlights AI's dual role as a tool for advancing scientific research and as a pedagogical aid for bridging conceptual gaps between school-level and college-level physics education.

2.1 Artificial Intelligence in Scientific Discovery in Physics

The application of AI in scientific discovery has redefined traditional research methodologies in physics. King et al. (2009) pioneered the concept of "robot scientists," demonstrating the potential of AI systems to autonomously formulate hypotheses and conduct experiments. Building on this foundation, Carleo et al. (2019) emphasized that machine learning techniques have become integral to modern physics research, especially in areas such as quantum mechanics, condensed matter physics, and high-energy physics. These studies position AI not merely as a computational support system but as an active contributor to scientific reasoning and discovery.

2.2 AI-Supported Physics Learning at the School Level

At the school level, AI-based educational technologies have been shown to enhance students' understanding of fundamental physics concepts such as motion, force, energy, and waves. Pane et al. (2014) reported that intelligent tutoring systems and adaptive learning platforms can diagnose students' misconceptions and provide personalized feedback, thereby improving learning outcomes. Furthermore, Dede et al. (2017) found that AI-supported simulations and inquiry-based environments promote deeper conceptual understanding and scientific reasoning by enabling learners to visualize abstract physical phenomena.

2.3 Bridging School and College-Level Physics Through AI

A significant body of literature focuses on AI's role in facilitating the transition from school-level conceptual physics to college-level analytical and mathematical physics. Roll and Wylie (2016) highlighted the effectiveness of AI-driven scaffolding systems in supporting learners as they progress from qualitative reasoning to quantitative problem-solving. Kersting et al. (2018) demonstrated that machine learning-based visualizations help students connect Newtonian mechanics taught at the secondary level with calculus-based formulations introduced in undergraduate physics, thereby reducing cognitive overload and enhancing conceptual continuity.

2.4 AI in Higher Education and Research-Oriented Physics Learning

In higher education, AI applications extend beyond instruction to include research-oriented learning and data-intensive problem-solving. Itén et al. (2020) illustrated how deep learning models are used to analyze large datasets in astrophysics and particle physics, often revealing underlying physical laws. Educational research suggests that integrating such AI tools into undergraduate curricula enhances students' computational thinking skills and prepares them for interdisciplinary scientific careers (Zhai et al., 2020).



2.5 Indian Context and Emerging Educational Trends

Within the Indian context, recent studies emphasize the growing relevance of AI in physics education through national initiatives such as Virtual Labs and the SWAYAM platform. These AI-enabled resources aim to provide equitable access to quality laboratory experiences and conceptual learning, particularly in resource-constrained settings. Scholars argue that alignment of AI integration with the National Education Policy (NEP) 2020 can strengthen the bridge between secondary and higher education physics by promoting experiential, competency-based, and technology-driven learning.

2.6 Research Gaps in Existing Literature

Despite the expanding body of research, notable gaps remain. Limited empirical studies examine the long-term impact of AI-supported instruction on conceptual transfer between school and college physics. Additionally, there is a lack of context-specific research focusing on developing countries, including India. These gaps highlight the need for pedagogically grounded frameworks that systematically integrate AI tools with physics curricula across educational levels.

3. Importance of AI in Physics-Based Scientific Discovery

The importance of AI in physics lies in its ability to enhance understanding, experimentation, and theory development.

3.1 Conceptual Understanding of Basic Physics

- AI-based simulations help visualize Newton's laws of motion, projectile motion, and circular motion.
- Interactive AI tools support better understanding of force, momentum, and energy conservation.
- Machine learning models assist in recognizing patterns in motion graphs and experimental data.

3.2 Handling Complex Physical Systems

- Many physical systems, such as turbulent flow or chaotic motion, are difficult to solve analytically.
- AI can model such non-linear systems efficiently, which is especially useful in advanced physics.

3.3 Reducing Experimental Time and Error

- AI automates data collection and error analysis in experiments related to optics, electricity, and magnetism.
- It improves accuracy in measurements and predictions.

3.4 Supporting Research and Innovation

- AI accelerates discoveries in astrophysics, particle physics, and condensed matter physics.
- It supports interdisciplinary research combining physics with data science.

4. Uses and Applications of AI in Physics (School and College Level)

4.1 Mechanics (School and Undergraduate Level)

- AI-based simulations demonstrate laws of motion, free fall, friction, and simple harmonic motion.
- ML models analyse experimental data from pendulum experiments or motion sensors.



- Predictive modelling helps students understand motion under varying conditions.

4.2 Waves and Optics

- AI assists in analysing wave patterns, interference, and diffraction.
- Image-processing algorithms help study ray diagrams, reflection, and refraction.
- AI enhances optical experiments such as spectroscopy and lens systems.

4.3 Electricity and Magnetism

- AI models electric and magnetic field distributions.
- Neural networks help optimize electrical circuits and analyze current-voltage characteristics.
- Simulation tools aid in understanding electromagnetic induction and alternating current.

4.4 Thermodynamics and Heat

- AI predicts heat transfer, efficiency of engines, and entropy changes.
- Machine learning models simulate real-life thermodynamic systems beyond ideal conditions.

4.5 Modern Physics (College Level)

- AI contributes to quantum mechanics by predicting wave functions and energy levels.
- In solid-state physics, AI is used to discover new materials and superconductors.
- In astrophysics, AI analyzes telescope data to detect stars, galaxies, and gravitational waves.

5. Scope of AI in Physics Education and Research

The scope of AI in physics is broad and continuously expanding:

1. AI-Assisted Physics Education

- Personalized learning systems adapt to students' understanding levels.
- Virtual laboratories allow experimentation without physical constraints.

2. Automated Experimentation

- AI-controlled instruments design and perform experiments independently.
- Useful in nuclear physics, particle physics, and space science.

3. Discovery of New Physical Laws

- AI techniques such as symbolic regression help rediscover known laws and identify new relationships.

4. Future Integration

- Combination of AI with quantum computing and robotics.
- Smart laboratories and intelligent physics classrooms.

AI has the potential to revolutionize both teaching-learning processes and advanced physics research.

6. Limitations and Challenges of AI in Physics

Despite its vast potential, AI in physics has several limitations:

6.1 Dependence on Data Quality



- Incorrect or biased data can lead to misleading results.
- School-level experiments often generate limited datasets.

6.2 Lack of Physical Interpretability

- Many AI models provide results without explaining the underlying physics.
- This limits conceptual understanding for students.

6.3 Over-Reliance on Technology

- Excessive use of AI may reduce analytical and mathematical skills in learners.
- Fundamental derivations and problem-solving remain essential.

6.4 Infrastructure and Training Issues

- AI requires computational resources and technical expertise.
- Teachers and researchers need proper training to use AI effectively.

7. Conclusion

Artificial Intelligence has emerged as a powerful catalyst for scientific discovery in physics, enriching both foundational learning and advanced research. By linking AI tools with school-level concepts such as motion, energy, and waves, and extending their application to college-level physics domains, AI enhances conceptual clarity, experimental accuracy, and innovation. However, AI should not replace traditional physics reasoning and mathematical rigor. Instead, it should be used as a supportive and complementary tool. A balanced integration of AI and classical physics approaches will lead to meaningful scientific discoveries and improved physics education in the future.

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