

AI-Driven Instructional Strategies in Secondary Physics Education: A Systematic Review

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Abstract- The systematic review examines how Artificial Intelligence (AI) is used in Physics instructional design in secondary schools. The engagement of students through personalised instruction will improve conceptual understanding. Technologies like Intelligent Tutoring Systems, conversational agents and adaptive learning platforms play a significant role. This review paper summarises the empirical results about the pedagogical impact of AI-based teaching approaches in Physics based on current empirical research. It highlights how AI facilitates the visualisation of difficult ideas, permits customised learning routes and facilitates real time feedback techniques. The present study addresses implementation related topics such as algorithmic bias, content accuracy, digital equity, infrastructure limitation, professional development opportunities and teacher training along with monitoring benefits. There is limited studies related to long term impact of Artificial Intelligence (AI) on retention, critical thinking and cognitive development. Most of the studies show promising short term results. Overall the paper focuses on how AI can revolutionise Physics education and calls for evidence based and thoughtful implementation techniques.

Keywords: Secondary education, Instructional strategies, Artificial Intelligence, Physics education

I. INTRODUCTION

Physics being a foundational subject in secondary school plays a significant role in the development of logical skills, analytical abilities and scientific literacy. These skills not only contribute for professional development and academic achievement in STEM careers, but also produce thoughtful, educated and responsible citizens in the digital era. Physics educates students to consider and describe the physical world in terms of empirical evidence, rational argument, and mathematical formulae. But even though it is relevant, the subject is also typically considered abstract, difficult, and irrelevant to everyday life.

Traditional pedagogical methods of teaching physics, like excessive reliance on the lecture method, bookish knowledge and a mechanical problem-solving approach, fail to cater to different learning needs in the contemporary classroom. Physical phenomena's mysteriousness, increased dependence on mathematics, insufficient utilisation of applied and contextualised learning abilities to problems, are likely to create a gap, baffling learners and leading to under achievement. It is challenging to deal with electromagnetic waves, Newtonian mechanics and Quantum mechanics as it requires a deep conceptual understanding. AI can address all these issues.

Artificial intelligence (AI) offers new ways to address pedagogical challenges and bring change to physics education. AI refers to machines and computer systems that mimic human intelligence, capable of decision making, understanding language, recognising patterns, and solving problems. Technologies such as machine learning algorithms, natural language processing (NLP), computer vision, and expert systems are increasingly being adopted in schools. AI technology enables valuable services such as personalised learning, adaptive testing, instant feedback, and interactive content delivery, all of which are transforming education.

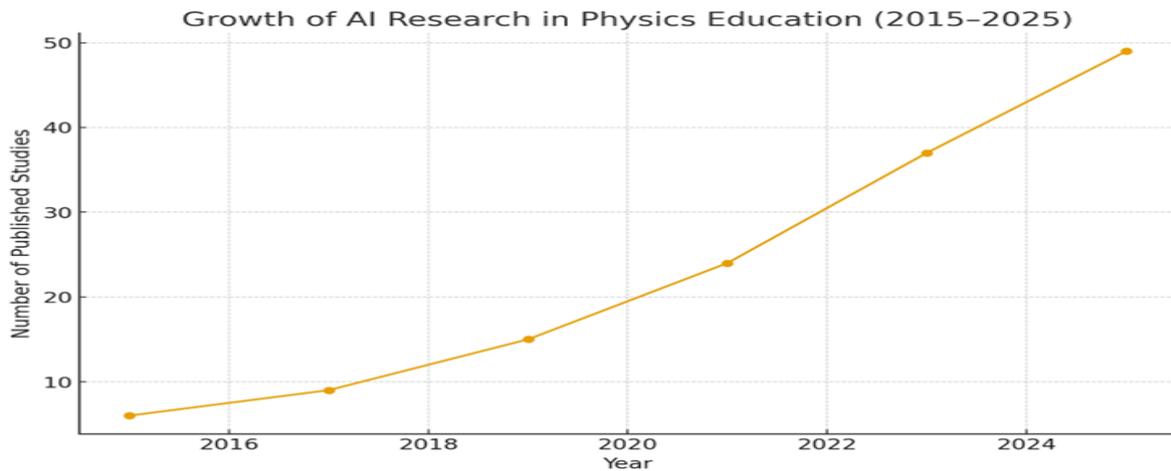
AI supports the rapid development of dynamic and interactive environments, adapting to the individual learner in Physics education. In the case of AI-driven systems, gaps in learning are identified, content is personalised depending on the level of cognition, and varying levels of support can be provided from the lower-order support of simulations, intelligent tutoring systems and conversational agents. How AI can process information on students and respond to it has a more humane and more responsive sound to it than traditional models have. Additionally, AI integration brings education in line with 21st-century skills like

digital literacy, collaboration, metacognition, and self-regulated learning, which are relevant to contemporary curriculum.

This systematic review assesses recent innovations of artificial intelligence technologies for enhancing physics education at secondary school. This study combines theoretical and empirical findings to

examine AI technology applications that support teaching techniques while enhancing student conceptual comprehension through personalised instruction and increased engagement. AI can effectively support teaching assessment and growth by considering its strengths and limitations.

Figure 1: Growth of AI Research in Physics Education (2015–2025)



Source: Compiled from Scopus database (2025)

The graph indicates a consistent rise of AI applications in Physics education

Based on this, the present study focuses on the application of AI technologies in secondary school Physics education. The main concerns like digital divide, teachers readiness and ethical concerns are to be addressed for the implementation of a digital world.

II. METHODOLOGY

This study drew considerable data from trustworthy academic databases available online on their sites, such as IEEE Xplore, ACM Digital Library, ScienceDirect, and Google Scholar. Literature searching used the following keywords: "artificial intelligence," "physics education," "intelligent tutoring systems," "adaptive learning," and "personalised learning." Literature studies with valid methods and empirical evidence with proven applicability in secondary-level Physics education were used for the review.

Among the studies included, Mustofa et al. (2024) was a systematic review according to PRISMA guidelines, evaluating the effect of applications of AI technologies such as ChatGPT on enhancing problem-solving abilities and pedagogy strategies in physics.

Bessas et al. (2023) discussed the attitude of high school students on the implementation of ChatGPT in the classroom. He presented the advantages and disadvantages of the AI tool. Hadzhikoleva et al. (2025) conducted an experimental study using a specially devised chatbot named Zapier, to guide grade seven students to understand the concept of light and sound. He clearly stated the improvement in comprehension and motivation of students which validates the efficacy of AI tools in understanding concepts in Physics. Younas et al. (2023) examined macro-level trends in AI embedding at higher education level. This includes development of smart campuses, AI driven assessment systems and adaptive learning systems for developing dynamic and inclusive learning environments. His thematic synthesis demonstrates the infrastructure and institutional changes required for effective AI implementation.

Patero (2023) used a mixed-method design to explore the potential of AI to enhance learning outcomes and learner engagement in secondary Physics teaching. The research blended qualitative student and teacher feedback with quantitative performance measures to demonstrate gains in achievement and instructional flexibility. Zhang et

al. (2024) concentrated on the application of AI in teaching instruction, where it was explored to see its effect on five factors: classroom management, inclusion, digital literacy, comprehending student learning style, and enhancing teacher-student relationships. Information collected from more than 200 lecturers and students in a university yielded rich details on affordances and challenges to teacher training through AI.

Mahligawati et al. (2023) synthesised existing research to establish a knowledge base examining AI technologies' impact on conceptual learning as well as personalisation and assessment methods in Physics education. In his 2017 study, Suleman implemented a pretest-posttest experimental design to assess how Computer-Aided Instruction impacted ninth-grade Pakistani students' performance. SPSS analysis demonstrated statistical significance in test score improvements with CAI as an effective teaching intervention. Shafiq et al. (2025) conducted a study on AI in physics education from primary to university students. AI tools like ChatGPT and Intelligent Tutoring Systems provide simulation and interactive learning experiences. Virtual labs and PhET simulations enable the students to get the concept very clearly. Even though AI is revolutionising education, the primary concerns like digital divide, equity has to be addressed.

This paper investigates the integration of artificial intelligence (AI) in physics education to enhance learning for accommodative learners as per Kolb's model. Utilizing a qualitative approach, it includes a case study of 85 high school girls in science stream, collecting data through questionnaires and interviews to assess challenges faced in learning Physics. Findings suggest that AI can provide tailored learning solutions to meet individual needs, leading to recommendations for optimizing AI use in pedagogy. This study marks the importance of personalised teaching approaches for catering individual needs while learning Physics.

All the above studies show the role of Artificial Intelligence in helping secondary school students to learn Physics. There is an urgent need of further research to find more pedagogically aligned AI tools which are ethical and relevant to environment. Learning digital disruption allows AI's capacity to bridge gaps in equity, engagement, and effectiveness in Physics teaching and learning to be highlighted.

III. RESULTS AND DISCUSSION

Artificial Intelligence (AI) technologies in physics education at the secondary level have proved huge pedagogical benefits, including increased conceptual understanding, tailored learning, and enhanced students' motivation. Abstract and mathematically, as physics is, it becomes a compulsory machinery with AI to move beyond its conventional boundaries in physics education through imagery and interactive learning phenomena to address the needs of students.

3.1 Enhancing Conceptual Understanding through Visualisation and Simulation

One of the most radical aspects of AI in physics instruction is how it might revolutionise difficult scientific concepts by cutting them up more neatly in format using simulations, animations, and interactive modules. Electromagnetic waves, projectile motion, and sound waves—complicated processes previously difficult to illustrate through static diagrams—are dynamically created by AI-powered software. As stated by Mahligawati et al. (2023), AI modules enable students to learn concepts in a more discovery-based way, thereby enhancing active learning. For instance, AI-driven 3D simulations plot vector fields, interference of waves, and forces in real-time, enabling students to build precise mental models. Further, the interactive nature of such a site provides immediate feedback and concept understanding assistance. This active method of learning, rather than passive learning, is required in physics as memorisation alone cannot be adequate to generate true understanding. AI facilitates inquiry-based learning by allowing students to manipulate variables and observe resulting changes, thus making scientific reasoning and experimentation abilities more accessible.

3.2 Personalised Instruction and Adaptive Learning Systems

Another important advantage of AI integration is that it is capable of customisation. AI systems evaluate each pupil's existing knowledge, rate of learning, and style of modality (e.g., visual, auditory, or kinesthetics), and proceed to adjust the presentation of content to suit individual profiles. This provides the possibility of differentiated instruction within heterogeneous classrooms where students are likely to differ considerably in scholarly readiness and style of learning.

Mustofa et al. (2024) proved that AI-based tutoring systems such as ChatGPT are capable of supporting students with difficult problem-solving steps in a step-by-step personalised explanation. These models not only replicate human-like tutoring behaviour, but they also enable students to learn at their own pace and come back to hard-to-concept topics any number of times. This scaffolding impact promotes retention and understanding of the fundamental concepts of Physics. To this effect, in evidence, Patero (2023) established that the adaptive AI-based learning students recorded a 27% academic improvement, accounting for the effectiveness of personalised learning streams.

3.3 AI-Enhanced Engagement and Motivation

AI technologies boost student engagement in Physics classroom. Intelligent chatbots, gamification and virtual lab create dynamic learning environment. Hadzhikoleva et al.(2025) demonstrated the use of Physics GPT ,a chatbot significantly contribute to middle school Physics instruction. This will not only motivate but also improve the understanding of basic concepts in Physics.AI enhance affective learning by developing interest, curiosity and resilience among students. Chatbots, which are interactive develop fast reply for students enquiries and doubts.

3.4 Support for Teachers and Pedagogical Efficiency

AI not only helps students but also transforms the nature and effectiveness of teachers. Pedagogically, AI facilitates teachers in instructional planning, student performance analysis, and identification of learning gaps. Zhang et. al (2024) revealed that teacher training by AI improves classroom discussion, accessible and sensitive to diversity among students. For instance, teachers can employ AI-driven analytics to tailor teaching, identify struggling students, and modify teaching approaches in response. AI is beneficial for learners but also improves in improving their effectiveness by reducing their administrative tasks, lesson plan preparation and maintaining students records (Williamson & Eynon, 2020; Zhang et al., 2024).

In addition to classroom instruction, AI facilitates instant grading and assessment, according to Suleman et al. (2017). Instant feedback is delivered by Computer-Assisted Instruction (CAI) software, hence relieving workload stress from hand marking

and giving teachers more time to attend to content delivery and student counselling. CAI software also makes personal study suggestions, thereby complementing formative assessment processes and allowing instructors to implement evidence-based interventions.

3.5 Inclusive Education and Support for Diverse Learners

Among the most important contributions of AI is its capacity to build inclusive learning environments. Adaptive learning environments are capable of adjusting content delivery modalities and rates to respond to learners with special education needs. The visually impaired learners, for example, can be served using audio-enriched instruction, and learners with dyslexia can be facilitated using text-to-speech capability. All these facilitations promote equity in access and participation and hence uphold the pillars of inclusive education.

Moreover, AI can assist in the identification of hidden learning disability or attention deficits via behavioural analytics for the sake of making early interventions. Substantiating inclusive classrooms where all students' needs are revealed and addressed, AI supports universal learning design (UDL) principles.

3.6 Systemic and Macro-Level Impacts

Outside the classroom, a few of the applications of AI in education are intelligent infrastructure development, organisational intelligence, and institutional-level analytics. Younas et al. (2023) discussed AI applications in developing "smart campuses" with real-time learning analytics, monitoring performance, and AI-based administrative uses. Such platforms allow institutions to track learning outcomes in real-time, optimise resource allocation, and make data-driven decisions. This macro-level alignment of AI results in transparency, accountability, and continuous improvement, resulting in improved quality of instruction and student performance. It also allows for longitudinal monitoring of students' progress from grade to grade, which can help support curriculum development and strategic planning.

3.7. Challenges and Considerations

Despite the numerous benefits, the use of AI in secondary school physics has not been without hitches. Invasion of privacy of data, overreliance on computerised materials, and de-skilling of teachers

are some of the issues that have continued to emerge. Bessas et al. (2023) established that although the students had exhibited good attitudes towards ChatGPT, challenges had existed as far as the correctness of the answers and overreliance on non-human feedback were concerned. Access to AI resources in a just manner also remains a concerning issue, especially in poorly resourced schools where computerised resources are absent. Successful AI integration, therefore, requires comprehensive teacher training, organisational assistance, and

standards of ethics to reduce threats and enhance learning advantages. As Zhang et al (2024) reiterated, inducting instructors to use AI effectively in classrooms is a key prerequisite to initiating pedagogic innovation.

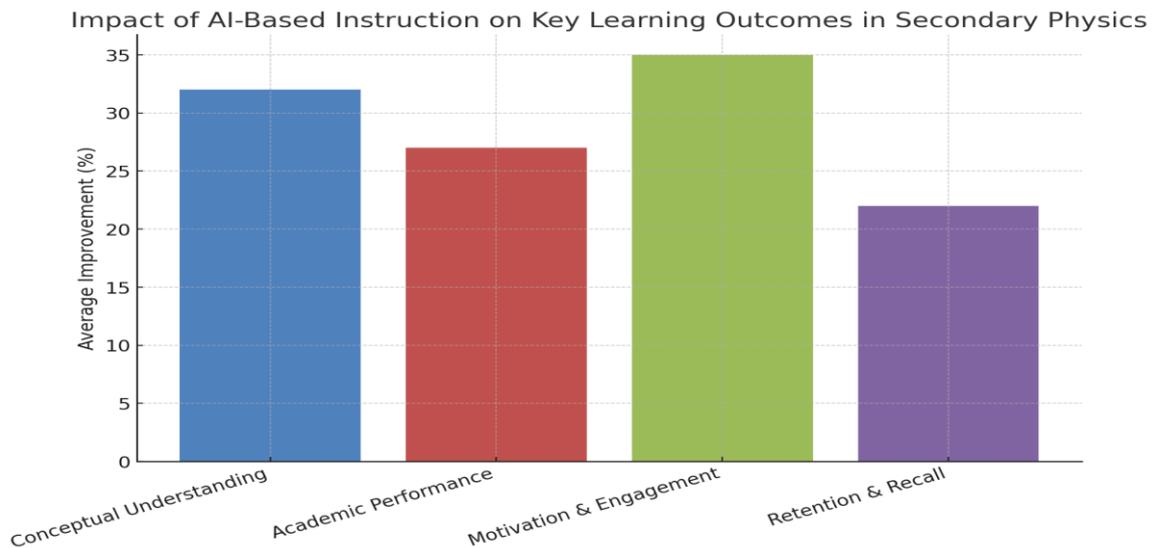
3.8. Summary of Key Studies

To provide an overview of the empirical and theoretical foundations discussed, the table below summarises notable studies that informed this review.

Table 1: Summary of Key Studies on AI in Secondary Physics Education

Author(s)	AI Tool/ Approach	Level	Focus Area	Methodology	Key Findings
Mustofa et al. (2024)	ChatGPT, AI tutoring	Secondary school	Problem-solving guidance	Systematic review	ChatGPT enables dynamic step-by-step problem-solving.
Muhammad Shafiq et al. (2025)	ChatGPT, PhET Simulations, Virtual Labs	Primary to University	Physics learning enhancement through AI	Narrative Review	AI tools improve engagement, conceptual understanding, and personalized learning in physics education
Kotsis (2025)	ITS, adaptive learning, and virtual labs	Primary & Secondary School Physics	Pedagogy–Technology–Policy framework	Narrative literature review	AI improves personalized and inquiry-based physics learning.
Kemouss et al.(2025)	AI-based personalized learning for Kolb’s <i>accommodator</i> style	Secondary school physics.	AI-based personalized physics learning for accommodator-type students.	Case Study	AI increased student engagement. Improved physics understanding for accommodator learners.
Bessas et al. (2023)	ChatGPT	High school	User perceptions	Survey research	Positive attitudes, concerns about overreliance and accuracy.
Hadzhikoleva et al. (2025)	PhysicsGPT (Chabot)	Middle school	Concept learning (Light and Sound)	Experimental design	Increased motivation and understanding.
Younas et al.(2023)	General AI in education	K–12 and tertiary	Smart campuses, adaptive tools	Thematic review	Identified flexible, data-driven learning models.
Patero (2023)	Adaptive instruction	Secondary school	Engagement & learning outcomes	Mixed methods	27% increase in achievement; improved personalisation
Zhang et al. (2024)	AI for teacher training	Teacher education	Classroom dynamics, pedagogy	Survey & statistical analysis	AI aids inclusive teaching and digital literacy development.
Mahligawati et al.(2023)	Conceptual framework	Secondary education	Personalised instruction, assessment	Literature synthesis	Proposed a model integrating AI into teaching and evaluation.

Figure 2: Impact of AI-Based Instruction on Key Learning Outcomes in Secondary Physics



Compiled from Mahligawati et al. (2023); Mustofa et al. (2024); Younas et al. (2023); Patero (2023); Chen et al. (2021); Alqahtani & Rajab (2022); Tan & Lim (2023).

IV. CHALLENGES AND LIMITATIONS

Although there is considerable promise and probable gain in the application of Artificial Intelligence (AI) to enhance the instruction of Physics in high schools, there are various critical areas and restrictions. These must be confronted regularly so that AI-enhanced learning will not merely work but also be equitable, ethical, and contextually viable.

4.1 Accuracy and Reliability of AI-Generated Content

Most potentially critique-worthy is the reliability and accuracy of AI-synthesised material, especially in advanced subject matter like Physics. Although AI software like ChatGPT and other language models can generate step-by-step solution explanations and summary ideas, they are not infallible. Increasingly, the responses provided by AI may lead to misinterpretations of basic concepts or mathematically incorrect answers, particularly when it comes to complex areas needing improved reasoning or relating of concepts.

Research such as that by Mustofa (2024) and Bessas (2023) recognises that, even though AI sites can add to learning and problem-solving, they need critical oversight. In the absence of expert engagement from teachers, pupils stand to be misled by incorrect or oversimplification explanations. It is for this reason that human teachers remain essential, whose role

shifts from being a content provider to facilitator, authenticator, and suitor of AI-generated support. Teachers will have to critically assess AI works and instruct pupils on how to utilise them as auxiliary resources, not source texts.

4.2 Lack of Visual and Simulation Capabilities

Physics education is replete with graphical thinking and comprehension of dynamic phenomena—moving from projectile motion to the action of electromagnetic waves and quantum processes. But most conventional AI applications these days cannot afford to present complete graphical simulations, real-time animations, or interactive models necessary to introduce these phenomena. For instance, ideas like wave-particle duality, rotational mechanics, or Lorentz transformations tend to call for visualisation to be fully understood by the students.

The lack of useful visualisation tools in mainstream AI packages diminishes their teaching capabilities in Physics education. While certain domain-specific AI packages, such as PhET simulations or Labster, can offer interactive models, they are standalone packages and are not compatible with mainstream AI packages nor cannot be used with natural language platforms such as ChatGPT. This gap is a serious barrier to the complete integration of AI into STEM education.

4.3 Algorithmic Bias and Equity Concerns

Another limitation is the built-in biases in AI software, which have a tendency to be developed and learned from large datasets that are not necessarily representative of every student population or learning setup. Unchecked, they can reinforce or even widen learning disparities. For instance, AI tutoring systems learned from Western-curriculum inclined datasets will not be able to account for regional differences in curriculum or student culture arrangements. Likewise, English-dominated AI tools can be less effective for learners whose native study language is other than English. Fairness of algorithm is the prime concern in the implementation of AI in education. According to Younas et al.(2023),limiting the exclusion of marginalised student group requires equal access and culturally relevant information.AI designers should include equity and transparency principles in the routine audit of schools to prevent improper outcomes or decision patterns.

4.4 Infrastructure and Digital Divide

The digital divide is a significant barrier for the implementation of AI in Physics education especially in underdeveloped countries. Effective AI usage necessitates a solid internet connection, sufficient hardware and dependable digital infrastructure which are lacking in rural or economically disadvantaged institutions. These distinctions create uneven learning chances and promote socio-economic gaps in educational achievement. The remote institutions also lack software cloud storage and the technical competence needed to maintain AI systems. Zhang et al. (2024) underlined the requirements for institutional preparedness which include budgeting, maintenance provisions and administrative support. Infrastructure investment should be given top priority in the educational policy for access to AI technology.

4.5 Teacher Readiness and Professional Development

Teachers' digital literacy, confidence and preparedness are crucial in the successful implementation of AI in classrooms. Many teachers are not fully equipped to employ AI in pedagogy, risking misuse through over reliance or incorrect application. This can affect classroom dynamics and diminish students critical thinking. In order to bridge the gap, continuous professional development courses incorporating AI tool usage for pedagogic assistance and embedding AI into curriculum

assessment are required. Long term initiatives like seminars, workshops and structured AI pedagogy certifications can boost teachers confidence and competence.

4.6 Student Digital Literacy and Cognitive Dependence

Students must have a basic digital literacy of AI applications. Most of the students in the secondary level might not have the needed technological ability to actively participate in interaction with AI technology. This includes interface control, AI feedback interpretation and responsible usage of created content. Students may use AI tools without proper training may lead to cognitive dependence instead of skill acquisition.

Another major concern is that the over- reliance on AI assistance can affect their ability to solve problems on their own. As Patero (2023) pointed out, AI can support learning, but is never employed as a replacement for active knowledge building by students. Teachers should lead learners to utilize AI as a tool to improve inquiry among students.

4.7 Data Privacy and Ethical Concerns

The use of AI tools presents ethical concerns about data collection, student privacy and informed decision making .AI applications are expected to collect and interpret copious amounts of data on pupil engagement during personalised learning and tracking achievement. The confidentiality of students data will be compromised if there are poor data protection regulations. Authorisation, privacy and security criteria are vital for educational organisations. Parents and students should be informed about data handling. According to OECD, AI technologies must undergo pilot testing and ethical review.

V. CONCLUSION

The paper aimed to address the revolutionary potential and realistic limits connected with implementation of AI tools in teaching Physics at school level. AI enabled software have significant potential for increasing student motivation and providing personalised learning experiences. The technologies assist in automatic grading, instant feedback and active involvement in comparison with traditional learning medium.

Several studies highlight the positive impacts of AI aided instruction. AI has been an effective tool in

teaching abstract concepts and facilitate self-directed learning. Since Physics is a difficult subject for students, AI can contribute much in teaching numerical and abstract concepts. AI is not a substitute for conventional pedagogic techniques. The successful implementation of this additive element requires pedagogically sound frame works that combines digital technology, curricular objectives and learner diversity. The teacher remains at the core as a guide, interpreter and moral protector of technology use.

Without such pedagogical correlate conditions, AI tools can be abused or are unable to respond to simple cognitive learning goals.

Furthermore, proper deployment of AI in physics pedagogy depends on several factors of enablement: robust infrastructure, data safeguarding policies, ethics, and complete teacher training. As is posited in the challenges section, unfair inequalities of access to digital technology, biased algorithms, and poor professional development may interfere with the equitable deployment of AI. To be sustainable and inclusive, education systems need to invest in capacity building, put in place policy guidelines that guarantee responsible use, and develop equity in AI opportunity access.

Yet another important gap discussed in the earlier literature is the sparse attention to long-term monitoring. The majority of the available studies have an interest in short-term interventions and frequently take place under piloted or controlled conditions. Large population, longitudinal studies ought to measure the long-term influence of AI on secondary school pupils' metacognitive development, critical thinking, and long-term retention of knowledge. Research should also investigate in the future ,the extent to which AI tools may be configured to align with varying types of educational systems, socio-economic environments, and cultures. Such context-relevant research is needed to guide policy-making in pursuit of enhancing AI usage in a pedagogically suitable, responsive, and inclusive manner.

Finally, AI has the potential to be a great innovation driver in Physics teaching. If professionally developed, ethically implemented, and pedagogically utilised, AI can assist in creating more interactive, individualised, and efficient learning environments for high school students. The path to complete integration, though, calls for careful design, enlightened action, and ongoing reflection. As AI technology advances, pedagogy and policy

need to evolve as well to ensure that learning in the future will be both technologically sophisticated and human, equitable and intellectually stimulating.

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