LatIA. 2025; 3:89
doi: 10.62486/latia202589
ISSN: 3046-403X

REVIEW

Integrating Artificial Intelligence for Science Teaching in High School

Integración de la inteligencia artificial para la enseñanza de las ciencias en la educación secundaria

Konstantinos T. Kotsis[1]

[1]University of Ioannina, Department of Primary Education, Lab of Physics Education and Teaching. Ioannina, Greece.

Cite as: T. Kotsis K. Integrating Artificial Intelligence for Science Teaching in High School. LatIA. 2025; 3:89. https://doi.org/10.62486/latia202589

Submitted: 01-03-2024 **Revised:** 12-07-2024 **Accepted:** 18-02-2025 **Published:** 19-02-2025

Editor: Dr. Rubén González Vallejo

Corresponding author: Konstantinos T. Kotsis

ABSTRACT

This paper studies the potential benefits and challenges of incorporating AI into science education for secondary-level schools. It explores how AI-driven tools can enhance personalized learning, improve student engagement, and reshape teaching methodologies while addressing concerns regarding equity, accessibility, and teacher-student interactions. A literature review and analysis of AI applications in education focused on adaptive learning technologies, interactive simulations, and AI-driven feedback systems. AI technologies, including ChatGPT, facilitate personalized learning through adaptive feedback that targets individual knowledge gaps and learning preferences, promoting a more profound comprehension of intricate subjects such as physics. Findings indicate that AI enhances learning experiences by providing personalized feedback, fostering interactive and collaborative learning environments, and supporting differentiated instruction. However, challenges such as limited access to technology, teacher training, and ethical considerations regarding data privacy must be addressed to ensure equitable AI implementation in education. AI has the potential to revolutionize science education by making learning more engaging and tailored to student needs. However, successful integration requires addressing challenges related to infrastructure, teacher training, and ethical concerns. This study highlights the need for comprehensive policies and professional development programs to maximize the benefits of AI while ensuring fair and effective implementation in science education.

Keywords: AI in Education; Personalized Learning; Science Education; Collaborative Learning.

RESUMEN

Este artículo examina el potencial transformador de la incorporación de la inteligencia artificial (IA) en la educación científica, haciendo hincapié en su capacidad para mejorar la participación de los estudiantes y los resultados de aprendizaje. Las tecnologías de IA, incluido ChatGPT, facilitan el aprendizaje personalizado a través de una retroalimentación adaptativa que se enfoca en las brechas de conocimiento y las preferencias de aprendizaje individuales, promoviendo una comprensión más profunda de temas complejos como la física. Las plataformas impulsadas por inteligencia artificial permiten a los educadores personalizar las lecciones de acuerdo con las necesidades únicas de cada estudiante, fomentando una experiencia de aprendizaje personalizada que mejora la comprensión y la retención de conceptos científicos. Las herramientas interactivas y las simulaciones mejoran la participación de los estudiantes al convertir el aprendizaje convencional en experiencias dinámicas e inmersivas, fomentando la colaboración y el aprendizaje entre pares. La incorporación de la IA en entornos educativos genera importantes preguntas sobre la equidad, la accesibilidad y la dinámica entre profesores y estudiantes, lo que requiere un examen minucioso para

mejorar sus efectos beneficiosos. Al adoptar los avances de la IA y promover prácticas justas, los educadores pueden cultivar entornos inclusivos que utilicen la IA para mejorar la participación y el logro en la educación científica para cada estudiante. Este documento destaca la necesidad de proporcionar a los estudiantes habilidades esenciales de alfabetización digital, garantizando que estén preparados para una sociedad orientada a la tecnología y un panorama laboral que cambia rápidamente.

Palabras clave: Inteligencia Artificial en la Educación; Aprendizaje Personalizado; Educación Científica; Aprendizaje Colaborativo.

INTRODUCTION

Incorporating artificial intelligence (AI) in education represents a significant shift, especially in the crucial area of science instruction in high schools. As educators confront the persistent challenge of engaging a diverse student body, characterized by a range of learning styles and varying academic progress rates, AI tools have surfaced as essential resources that can significantly personalize the educational experience. These advanced technologies support personalized instruction, allowing educators to customize their teaching methods according to each student's distinct needs and capabilities. Moreover, the capacity of AI to process extensive datasets enables educators to discern significant trends in student performance, resulting in more knowledgeable and efficient teaching methods that can evolve over time.

Although the advantages of integrating AI into educational environments are considerable, it is essential to acknowledge that introducing these technologies in the classroom brings forth critical inquiries regarding equity, access, and the fundamental dynamics of the teacher-student relationship. It is crucial to tackle these intricate issues to enhance the beneficial effects of AI on science education and to guarantee that every student, irrespective of their background or situation, can succeed in a progressively technological environment. By adopting these advancements and promoting fair practices, educators can cultivate an inclusive atmosphere that utilizes AI to enhance engagement and achievement in science education for every student.[1]

Artificial intelligence includes machine learning, natural language processing, and cognitive computing, allowing systems to execute tasks that usually need human intelligence. This definition indicates that AI is not just a tool but a transformative force that is reshaping various sectors, including education.[1] In the realm of education, the significance of AI is diverse, as it has the potential to tailor learning experiences, adjust to the unique needs of each student, and enhance the efficiency of administrative tasks that frequently take up considerable time for educators.[2] Adopting AI technology enables educators to concentrate more on instruction rather than assessment, creating a setting where students can flourish and achieve their maximum potential.[3]

The capacity of AI to captivate students using creative approaches corresponds with the demand for different teaching methods, especially for individuals at risk of leaving school.[4] This specifically encompasses migrants and students hailing from difficult socio-economic circumstances,[5] as they could gain considerable advantages from customized educational strategies. As educational institutions navigate the integration of AI into their curricula and systems, it is crucial to shift the paradigm from punitive measures that may alienate students towards a framework that emphasizes guidance, support, and developmental opportunities.[6] This transition significantly enhances the educational experience for every student, underscoring the principle that learning must be inclusive and accessible to all. Utilizing AI, educators can foster a more supportive and effective environment for science instruction that caters to the varied needs of students and equips them for a swiftly changing future.

Recent advancements in science education indicate a notable transition towards collaborative, student-focused learning settings that leverage the transformative capabilities of technology.[7] The integration of AI into science education for primary education has been proposed,[8] and several studies have been conducted on this topic.[9,10]

Educators are placing greater importance on Project-Based Learning as an effective approach to actively involve students in authentic scientific exploration, enabling them to explore intricate subjects while honing vital skills in critical thinking, problem-solving, and collaboration.[11] This innovative approach closely aligns with broader trends observed in various educational reforms, such as those at X University in northern China, where educators adapt to new curriculum initiatives. In these contexts, promoting collaborative professional growth by creating peer support groups has emerged as a key approach to improving teaching effectiveness and educational results.[12]

Incorporating artificial intelligence (AI) technologies in educational settings is increasingly common, providing tailored learning experiences that address the varied needs of each student and enabling the adoption of creative teaching strategies that align with the preferences of contemporary learners.[13] As highlighted in current scholarly dialogues and investigations, resources like the Faculty Notebook at Gettysburg College are

essential in fostering the exchange of teaching innovations among faculty, enhancing a culture of ongoing development and cooperation in science education.[14] These trends improve the educational experience and equip students to confront and address real-world challenges in a world that is becoming more complex and interconnected.

Incorporating Artificial Intelligence (AI) into high school science education presents a remarkable opportunity to revolutionize teaching methodologies and improve learning results in ways that were once impossible. Utilizing AI tools allows educators to tailor instruction to accommodate each student's diverse and unique needs, which is crucial for creating a more inclusive and effective educational environment where all students can succeed.[15] Recent studies emphasize that AI applications enable teachers to connect with students more meaningfully and encourage educators to enhance their comprehension of scientific principles and the ethical implications of engaging with technology and its societal effects.[16] This dual approach promotes a more holistic educational framework emphasizing knowledge acquisition and ethical responsibility.

Educators utilizing AI-driven curricula have observed a significant transformation in their teaching methods, enabling them to innovate and captivate students through interdisciplinary strategies that connect various fields of study and establish real-world relevance.[17] This shift in teaching methods highlights the crucial need to incorporate AI, as it provides students with vital digital literacy skills that are essential in our technology-focused world and readies them for a rapidly changing job market that increasingly requires adaptability and tech-savviness.[18] This integration significantly boosts student engagement and comprehension of scientific concepts, while also increasing the relevance and effectiveness of high school science education. It ensures that students are adequately prepared to tackle future challenges in their educational and professional journeys.

This study explores the integration of Artificial Intelligence (AI) in high school science education by analyzing its potential to enhance personalized learning, increase student engagement, and improve teaching methodologies. It investigates how AI-driven tools, such as adaptive learning systems and interactive simulations, can support differentiated instruction and foster critical thinking. Additionally, the study identifies key challenges related to accessibility, teacher training, and ethical considerations, proposing strategies for the equitable and effective implementation of AI in science classrooms.

METHOD

This study employs a qualitative research approach, utilizing a systematic literature review to examine the integration of Artificial Intelligence (AI) in high school science education. The research analyzes existing studies exploring AI-driven learning tools and adaptive learning technologies and their impact on teaching methodologies, student engagement, and personalized learning. Peer-reviewed literature was selected from Google Scholar, Scopus, Web of Science, and IEEE Xplore, using keywords such as AI in education, personalized learning, adaptive learning, AI-driven simulations, and AI in science teaching. The inclusion criteria comprised studies published in indexed journals within the last five years, research discussing AI-driven personalized learning, interactive simulations, AI-based assessment methods, and case studies analyzing real-world AI applications in high school classrooms. A content analysis method was applied to categorize findings into four main areas: applications of AI in science education, impact on student engagement and learning outcomes, challenges of AI integration—including accessibility and ethical concerns—and teacher training needs. A coding framework was developed, and thematic analysis was conducted to identify recurring trends and patterns. The findings were synthesized to highlight best practices, challenges, and strategies for effective AI implementation in science education. This approach ensures transparency and replicability, allowing future research to build upon these findings and further investigate the role of AI in enhancing high school science instruction.

The study looks into a number of questions about how to include artificial intelligence (AI) in high school science classes. The study leads us to ask the following important questions:

1. How can AI technologies enhance personalized learning in science education? The paper investigates the role of AI in providing adaptive feedback and personalized learning experiences that cater to individual student needs, thereby improving engagement and understanding of complex scientific concepts.
2. How does AI integration impact student engagement and learning outcomes? The research examines how AI tools, such as interactive simulations and real-time feedback systems, affect student engagement and learning outcomes, particularly in fostering critical thinking and problem-solving skills.
3. What challenges and opportunities are associated with implementing AI in educational settings? The paper addresses the potential benefits and challenges of AI integration, including issues of equity, access, and the need for comprehensive training and support systems for educators.
4. How can professional development programs support teachers in effectively using AI tools? The study explores the importance of professional development and training programs in equipping teachers with the skills necessary to integrate AI effectively into their teaching practices.
5. What collaborative frameworks can enhance the implementation of AI in science education? The paper considers the role of collaborative efforts among educators in sharing resources and best practices

to create more inclusive and effective learning environments.

These inferred research questions guide the investigation into how AI can transform science education, addressing both the potential benefits and the challenges of technological integration.

DEVELOPMENT

Benefits of ai in science education

Incorporating AI in science education presents substantial opportunities for enhancing student engagement and academic outcomes. Employing adaptive learning technologies enables educators to tailor lessons to meet the distinct needs of each student, fostering a personalized learning experience that promotes a deeper understanding and passion for science. For instance, platforms driven by artificial intelligence can evaluate student performance and provide instant feedback. They enable educators to identify areas of confusion and adjust their teaching strategies accordingly, ensuring that every student receives the essential support.[19] Moreover, the ability of AI to present complex scientific ideas through interactive simulations and visualizations can significantly improve comprehension and memory retention among learners, transforming abstract concepts into tangible experiences.[20] Considering the increasing importance of technology in education, it is essential to analyze how AI improves different learning styles and boosts motivation, cultivating a more inclusive environment where students are inspired to explore and ask questions.

The adaptability of AI tools enables the integration of multimedia resources, catering to various learning styles, which can help elucidate intricate scientific concepts.[21] Research shows that incorporating a variety of techniques—like music, pauses, and interactive resources—boosts cognitive growth in learners,[22] subsequently leading to better academic outcomes.[23] The thoughtful incorporation of AI in educational contexts enables educators to create stimulating learning atmospheres that prepare students for success and nurture a deep-seated interest in scientific inquiry and creativity.

Tailoring educational experiences to address the distinct needs of every student is crucial for improving engagement and comprehension, particularly in complex subjects like physics, where traditional teaching methods often fall short. AI technologies like ChatGPT enable personalized learning by providing adaptive feedback that addresses specific knowledge gaps and corresponds with students' learning preferences.[24] One study demonstrated that the integration of ChatGPT as a teaching assistant led to a notable enhancement in student engagement, facilitating interactive and inquiry-based learning that effectively supports the understanding of abstract concepts through practical applications and relatable examples.[25] This customized approach helps individuals tackle particular challenges associated with the topic and promotes a positive attitude towards learning and discovery.

The results demonstrated that when students received prompt feedback and clarifications, their analytical thinking skills were improved and developed, highlighting the significance of customized experiences in achieving deeper and more meaningful learning outcomes.[26] This customized method of learning holds significance that transcends simple academic success; it nurtures confidence and develops a mindset geared towards lifelong learning. The incorporation of AI into science education offers a remarkable chance to create customized learning experiences that cater to the unique requirements of each student, promoting active engagement in their educational process instead of just passively absorbing information.[27] By implementing these technologies, educators can significantly reshape the classroom environment, fostering inclusivity and adaptability to address the diverse needs of students.

The incorporation of interactive tools in science education significantly boosts student involvement, transforming traditional learning into dynamic and engaging experiences. The tools, particularly those driven by artificial intelligence, offer a unique opportunity to improve personalized learning that caters to the diverse needs and preferences of students, ensuring that each individual can thrive in their educational pursuits.[28] Analyzing mobile robotics in undergraduate courses illustrates the impact of hands-on sessions on enhancing comprehension and fostering active engagement among students, encouraging them to take ownership of their learning journey.[29] Similarly, the application of AI simulators, as discussed in the study of physics education, illustrates how platforms like ChatGPT can enhance curiosity and strengthen critical analytical thinking.[30]

Students involved in AI-supported demonstrations regularly show increased motivation and a deeper comprehension of complex concepts, underscoring the notion that authentic, interactive experiences boost the enjoyment, impact, and effectiveness of learning.[31] Furthermore, interactive tools facilitate collaboration and peer-to-peer learning, which enhances social interaction and strengthens the educational community. Considering these significant findings, the use of interactive tools is not just beneficial for enhancing student engagement; it is essential for creating a vibrant and effective learning atmosphere that actively engages students in the present while preparing them for future academic and career challenges.[32] The integration of these innovative technologies is enabling educators to create a transformative learning environment that fosters curiosity, enhances knowledge, and equips students to navigate the complexities of the 21st century.[33]

The incorporation of cutting-edge technologies, particularly artificial intelligence, into science education

holds significant promise for enhancing assessment and feedback mechanisms, ultimately fostering increased student engagement and achievement. Traditional assessment methods often fail to provide timely or customized feedback, hindering students' understanding and progress in their learning journey.[34] By concentrating on the incorporation of AI-powered systems, educators can deliver immediate insights into student performance, enabling a more tailored learning experience that meets each student's unique needs.[35]

Integrating natural game mechanics into educational frameworks can enhance student engagement with course content and accommodate the intricacies of individual learning speeds, as noted in Gordon et al., 2013.[36] This method improves the interactive nature of education and motivates learners to actively participate in their personal growth. Furthermore, as detailed in Cielniak et al., 2012,[29] the practical applications in mobile robotics enable students to engage in assessments that reflect real-world scenarios, thus increasing the relevance and enthusiasm of the learning experience. These practical experiences bridge theoretical knowledge with real-world skills, enhancing the learning process.[37] By applying these innovative strategies, educational institutions can improve the effectiveness of assessments and create a more adaptive and supportive environment for high school science education. In summary, the integration of advanced evaluation and feedback mechanisms cultivates a learning atmosphere that emphasizes individual growth and continuous improvement, equipping students with the essential tools to succeed in an ever-evolving context.

Challenges of implementing ai in high school science

A significant challenge in incorporating AI into high school science education is the disparity in resources, which can worsen the existing inequities in access to education. Numerous rural high schools encounter considerable disparities in funding, which greatly restricts their capacity to effectively integrate new technologies and stay aligned with advancements in educational practices.[38] Consequently, the adoption of AI could exacerbate the disparities between well-funded urban schools equipped with cutting-edge technologies and rural institutions that are facing challenges in fulfilling their fundamental educational requirements.[39] This gap influences the availability of cutting-edge resources and affects student involvement and passion for STEM fields, establishing a cycle of disadvantages that can be challenging to overcome.

Although AI can revolutionize personalized learning and data analysis within curriculum design, its successful implementation requires thorough training for educators and continuous support to improve teaching methodologies.[40] Educators frequently exhibit diverse degrees of technological expertise, leading to significant challenges in effectively integrating AI tools in the classroom setting. Without sufficient professional development opportunities designed for varying skill levels, educators might struggle to effectively implement AI, resulting in less-than-ideal learning outcomes and perpetuating negative views of inadequacy in resource-constrained settings.[41] Moreover, the swift advancement of technology can create a sense of overwhelm among educators, leading to uncertainty about which tools are most advantageous for their students.[42] Confronting these complex challenges is vital for effectively transitioning to AI-driven science education in high schools, as ensuring equitable access to training and resources is fundamental for cultivating an inclusive educational environment that serves all students.

Technical barriers and infrastructure requirements

The effective incorporation of AI into high school science education largely depends on addressing technical challenges and fulfilling necessary infrastructure needs. A significant number of educators express a strong interest in integrating technology into their classrooms; however, they frequently face obstacles like inadequate hardware and software resources that hinder their initiatives.[43] Recent studies reveal that positive perceptions of technology in education can be compromised by both technical and non-technical barriers educators encounter, highlighting a complex relationship between enthusiasm and systemic limitations.[44] This disparity underscores the critical necessity for robust infrastructure that can accommodate advanced AI tools designed to create personalized learning experiences that cater to the varied needs of students.

While there is potential for improved educational results via technology, particularly in tailored learning settings, there is a notable lack of evaluation studies, especially in regions such as Germany, where the practical effectiveness has not been comprehensively examined and understood.[45] The absence of thorough evaluation prompts questions regarding the realization of expected advantages of AI in educational environments and whether educators are equipped with sufficient training and resources to utilize these technologies effectively. Overcoming these technical challenges is essential to guarantee that AI can significantly enhance the high school science curriculum, while also promoting a setting that encourages collaborative learning and innovation.[46] As educational institutions strive to adopt technological advancements, it is essential that they also focus on establishing strong support systems. This includes providing continuous professional development for educators alongside ensuring sufficient access to essential technological resources.

Teacher training and professional development needs

An essential component in incorporating AI into science education is the necessity for thorough teacher training and ongoing professional development.[47] With the rise of innovative technologies in educational settings, educators must possess the necessary knowledge and skills to effectively leverage these tools. Present educational programs frequently fall short of providing adequate training materials, resulting in teachers being inadequately equipped.[48] Often, educators lack the essential knowledge required to effectively adopt these emerging technologies, leading to a gap that can negatively impact the learning environment. For example, at institutions such as X University, the notable transition from conventional College English courses to innovative programs like 'xue ke' English underscores the importance of flexible professional development, especially in relation to new methodologies like Project-Based Learning.[12]

In this context, offering educators chances for practical experience and collaboration with colleagues is essential for building their confidence in effectively utilizing AI tools. Therefore, continuous support and organized training workshops are essential to help educators grasp AI tools and their pedagogical implementation.[49] This involves cultivating the ability to assess the suitability of diverse AI applications for various educational goals. In conclusion, the absence of a strong framework for professional development could impede the integration of AI in science education, limiting its ability to improve educational results.[50] Consequently, educational institutions should focus on extensive training programs that adapt to the swiftly evolving technological environment in education.

Ethical considerations and data privacy concerns

When incorporating AI into high school science education, it is crucial to address ethical considerations and data privacy concerns, which are significant issues that must be considered.[51] AI technologies in educational settings prompt important inquiries about protecting personal information, underscoring the need for institutions to adopt robust strategies to safeguard student data while promoting fair access to educational resources.[52] With the emergence of new platforms that collect vast amounts of student data to develop customized learning experiences suited to specific needs, educational institutions must emphasize the importance of secure data management practices.[53] This proactive strategy is crucial for reducing the risks of possible privacy breaches, which may adversely affect students' well-being and confidence in the educational system.

Platforms like Box demonstrate strong ethical practices by fostering secure environments that improve data protection and encourage digital equity. This guarantees that every student, regardless of background, has fair and equitable access to essential educational resources.[54] Moreover, gaining a detailed insight into educators' views on the ethical ramifications of AI is essential for creating responsible curricula that adhere to modern ethical benchmarks. Studies indicate that the perspectives of educators regarding AI can greatly affect its efficacy and incorporation in the classroom, which in turn influences student learning results.[16] Therefore, thoroughly tackling these ethical considerations and data privacy issues is crucial for creating a secure, responsible, and inclusive educational environment that enables educators and learners to thrive in today's technological landscape.

The integration of artificial intelligence into the teaching of science

The incorporation of AI in high school science education shows considerable promise for improving teaching methods and student learning results in a transformative manner. A significant approach included using AI-driven platforms that enabled collaborative learning and customized instruction designed to address the varied needs of students.[55] These innovative systems tailored educational content to align with individual student preferences and learning styles while enhancing classroom engagement levels, a crucial factor for effective learning.[56] Moreover, a further study emphasized that with the backing of sophisticated AI tools, project-based learning approaches enabled educators to enhance their lesson plans and elevate classroom discussions, fostering a more vibrant and engaging learning atmosphere.[23] This method echoes the collaborative peer-support model college English instructors utilize as they navigate curriculum changes, illustrating how AI can improve the educational experience across various fields.[12]

A recent study of an AI-based adaptive learning Moodle plugin involving 102 Moroccan high school students highlighted its considerable effect on student engagement and academic performance when compared to traditional learning methods.[57] This study highlights the effectiveness of AI in promoting an active learning environment, emphasizing that carefully integrated AI not only improves instructional strategies but also significantly transforms science education. This approach fosters an environment that is attuned to the varied needs of learners, promoting the development of critical skills through teamwork and exploration. It encourages students to engage actively in their educational experiences, preparing them with the vital competencies to tackle future challenges. The continuous advancement of AI in education presents the potential to enhance and deepen the teaching environment in high school science classrooms.

Innovative educational strategies that utilize technology have achieved notable success in numerous high

schools throughout the United States.[58] One significant application includes incorporating mobile robotics into the science curriculum, which improves students' engagement and comprehension of intricate concepts. A study demonstrates that practical sessions with Rovio mobile robots enhanced students' hands-on skills and promoted a deeper understanding of robotics and computer vision principles.[59] Moreover, crowdfunding approaches in educational contexts have played a crucial role in funding initiatives that enhance student learning experiences. This method enables high schools to tap into various funding sources, facilitating the creation of programs that resonate with students' interests and practical applications in the real world.

Evidence suggests that incorporating Artificial Intelligence (AI) into the science curriculum can markedly improve student engagement and learning outcomes. Some educators acknowledge the promise of AI, even while confronting obstacles like insufficient training and technological infrastructure.[60] Integrating AI-driven tools and creative funding approaches highlights the necessity of flexibility in educational methods, equipping high schools to more effectively prepare students for upcoming scientific pursuits.[61]

The transition from conventional teaching approaches to AI-driven methodologies signifies a pivotal change in educational practices, especially within the realm of science education. Conventional methods frequently depend on uniform curricula and explicit teaching, neglecting varied student requirements and exacerbating achievement disparities, as noted in multiple educational contexts.[62] In this context, assessing teaching effectiveness in online platforms, as outlined in the Faculty Evaluation for Online Teaching study, highlights the necessity for valid and reliable tools that accurately reflect the complexities of faculty performance in AI-enhanced environments.[63]

The significance of this alignment lies in the fact that AI-enhanced teaching methods provide personalized learning experiences, leveraging data analytics to tailor content and pacing to the specific needs of each learner.[64] The flexibility provided by AI corresponds with the growing acknowledgment of the importance of tailored instruction in educational settings. Despite ongoing challenges in effectively implementing these technologies—such as the need for teacher training and resource allocation[65]—the potential advantages encompass enhanced student engagement and better academic results. As a result, the comparative analysis indicates that although traditional methods serve as a crucial foundation, AI-enhanced strategies present considerable potential for creating a more inclusive and effective learning environment in high school science education.

Outcomes for students in classrooms that integrate AI frequently demonstrate notable enhancements in both engagement and comprehension, highlighting the substantial influence that technology can exert on the educational landscape. Educators who adopted modules from the MIT Responsible AI for Computational Action curriculum observed significant changes in their teaching methods, resulting in increased student engagement and enthusiasm in a range of science subjects.[17] Incorporating AI technologies such as ChatGPT enhances this engagement by offering personalized feedback to students and promoting interactive learning experiences. This approach makes complex physics concepts more accessible and understandable for primary school students.[65] Incorporating AI has demonstrated advantages in creating a learning atmosphere that simplifies and comprehends intricate concepts. Educators have noted that these AI tools encourage critical analytical thinking and clarify complex scientific concepts, helping students sustain a positive outlook on their science education.[25] Nevertheless, insights from educators highlight the importance of continuous support and sufficient resources to fully leverage the capabilities of AI in educational settings.[2] The significance of ethical considerations in applying AI technologies is highlighted, along with the necessity for thorough professional development for educators, as essential elements that can greatly improve student outcomes. By focusing on these elements, educational institutions can develop more impactful learning spaces where artificial intelligence plays a crucial role in nurturing curiosity and a passion for science in young students.

DISCUSSION

Incorporating artificial intelligence into high school science education presents significant opportunities for improving learning outcomes and increasing student engagement. Utilizing AI technologies allows educators to develop interactive and personalized learning experiences that replicate the effectiveness of individualized instruction, similar to the Intelligent Computer-Aided Training systems suggested by NASA, which simulate the mentorship of expert trainers.[66] These systems enhance comprehension of intricate scientific ideas and foster a greater enthusiasm for the subject through hands-on applications. Moreover, initiatives that integrate robotics and computer vision, as noted in earlier research, show significant enhancements in student performance and engagement, confirming the positive effects of these tools.[29]

Although AI shows significant potential for enhancing science education, studies reveal that educators' comprehension and acceptance remain constrained by obstacles like insufficient training and inadequate technological infrastructure.[60] In conclusion, the careful incorporation of AI has the potential to connect conventional educational approaches with contemporary technological progress, equipping high school students to face future challenges in science and other fields.

The evolution of artificial intelligence offers exciting opportunities for improving student engagement

and comprehension in science education. Creating a curriculum that integrates AI tools can enhance critical thinking and problem-solving abilities, which are vital for future scientific exploration. A recent study emphasizes the significance of systematic methodologies in the integration of AI, particularly through a structured framework for computer vision education that advances from fundamental to complex concepts.[67] This framework demonstrates the potential for thorough AI integration while highlighting the importance of practical, experiential learning to enhance student comprehension of intricate subjects. Collaborative learning experiences hold significant importance; for example, peer support groups among educators can enhance the exchange of effective strategies for integrating AI in the classroom, as demonstrated in various educational settings.[12] This emphasis on collaboration could indicate a shift away from conventional teaching approaches, fostering a more dynamic learning atmosphere that effectively meets student needs.

As shown in industry practices, the ongoing adjustment and enhancement of instructional strategies will be essential to staying aligned with technological progress in AI.[68] The future of science education relies on acknowledging AI's capacity to revolutionize teaching methods and enhance the overall learning experience.

One significant advance in contemporary education is the incorporation of Project-Based Learning with cutting-edge technologies such as AI to improve teaching and learning results. Studies show that teamwork among educators can result in effective course modifications and enhanced teaching methods.[69] This initiative demonstrates the potential of collaborative frameworks to create effective learning environments through resource sharing and promoting professional development.

Assessing the effectiveness of professional development initiatives highlights the presence of various metrics, emphasizing the need for comprehensive evaluations to grasp their impact.[70] Integrating AI in education presents opportunities and challenges, especially in language teaching, highlighting the necessity for careful implementation to enhance creativity in learning environments.[71] The findings emphasize the promise of incorporating AI into science education, as it can boost engagement, encourage collaboration, and ultimately improve student learning outcomes in high school environments.

Educators and policymakers need to focus on developing thorough training and support systems to effectively utilize artificial intelligence's capabilities in high school science education. Initially, it is essential to implement professional development programs that will provide educators with the skills to effectively incorporate AI tools into their curricula. This training must cover the technical elements of utilizing AI and teaching strategies that boost student engagement and comprehension, ensuring educators have the confidence and skills necessary to implement these technologies effectively.

Policymakers need to allocate resources towards ensuring fair access to technology and equipping schools in disadvantaged regions with the required financial support, infrastructure, and training. Ensuring every school, irrespective of socioeconomic status, has access to AI-driven resources can help reduce the achievement gap frequently observed in education. Additionally, it is essential to implement continuous evaluation systems to measure the impact of these AI tools on enhancing scientific literacy and to generate data-driven insights that can guide future methodologies. The evaluations must prioritize student outcomes and engagement levels, offering essential feedback to educators and curriculum developers. Creating a collaborative environment that encourages educators to exchange best practices and outcomes, both locally and across state borders, will enable stakeholders to enhance their strategies more effectively. This partnership will result in stronger and more inclusive science education in high schools, guaranteeing that every student gains from technological progress and is equipped to face the challenges of an ever-evolving world.

CONCLUSIONS

This study examined the integration of Artificial Intelligence (AI) in high school science education, focusing on its potential to enhance personalized learning, improve student engagement, and transform teaching methodologies. The findings indicate that AI-driven tools, such as adaptive learning systems and interactive simulations, can effectively support differentiated instruction and foster critical thinking. However, challenges related to accessibility, teacher training, and ethical considerations must be addressed to ensure equitable implementation. To maximize AI's benefits, it is essential to develop comprehensive teacher training programs, establish clear policies for ethical AI use, and invest in infrastructure to support AI-driven learning environments. By addressing these challenges, AI can become a powerful tool for improving science education and preparing students for a technology-driven future. As educational institutions embrace these innovations, collaboration among educators, technologists, and policymakers will be crucial to creating a sustainable framework that promotes continuous improvement and adapts to the evolving needs of students. This collaborative approach will enhance AI's effectiveness in education and foster an inclusive environment where diverse perspectives are valued and integrated into the learning process. Building on this foundation, ongoing research and feedback from all stakeholders will be essential to refine AI applications in education, ensuring they meet the diverse needs of learners while maintaining ethical standards.

REFERENCES

1. Noble R, Noble D. Artificial Intelligence. In: Understanding Living Systems. Cambridge: Cambridge University Press; 2023. p. 99–112.

2. Abdulmunem RA. Artificial Intelligence in Education. In: Khlaif Z, Sanmugam M, Itmazi J, editors. Comparative Research on Diversity in Virtual Learning: Eastern vs. Western Perspectives. IGI Global Scientific Publishing; 2023. p. 241–55. https://doi.org/10.4018/978-1-6684-3595-3.ch012

3. Mohammad SS, Saheal H. A Sneak Peek into the Future of Artificial Intelligence in Education: Opportunities and Challenges. In: Digital Transformation in Education: Emerging Markets and Opportunities. 2023. p. 207–19. https://doi.org/10.2174/9789815124750123010016

4. Cruz-Benito J. AI in Education. MDPI Books; 2022. https://doi.org/10.3390/books978-3-0365-4342-0

5. Miranda E, Troisi A. Research Report - October 2009. Elaboration of the Module: Definition of the Programme. EU Commission; 2009. https://eprints.bournemouth.ac.uk/21607/

6. Cheng X. The Widespread Application of Artificial Intelligence in Education Necessitates Critical Analyses. Sci Insights Educ Front. 2023;16(2):2475–6. https://doi.org/10.15354/sief.23.co081

7. Kalid KS, Ahmad WFW, Amar MSS, Sulisworo D, Fitrianawati M, Subrata AC. A Proposed Implementation of Internet of Things as a Teaching Aid for Learning Science Collaboratively. In: 2022 Applied Informatics International Conference (AiIC). IEEE; 2022. p. 131–6. https://doi.org/10.1109/AiIC54368.2022.9914591

8. Kotsis KT. Integration of Artificial Intelligence in Science Teaching in Primary Education: Applications for Teachers. Eur J Contemp Educ E-Learn. 2024;2(3):27–43. https://doi.org/10.59324/ejceel.2024.2(3).04

9. Kotsis KT. Artificial Intelligence Creates Fairy Tales for Physics Teaching in Primary Education. Eur J Open Educ E-Learn Stud. 2024;9(1):1–16. http://dx.doi.org/10.46827/ejoe.v9i1.5250

10. Kotsis KT. Artificial Intelligence Helps Primary School Teachers to Plan and Execute Physics Classroom Experiments. J Eff Teach Methods. 2024;2(2):1–9. https://doi.org/10.59652/jetm.v2i2.158

11. Haatainen O, Aksela M. Project-based learning in integrated science education: Active teachers' perceptions and practices. LUMAT: Int J Math Sci Technol Educ. 2021;9(1):149–73. https://doi.org/10.31129/LUMAT.9.1.1392

12. Wang Y, Wang J, Wang L. Trialing project-based learning in a new EAP ESP course: A collaborative, reflective practice of three college English teachers. 2019;78. https://core.ac.uk/download/287723764.pdf

13. Alrajeh TS. Project-based learning to enhance pre-service teachers' teaching skills in science education. Univ J Educ Res. 2021;9(2):271–9. https://doi.org/10.13189/UJER.2021.09020

14. Petrescu AA, Gorghiu LM, Gorghiu G, Bîzoi M. New Trends In Teaching Sciences: A Case Study From The Engage Project. In: Chis V, Albulescu I, editors. Education, Reflection, Development – ERD 2017, vol 41. European Proceedings of Social and Behavioural Sciences. Future Academy; 2018. p. 612–8. https://doi.org/10.15405/epsbs.2018.06.72

15. Harry A, Sayudin S. Role of AI in education. Interdiscip J Humanit. 2023;2(3):260–8. https://doi.org/10.58631/injurity.v2i3.52

16. Zhou C. Teacher's Perceptions of Applying Artificial Intelligence in Education: A Systematic Review. World J Soc Sci Res. 2024;11(3):62–72. https://core.ac.uk/download/616936753.pdf

17. Ravi P, Broski A, Stump G, Abelson H, Klopfer E, Breazeal C. Understanding Teacher Perspectives and Experiences after Deployment of AI Literacy Curriculum in Middle-school Classrooms. ArXiv. 2023. preprint arXiv:2312.04839. https://doi.org/10.21125/iceri.2023.1716

18. Tan S. Harnessing Artificial Intelligence for Innovation in Education. In: Learning Intelligence: Innovative

and Digital Transformative Learning Strategies. Springer, Singapore; 2023. https://doi.org/10.1007/978-981-19-9201-8_8

19. Grace EG, Vidhyavathi P, Malathi P. A study on "AI in education: opportunities and challenges for personalized learning. Ind Eng J. 2023;52(05):750–9. https://doi.org/10.36893/iej.2023.v52i05.750-759

20. Tiwari R. The integration of AI and machine learning in education and its potential to personalize and improve student learning experiences. Int J Sci Res Eng Manag. 2023;7(2):1–11. https://doi.org/10.55041/ijsrem17645

21. Ashwini N, Kumar N, Nandan M, Suman V. Leveraging Artificial Intelligence in Education: Transforming the Learning Landscape. Int Res J Comput Sci. 2023;10(05):192–6. https://doi.org/10.26562/irjcs.2023.v1005.16

22. Nazaretsky T, Bar C, Walter M, Alexandron G. Empowering teachers with AI: Co-designing a learning analytics tool for personalized instruction in the science classroom. LAK22: 12th International Learning Analytics and Knowledge Conference; 2022. p. 1–12. https://doi.org/10.1145/3506860.3506861

23. Alam A, Hasan M, Raza MM. Impact of artificial intelligence (AI) on education: changing paradigms and approaches. Towards Excell. 2022;14(1):281–9. https://doi.org/10.37867/te140127

24. Santos RP. Enhancing Physics Learning with ChatGPT, Bing Chat, and Bard as Agents-to-Think-With: A Comparative Case Study. Soc Sci Res Netw. 2023;ssrn-4478305. https://doi.org/10.2139/ssrn.4478305

25. Kotsis KT. ChatGPT in Teaching Physics Hands-On Experiments in Primary School. Eur J Educ Stud. 2024;11(10):126–43. http://dx.doi.org/10.46827/ejes.v11i10.5549

26. Kotsis KT. ChatGPT as Teacher Assistant for Physics Teaching. J Eff Teach Methods. 2024;2(4):18–27. https://doi.org/10.59652/jetm.v2i4.283

27. Davies JN, Verovko M, Verovko O, Solomakha I. Personalization of e-learning process using AI-powered chatbot integration. In: Shkarlet S, Morozov A, Palagin A, editors. Mathematical Modeling and Simulation of Systems (MODS'2020). Vol. 1265. Springer, Cham; 2021. p. 209–16. https://doi.org/10.1007/978-3-030-58124-4_20

28. Girdzijauskienė R, Norvilienė A, Šmitienė G, Rupšienė L. Strengthening Student Engagement in Learning Through Use of Digital Tools. Acta Paedagogica Vilnensia. 2022; 49:115–30. https://doi.org/10.15388/ActPaed.2022.49.8

29. Cielniak G, Bellotto N, Duckett T. Integrating mobile robotics and vision with undergraduate computer science. IEEE Trans Educ. 2012;56(1):48–53. Retrieved from https://core.ac.uk/download/9052390.pdf

30. Vasconcelos MAR, Santos RP. Enhancing STEM learning with ChatGPT and Bing Chat as objects to think with: A case study. Eurasia J Math Sci Technol Educ. 2023;19(7):em2296 . https://doi.org/10.29333/ejmste/13313

31. Lampropoulos G. Augmented Reality and Artificial Intelligence in Education: Toward Immersive Intelligent Tutoring Systems. In: Geroimenko V, editor. Augmented Reality and Artificial Intelligence. Springer Series on Cultural Computing. Springer, Cham; 2023. https://doi.org/10.1007/978-3-031-27166-3_8

32. Ullah A, Anwar S. The Effective Use of Information Technology and Interactive Activities to Improve Learner Engagement. Educ Sci. 2020;10(12):349. https://doi.org/10.3390/educsci10120349

33. Sayfullayeva DA, Tosheva NM, Nematova LH, Zokirova DN, Inoyatov IS. Methodology of using innovative technologies in technical institutions. Ann Rom Soc Cell Biol. 2021;7505–22. https://doi.org/10.17762/PAE.V58I1.2136

34. Caspari-Sadeghi S. Artificial Intelligence in Technology-Enhanced Assessment: A Survey of Machine Learning. J Educ Technol Syst. 2023;51(3):372–86. https://doi.org/10.1177/00472395221138791

35. Anuyahong B, Rattanapong C, Patcha I. Analyzing the Impact of Artificial Intelligence in Personalized

Learning and Adaptive Assessment in Higher Education. Int J Res Sci Innov. 2023;10(4):88–93. https://doi.org/10.51244/ijrsi.2023.10412

36. Gordon N, Brayshaw M, Grey S. Maximising Gain for Minimal Pain: Utilising Natural Game Mechanics. Innov Teach Learn Inf Comput Sci. 2013;12(1):27–38. https://doi.org/10.11120/ital.2013.00004

37. Hooda M, Rana C, Dahiya O, Rizwan A, Hossain MS. Artificial Intelligence for Assessment and Feedback to Enhance Student Success in Higher Education. Math Probl Eng. 2022;2022(1):5215722. https://doi.org/10.1155/2022/5215722

38. Jiang S, Nocera A, Tatar C, Yoder MM, Chao J, Wiedemann K, et al. An empirical analysis of high school students' practices of modelling with unstructured data. Br J Educ Technol. 2022;53(5):1114–33. https://doi.org/10.1111/bjet.13253

39. Lee I, Perret B. Preparing High School Teachers to Integrate AI Methods into STEM Classrooms. Proc AAAI Conf Artif Intell. 2022;36(11):12783–91. https://doi.org/10.1609/aaai.v36i11.21557

40. Ritter S, Koedinger KR. Large-scale commercialization of AI in school-based environments. In: du Boulay B, Mitrovic A, Yacef K, editors. Handbook of Artificial Intelligence in Education. Edward Elgar Publishing; 2023. p. 524–36. https://doi.org/10.4337/9781800375413.00035

41. Sukmayadi D. Empowering STEM Education: Navigating Challenges and Embracing Innovations. Int J Res STEM Educ. 2023;5(2):104–12. https://doi.org/10.33830/ijrse.v5i2.1630

42. Flogie A, Krabonja MV. Artificial intelligence in education: Developing competencies and supporting teachers in implementing AI in school learning environments. In: 2023 12th Mediterranean Conference on Embedded Computing (MECO). IEEE; 2023. p. 1–6. https://doi.org/10.1109/meco58584.2023.10155054

43. Liu Y, Baucham M. AI Technology: Key to Successful Assessment. In: Meletiadou E, editor. Handbook of Research on Redesigning Teaching, Learning, and Assessment in the Digital Era. IGI Global Scientific Publishing; 2023. p. 304–25. https://doi.org/10.4018/978-1-6684-8292-6.ch016

44. Haidir H, Muhamad T, Roviati R, Evi E, Deka D. Penerapan Penerapan Chat GPT dalam Pembelajaran Biologi: Penerapan Chat GPT dalam Pendidikan. Jurnal sostech [Internet]. 2024Mar.28;4(3):182-9. https://doi.org/10.59188/jurnalsostech.v4i3.1064

45. Holmes W, Anastopoulou S, Schaumburg H, Mavrikis M. Technology-enhanced personalised learning: Untangling the evidence. Robert Bosch Stiftung GmbH; 2018. https://oro.open.ac.uk/56692/

46. Xu L. The dilemma and countermeasures of AI in educational application. In: Proceedings of the 2020 4th International Conference on Computer Science and Artificial Intelligence. 2021. p. 289–94. https://doi.org/10.1145/3445815.3445863

47. Al-Zyoud HMM. The role of artificial intelligence in teacher professional development. Univ J Educ Res. 2020;8(11B):6263–72. https://doi.org/10.13189/UJER.2020.082265

48. Guo X, Liu X. A Study of Strategies to Improve the Quality of Teacher Trainees from Teacher Training The Example of the Teacher Training Program at Liaoning Normal University. Learn Educ. 2022;10(5):189–90. https://doi.org/10.18282/l-e.v10i5.2732

49. Ng DTK, Leung JKL, Su J, Ng R, Chu SKW. Teachers' AI digital competencies and twenty-first century skills in the post-pandemic world. Educ Technol Res Dev. 2023; 71:137–61. https://doi.org/10.1007/s11423-023-10203-6

50. Chan CK, Tsi LH. The AI revolution in education: Will AI replace or assist teachers in higher education? arXiv preprint arXiv:2305.01185. 2023. https://doi.org/10.48550/arXiv.2305.01185

51. Holmes W, Porayska-Pomsta K, Holstein K, Sutherland E, Baker T, Shum SB, et al. Ethics of AI in education: Towards a community-wide framework. Int J Artif Intell Educ. 2022;1–23:504–26. https://doi.org/10.1007/

S40593-021-00239-1

52. Akgun S, Greenhow C. Artificial intelligence in education: Addressing ethical challenges in K-12 settings. AI Ethics. 2022;2:431–40. https://doi.org/10.1007/s43681-021-00096-7

53. Huang L. Ethics of Artificial Intelligence in Education: Student Privacy and Data Protection. Sci Insights Educ Front. 2023;16(2):2577–87. https://doi.org/10.15354/sief.23.re202

54. Rode V. FUTURE-READY DIGITALIZED EDUCATION: UNRAVELING THE DYNAMICS OF SUSTAINABLE AND ETHICAL DIGITAL TRANSFORMATION. CSUSB ScholarWorks. Electronic Theses, Projects, and Dissertations. 1999; 2024. https://scholarworks.lib.csusb.edu/etd/1999

55. Alonso JM. Teaching explainable artificial intelligence to high school students. Int J Comput Intell Syst. 2020;13(1):974–87. https://doi.org/10.2991/IJCIS.D.200715.003

56. Awad SOI, Mohamed Y, Shaheen R. Applications of Artificial Intelligence in Education. Al-Azkiyaa - Int J Lang Educ. 2022;1(1):71–81. https://doi.org/10.33102/alazkiyaa.v1i1.10

57. Ezzaim A, Dahbi A, Haidine A, Aqqal A. The Impact of Implementing a Moodle Plug-in as an AI-based Adaptive Learning Solution on Learning Effectiveness: Case of Morocco. Int J Interact Mob Technol. 2024;18(01):133–49. https://doi.org/10.3991/ijim.v18i01.46309

58. Fikriyah A, Kassymova GK, Nurbaiti N, Retnawati H. Use of technology in high school: A systematic review. Challenges Sci Issue V. 2022;109–14. https://doi.org/10.31643/2022.14

59. Galynska OM, Shkoliar NV, Dziubata ZI, Kravets SV, Levchyk NS. Innovative Teaching Technologies as a Way to Increase Students' Competitiveness. Int J Educ. 2021;15:215–26. https://doi.org/10.46300/9109.2021.15.22

60. Nugroho OF, Hikmawaty L, Juwita SR. Artificial Intelligence Technology Embedded in High School Science Learning: A Study of Teacher Perception. Pedagonal: J Ilm Pendidik. 2024;8(2):132–43. https://doi.org/10.55215/pedagonal.v8i2.16

61. Rubinton BJ. Crowdfunding: disintermediated investment banking. SSRN; 2011. https://mpra.ub.uni-muenchen.de/31649/

62. du Boulay B, Poulovasillis A, Holmes W, Mavrikis M. Artificial Intelligence And Big Data Technologies To Close The Achievement Gap. In: Luckin R, editor. Enhancing Learning and Teaching with Technology. UCL Institute of Education Press; 2018. p. 256–85. https://oro.open.ac.uk/53020/

63. Soriano G. Development and Psychometric Evaluation of Faculty Evaluation for Online Teaching (FEOT). Bedan Res J. 2021;6(1):220–39. https://doi.org/10.58870/berj.v6i1.28

64. Huang J, Saleh S, Liu Y. A Review on Artificial Intelligence in Education. Acad J Interdiscip Stud. 2021;10(3):206–17. https://doi.org/10.36941/AJIS-2021-0077

65. Lin R, Zhang Q, Xi L, Chu J. Exploring the Effectiveness and Moderators of Artificial Intelligence in the Classroom: A Meta-Analysis. In: Yang J, et al., editors. Resilience and Future of Smart Learning. ICSLE 2022. Lecture Notes in Educational Technology. Springer, Singapore; 2022. https://doi.org/10.1007/978-981-19-5967-7_7

66. Loftin RB, Savely RT. Intelligent computer-aided training and tutoring. NASA, Washington, Technology 2000, Volume 2; 1991. https://ntrs.nasa.gov/citations/19910014729

67. Jeon I, Kang SJ, Kang S. A Staged Framework for Computer Vision Education: Integrating AI, Data Science, and Computational Thinking. Appl Sci. 2023;14(21):9792. https://doi.org/10.3390/app14219792

68. Mena-Guacas AF, Urueña Rodríguez JA, Santana Trujillo DM, Gómez-Galán J, López-Meneses E. Collaborative learning and skill development for educational growth of artificial intelligence: A systematic review. Contemp Educ Technol. 2023;15(3):ep428 . https://doi.org/10.30935/cedtech/13123

69. Mujiono M. Educational Collaboration: Teachers and Artificial Intelligence. J Kependidikan: J Has Penelit Kajian Kepustakaan Bidang Pendidik Pengajaran Pembelajaran. 2023;9(2):618–32. https://doi.org/10.33394/jk.v9i2.7801

70. Merchie E, Tuytens M, Devos G, Vanderlinde R. Evaluating teachers' professional development initiatives: Towards an extended evaluative framework. Res Pap Educ. 2016;33(2):143–68. https://doi.org/10.1080/02671522.2016.1271003

71. Akyıldız ST. Enhancing or Hindering? AI's Role in Sparking Creativity in Language Teaching: Insights from Private High School EFL Teachers. Int e-J Educ Stud. 2024;8(18):234–54. https://doi.org/10.31458/iejes.1502509

FINANCING

The author did not receive financing for the development of this research.

CONFLICT OF INTEREST

The author declares that there is no conflict of interest.

AUTHORSHIP CONTRIBUTION

Conceptualization: Konstantinos T. Kotsis.
Research: Konstantinos T. Kotsis.
Methodology: Konstantinos T. Kotsis.
Resources: Konstantinos T. Kotsis.
Drafting - original draft: Konstantinos T. Kotsis.
Writing - proofreading and editing: Konstantinos T. Kotsis.