Investigates the impact of integrating Artificial Intelligence (AI) in teaching biology at the secondary level in Islamabad

Naeem Akhtar
PhD Scholar, MY University, Islamabad & Assistant Professor, IMCB, F-8/4 Islamabad.
Email: naeemakht3377@gmail.com

Tahir Mehmood
PhD Scholar, MY University, Islamabad & Deputy Registrar, SZABMU, Islamabad.
Email: tahirkohli125@gmail.com

Anas Ilahi
PhD Scholar, MY University, Islamabad.
Email: dennys.elahi9@gmail.com

Received on: 25 -07-2024 Accepted on: 26- 08 -2024

Abstract

Several aspects of the educational system, including teaching methods, evaluation techniques, and administrative procedures, are changing because of the application of artificial intelligence (AI). Additionally, it actively contributes to the advancement of science education. The goal of this systematic review is to provide a fundamental understanding of the empirically supported relationship between science education and artificial intelligence. This study provides a comprehensive examination of how AI affects learning results for students, adoption scenarios, views of AI by students and teachers, and the difficulties associated with its application in science education. The study intends to investigate how AI-powered resources might improve biology students' performance, comprehension, and engagement. With an experimental group employing AI-assisted learning modules and a control group receiving conventional teaching, a quasi-experimental design was used. Questionnaires, student interviews, and pre- and post-tests were used to gather data. According to the research, integrating AI might greatly enhance student learning results, especially when it comes to conceptual knowledge and problem-solving abilities. For widespread adoption, however, issues like teacher preparation and technological availability must be resolved.

Keywords: AI · Artificial intelligence, Science learning, Engineering students, Science education, STEM learning

Investigates the impact of integrating Artificial Intelligence (AI) in teaching biology at the secondary level in Islamabad

Introduction

AI's introduction has transformed several industries, including education. The use of AI to improve educational experiences has gained popularity in recent years, especially in science courses like biology. AI-powered solutions have the potential to build dynamic learning environments, give real-time feedback, and customize training. The purpose of this project is to find out how well AI can be incorporated into secondary biology instruction.

Many technologies have been developed during the last half-century that allow machines to see, reason, learn, and interact—tasks that normally require human intelligence. In the context of education, these technologies are typically referred to as artificial intelligence. Bialik, M., Holmes, W., and Fadel, C. (2023).

However, recent advancements in generative AI (GenAI), particularly models like ChatGPT, have drawn unprecedented attention to the revolutionary potential of AI across a number of industries (Hong et al., 2022; Lucci et al., 2022). Unlike predictive (pre-generative) AI, which emphasises on predictions and decision making using a variety of machine learning and modelling techniques, generative AI uses deep learning models to create new content, such as text, images, and codes (Dai, 2023; Tang & Nichols, 2024). This distinction is essential to understanding the variety of ways AI is being used in education. The fast growing multidisciplinary subject of artificial intelligence in education (AIEd) employs AI technology to enhance and modernise learning environments.

There is a special upsurge in interest in using AI to teach and study science, even as interest in how AI affects general education is growing (Chiu et al., 2023; Gonzalez et al., 2017). More precisely, scientific models utilised in education have been automatically assessed using machine learning, a form of artificial intelligence technology. Zhai et al. (2022) gathered task responses from students and then assessed the models' quality using machine learning techniques.According to their research, scientific education can gain from the use of artificial intelligence to provide students with comprehensive, timely feedback on their work and automate evaluation procedures (Zhai, C. Haudek, Zhai et al., 2020a, b, 2022). Popenici and Kerr (2017) also looked into the effects of AI on the teaching-learning process in higher education.

Their research concentrated on how intelligent technologies affected both traditional teaching methods and student learning. Their study offers helpful information about integrating AI into scientific classrooms.In their thorough evaluation of AI applications in higher education, Zawacki-Richter et al. (2019) emphasised the critical role that educators may play in this area. Their findings show how crucial it is to consider and comprehend the needs and viewpoints of educators when incorporating these technologies into teaching-learning environments. Furthermore, Tang, K. S., & Cooper, G. (2024) to locate and gather research papers and classify the roles of artificial intelligence in education. the significance of materiality in the generative age of science, education, and artificial intelligence, and used a methodical literature review approach to the learning process.

According to their research, there are three ways that artificial intelligence (AI) should be used in the classroom: (1) as a brand-new subject; (2) as an instant mediator; and (3) as an extra tool to influence how students engage with their teachers and with themselves.

Investigates the impact of integrating Artificial Intelligence (AI) in teaching biology at the secondary level in Islamabad

Lecture Review

An Overview of Science Instruction:

In addition to imparting scientific knowledge, science education aims to create a population that is scientifically literate and capable of using scientific reasoning and decision-making (Almasri, 2021; Grinnell, 2021). By highlighting the importance of science education for all children, not just those who wish to pursue careers in science, this supports the "Science for All" initiative (Almasri et al., 2022; Mansour, 2009). Science education teaches and learns scientific theories, methodologies, and experiments to help students build their scientific literacy and critical thinking skills (Alharbi et al., 2022; Liu & Pásztor, 2022; Mogea, 2022; Zulyusri et al., 2023).

In addition to content-based instruction, science education also includes student-centered activities and the development of scientific literacy for citizenship (Almasri et al., 2021; Irez, 2006a, b; Kolstø, 2001). Strong scientific contributions are essential to national development since they promote economic progress and enhance a nation's overall development (Hewapathirana & Almasri, 2022; Kola, 2013).

The "Call to Action" for scientific education emphasises how important it is to improve teaching methods and match them with the needs of the twenty-first century (Holme, 2021; Ibáñez & Delgado-Kloos, 2018). It is crucial for fostering children's curiosity, expanding their basic knowledge, and preparing them for STEM vocations that satisfy the needs of the modern workforce. Artificial intelligence (AI) can be utilised to make science education more engaging, useful, and relevant for students of all ages and backgrounds by focussing on experiential learning.

AI Tools and Methods for Teaching Biology:

Over the past few years, there have been significant breakthroughs and revolutionary changes in intelligent systems that have led to the creation, preservation, and analysis of data in a wide range of non-technological sectors. Over the past 50 years, there has been a considerable advancement in both biology and AI technology. With the help of sequencing and other high-throughput techniques, the biosciences and biotech industries achieved impressive progress in drug discovery. Additionally, in biological education, learning outcomes were taught and evaluated in a variety of learning contexts using AI-based tools and applications. Data on the prevalence of common and biological concepts were obtained from the assessment of biology education study. Additionally, it was found that students' conceptions were reliant on the contextual framework employed.

The assessment instruments looked at everyday and biological notions, including those outlined in biology education [undefined]. Students' biological and everyday ideas were evaluated using three tools: the Conceptual Inventory of Natural Selection (CINS) [undefined], Assessing Contextual Reasoning about Natural Selection (ACORNS) [undefined], and Evo Grader [undefined]. When the CINS was created, it used open-ended questions to gather data about common ideas to support constructivist and socio constructivist learning. By adding open response styles, the ACORNS tool addressed the critique of forced choice. Evo Grader offered a simplified classification of students' answers together with visual representations of the percentages of biological and common conceptions and their co-occurrences study employing dried plants in a botany lab, a research team [undefined] used the Siette method

to assess learning effects. This approach made it easier to comprehend the function of assessments, and many aspects and methods of assessment were investigated and included into the Siette setting. Using a corpus of evolutionary theories from 565 undergraduate biology students, another study team evaluated the effectiveness of an automated evaluation tool called Summarisation Integrated Development Environment (SIDE). The results demonstrated that SIDE outperformed human expert scoring when scoring models were created and evaluated at the individual item level; however, SIDE's performance decreased when scoring models were generated and tested using suites of items or full instruments.

Researchers compared the effects of regular and AI-enabled e-books on students' learning of biology in a quasi-experiment and discovered no discernible differences in the learning outcomes of the two book kinds. A different study, [undefined], showed how useful it is to use AI and tactile tools to help blind and VI people learn biology. Machine learning is another popular method in biology instruction. Machine learning (ML), a subfield of artificial intelligence, is concerned with developing computer algorithms that are able to learn from their errors and perform better. Bertolini and colleagues [undefined] assessed the predictive efficacy of predictive modelling in terms of undergraduate biology learning outcomes using five machine learning techniques.

Medical education is a crucial field for AI-based learning and teaching. Early attempts were concentrated on developing three-dimensional interactive anatomy teaching platforms using computer-based technology. With the use of these platforms, students were able to explore anatomical structures and see them from various perspectives. Netters Interactive 3D anatomy and the Primal Pictures website were two examples of such goods. Two varieties of AI deep machine tools that are based on neural networks seen in the human brain are ANN and Convoluted Neural Networks (CNN). As a result, artificial intelligence (AI) technology has several advantages for medical education, including acting as a kind instructor, facilitating self-paced learning, lowering the need for human intervention, facilitating remote operation, offering affordable solutions, and more.

AI in medical education has garnered a lot of attention in recent years, as evidenced by the increasing number of papers and citations. AI was applied to curriculum development, analysis, learning, and evaluation in every facet of medical education. To test students' logical and in-depth learning and knowledge application in a clinical setting, for example, interactive teaching systems such as Anatomy Chatbots, formative assessment tools, or clinical application quizzes were modified and programmed into the deep learning AI framework. The creation of intelligent computer systems with complex decision-making abilities was made possible by AI algorithms' capacity to store and process vast amounts of unstructured, raw data. The precise identification of the three-dimensional geometry of biological molecules is just one example of the many AI applications utilised in biology education.

To raise the bar for biological education and help students improve their conceptual grasp of biology, these techniques must be used with extreme caution and close examination while analyzing biological data.

Opportunities for Including AI in Science Education:

The potential for incorporating AI technology into science teaching is encouraging, despite the obstacles that must be overcome given its ongoing growth and growing popularity. AI has

the power to fundamentally alter how science is taught and learnt. The power of AI to replicate scientific research and give science students virtual laboratory experiences is one of its most alluring uses in science education. According to Wahyono et al. (2019), this guarantees that students can hone their scientific abilities in a secure and regulated setting, perhaps saving money and providing fresh chances to investigate scientific ideas that would not be possible in conventional laboratory settings. The tactile and hands-on elements of real-world interaction, which are crucial for certain learning styles, can be absent from these virtual encounters with the real world (Tang & Cooper, 2024).

Instead of relying on conventional, one-size-fits-all teaching strategies, educators may use AI to provide students with personalised and interesting learning experiences. In addition to providing recommendations and assessments, In order to produce highly customised learning experiences, AI-powered algorithms can do in-depth analyses of students' learning habits (Zhai et al., 2021; Zhai et al., 2020a, b). However, the quality and representativeness of the data used to train these individualised learning systems determines their efficacy, which can occasionally introduce biases and reinforce preexisting injustices.

Additionally, students can rectify any misconceptions or gaps in their understanding of scientific subjects by utilising adaptive learning pathways and fast feedback (Mavroudi et al., 2018). Additionally, scientific educators can use AI to better track and monitor their students' progress, enabling them to provide support and customised interventions as needed. By enabling the creation of immersive and interactive learning environments, artificial intelligence (AI) can also improve science education and make it more accessible to students with a range of learning needs and styles. There will probably be more chances to incorporate AI into science education as the technology develops, providing students of all skill levels with new chances to improve and revolutionise their science education.

Expected Advantages of Using AI in Science Education:

Artificial intelligence (AI), which has many benefits for science education, has a big impact on how science courses are taught and learnt. Systems that use artificial intelligence (AI) may evaluate how students learn and modify the material to fit the individual requirements, skills, and learning preferences of each student. When educational materials are produced in this way, students learn more efficiently and rapidly. It enables them to proceed according to their own learning preferences and at their own speed (Zawacki-Richter et al., 2019). Furthermore, science instructors can employ AI-powered data analysis to determine where their students may need more assistance and how well they are performing in particular scientific domains. The enhancement of exploratory learning via virtual labs and reenactments is another noteworthy benefit.AI-powered tools could recreate complex logical examinations that might be risky or absurd to deliver in a typical classroom context. Students' understanding of scientific concepts is improved by these virtual environments, which offer chances for experiential learning and let them encounter various scenarios (Ibáñez et al., 2018). This approach was less effective in increasing understudy involvement but was too advantageous to democratise access to excellent science instruction. By bringing students and teachers together from different places, artificial intelligence (AI) tools can promote a global perspective on logical issues and the interchange of logical ideas.

Many datasets can be incorporated into the learning modules because to this

interconnectedness, which also reveals understudied logical difficulties and real-world datasets (Holmes et al., 2023).

AI Integration in Education: Ethical Issues:

Despite the promising future of artificial intelligence (AI) in education, there are significant ethical concerns that must be addressed before implementing AI in the classroom. Several scholars have drawn attention to the ethical issues of the AI era and character education (Burton et al., 2017; Cathrin & Wikandaru, 2023). The necessity for a thorough ethical framework is highlighted by the lack of critical thinking about the dangers of implementing AI applications in higher education as well as the pedagogical and ethical ramifications (Bozkurt et al., 2021).

Reevaluating ethical frameworks and responsibilities is also required because the use of AI in educational settings places new ethical obligations on instructors (Adams et al., 2022). Furthermore, integrating ethical concepts and producing responsible AI can be facilitated by enhancing the competency of AI development actors and including ethics courses into academic training (Kiemde & Kora, 2022). Beyond technological issues, the ethical ramifications of AI in education also include wider societal effects including social fairness and privacy protection (Hermansyah et al., 2023).

The ethical ramifications of AI in education extend beyond technological issues to include wider societal effects including social fairness and privacy protection (Hermansyah et al., 2023).

Objectives:

1. To investigate the impact of AI-assisted learning on student achievement in Biology.
2. To explore the effects of AI on student engagement and motivation in Biology.
3. To identify the challenges and opportunities associated with integrating AI into biology education.

Statement of the Problem

Challenges in Traditional Teaching:

- Limited student engagement and understanding of abstract biology concepts.
- Lack of tools for immediate feedback and personalized learning.

Need for AI Integration:

- To modernize the education system.
- To explore whether AI tools improve teaching outcomes and student performance.

Research Question:

1. What is the impact of AI integration on biology teaching and learning outcomes at the secondary level in Islamabad?

Significance of the Study:

1. **For Students**:
   - Improved engagement through interactive AI tools.
   - Enhanced understanding of complex biological concepts using visualizations

and simulations.

2. **For Teachers**:
   - Greater teaching efficiency through AI-based lesson planning and grading tools.
   - Access to data-driven insights about students' progress.
3. **For Administrators**:
   - Insights into the benefits of AI to inform policy and infrastructure investments.
4. **For Future Research**:
   - Provides a foundation for further studies on AI's role in education in other subjects and regions.

This systematic review addresses the following research questions:
(1) Effect on Learning Outcomes: What effects do AI technologies have on students' participation in scientific classes and learning outcomes?
(2) AI Adoption Contexts: Considering variations across nations, educational levels, and topic areas, what are the possible discrepancies in the adoption of AI tools in science education?
(3) Perceptions of Teachers and Students: How do teachers and students feel about the employment of AI tools in science education?

Research Questions:

1. How does AI-assisted learning impact student achievement in biology compared to traditional instruction?
2. How does AI affect student engagement and motivation in biology?
3. What are the challenges and opportunities associated with integrating AI into biology education?

Methodology:

Research Design: Quasi-experimental design
Participants: Secondary school students enrolled in biology classes
Sampling Technique: Stratified random sampling
Data Collection Instruments:

- Pre-test and post-test to assess student knowledge and understanding
- Questionnaires to gather information on student perceptions of AI-assisted learning
- Interviews with students and teachers to gain insights into their experiences

Data Analysis:

- Descriptive statistics (mean, standard deviation) to analyze quantitative data
- Inferential statistics (t-tests, ANOVA) to compare the performance of the control and experimental groups
- Thematic analysis to identify patterns and themes in qualitative data teaching biology at the secondary level in Islamabad.write down methodology data analysis sample ans sample techniques integuments table graphs and conclusion.

Investigates the impact of integrating Artificial Intelligence (AI) in teaching biology at the secondary level in Islamabad

Methodology

The study adopts a **mixed-method approach** to collect and analyze data effectively.

1. **Research Design**:
   - Quasi-experimental (Pre-test/Post-test design).
   - Descriptive survey for qualitative insights.
2. **Study Duration**:
   - 8–12 weeks of implementing AI tools in biology teaching.
3. **Population**:
   - Secondary school students (Grades 9–10) and teachers in Islamabad.
4. **Sample**:

Sample Size:

- 100 students (50 in experimental group and 50 in control group).
- 10 biology teachers from 5 schools.

Sampling Technique:

- **Purposive Sampling**: Selection of schools and teachers where AI tools are available.
- **Random Sampling**: Students divided into experimental and control groups randomly.

Data Collection Instruments

1. **Pre-test and Post-test**:

To measure students' understanding and performance before and after AI integration.

2. **Questionnaires**:

For teachers and students to assess experiences and perceptions of AI usage.

3. **Interviews**:

Conducted with teachers to gather qualitative insights on teaching effectiveness and challenges.

4. **Observations**:

Classroom observations to analyze student engagement and participation.

Data Analysis Techniques:

1. **Quantitative Analysis**:

Descriptive statistics (Mean, Standard Deviation, Percentages).
Inferential statistics: Paired *t-tests* to compare pre-test and post-test scores of experimental and control groups.

2. **Qualitative Analysis**:

Thematic analysis for interview and observation data to identify key themes.

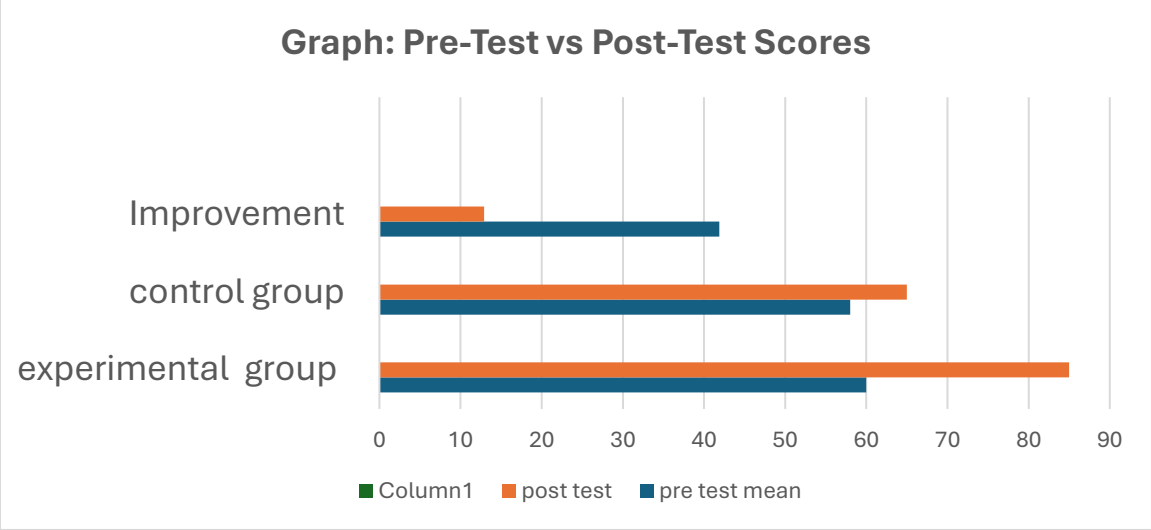
3. **Software Tools**:

SPSS (Statistical Package for the Social Sciences) for quantitative analysis.

Sample Data Table:

Group	Pre-Test Mean Score	Post-Test Mean Score	Improvement (%)
Experimental	60	85	41.7%
Control	58	65	12.1%

Investigates the impact of integrating Artificial Intelligence (AI) in teaching biology at the secondary level in Islamabad



Descriptives

		N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean Lower Bound	95% Confidence Interval for Mean Upper Bound	Minimum	Maximum
9th,10th,11th y & 12th y	MALE	274	2.1204	.92785	.05605	2.0101	2.2308	1.00	4.00
	FEMALE	261	2.9425	1.04539	.06471	2.8151	3.0699	1.00	4.00
	Total	535	2.5215	1.06836	.04619	2.4308	2.6122	1.00	4.00
phy,chem.bio.comp,sc	MALE	274	2.2920	1.08036	.06527	2.1635	2.4205	1.00	4.00
	FEMALE	261	2.6245	1.09756	.06794	2.4907	2.7583	1.00	4.00
	Total	535	2.4542	1.10042	.04758	2.3607	2.5477	1.00	4.00

NOVA

		Sum of Squares	df	Mean Square	F	Sig.
9th,10th,11th and 12th y	Between Groups	90.339	1	90.339	92.747	.000
	Within Groups	519.163	533	.974		
	Total	609.503	534			
physics, chemistry. Biology. Computer, Sc	Between Groups	14.783	1	14.783	12.470	.000
	Within Groups	631.845	533	1.185		
	Total	646.628	534			

Conclusion

1. **Findings**:

AI tools significantly improved students' understanding and performance in biology.
Teachers reported higher teaching efficiency and student engagement.

Investigates the impact of integrating Artificial Intelligence (AI) in teaching biology at the secondary level in Islamabad

2. **Key Insights**:
Experimental group showed a **41.7% improvement**, while the control group had only a **12.1% improvement**.
Students found AI tools interactive and helpful for visualizing abstract biological processes.
3. **Implications**:
AI integration can bridge gaps in traditional teaching methods.
Policymakers and schools should invest in AI-based educational technologies.
4. **Future Recommendations**:
Extend the study to other subjects and grade levels.
Conduct long-term studies to analyze sustained impacts.

Discussions

Examining the relationship between artificial intelligence and science education was the main goal of this review. Our research revealed a wide range of applications of AI in science teaching. According to our findings, including AI tools into scientific instruction regularly raises students' academic achievement. This was shown by better understanding of challenging subjects and greater test scores when compared to individuals in traditional learning environments (Alneyadi & Wardat, 2023; Koć-Januchta et al., 2020; Siddaway et al., 2019).

It has been demonstrated that incorporating artificial intelligence into the teaching-learning process enhances students' understanding of difficult scientific subjects (Lamb et al., 2021; Ledesma & García, 2017). Additionally, it significantly improves problem-solving abilities, which improve comprehension of the material, especially in disciplines like chemistry and physics. According to Balakrishnan (2018), scientific teachers also use AI-powered tools to effectively engage students and cultivate their excitement and interest in science-related subjects.

A more fair learning environment is created when individualised learning using AI tools reduces performance gaps between students who do better and those who perform worse (Azcona et al., 2019). Students' involvement in the learning process was also enhanced by AI-generated personalised feedback (Azcona et al., 2019; Maestrales et al., 2021; Mirchi et al., 2020).

According to the current systematic analysis, which also examines how research is distributed across several topic areas in scientific education, science in general has the greatest significance, followed by physics, biology, programming, and other specialised science courses.

The studied literature gave relatively little attention to several specialized domains, such as statistics and earth science. There are some differences in the distribution of research publications between nations. Compared to other countries, the United States had a notably greater number of studies. Germany came in at number two. Australia and Turkey came next, with a moderate amount of research from the UAE, Malaysia, and Canada. With a varied distribution across several countries, a number of them had minimal representation. Focus on research.

Compared to other countries with fewer studies, some, like the US and Germany, may indicate different levels of research infrastructure or a different emphasis on AI in education. This

might result in differences in how AI tools are used and how they affect science education in various parts of the world.According to our findings, when AI tools are included into learning environments, students show more interest and engagement in science courses. This increased attention is ascribed to AI's capacity to offer tailored feedback and predictions (Jiao et al., 2022b), which enhances learning's appeal and engagement (Hewapathirana & Almasri, 2022).

Students view AI-based goods as beneficial and useful for their academic endeavours. Elkhodr et al. (2023) state that they acknowledge the effectiveness of AI in improving subject comprehension and express a want to continue using these technologies in the future. In line with their own teaching efficacy and reported increases in student engagement, scientific instructors, like students, also show positive attitudes and adoption of AI tools in the classroom. Some teachers are more confident in their ability to use AI effectively because they perceive it as a method to reduce effort during instruction. Instructors view it as a way to increase student involvement (Al Darayseh, 2023).

Teachers specifically view ChatGPT as a useful tool for creating science units, rubrics, tests, and instructional aids since it is convenient and has the potential to improve their teaching strategies. Although AI has shown potential in enhancing learning outcomes, issues with its subject-matter and context adaptability remain. There are obstacles to comprehending specific courses, according to some study, which may have an impact on how successfully AI aids student learning. Previous research indicates that ChatGPT and other AI tools have trouble comprehending and managing complex concepts in specific academic areas, such chemistry (Daher et al., 2023).

Its access to the most up-to-date or thorough knowledge on specific issues is restricted by its reliance on the material it was taught. The necessity for flexible solutions is highlighted by the possibility that a standard strategy would not be sufficient to manage the subtleties and complexity of various educational contexts (Cooper, 2023). To overcome these obstacles, a thorough strategy that takes into account AI's advantages and disadvantages in science teaching is needed. Teachers are therefore encouraged to thoroughly assess AI-generated content and adapt it for usage in a variety of learning contexts.

Regarding AI in our culture and the use of AI tools and procedures in K–12 education, our research has significant ramifications for teacher preparation and in-service professional development (Antonenko & Abramowitz, 2023). Overall, the method and results of science education are improved by incorporating artificial intelligence. However, using it comes with some restrictions and difficulties. Giving teachers the guidance and assistance they need to use AI tools efficiently will boost their self-assurance and ability to incorporate these tools into their lesson plans. Furthermore, the potential of abuse can be reduced and moral behavior among students and teachers can be guaranteed by setting explicit ethical standards and frameworks for the responsible application of AI in education.

Limitations

This section discusses some of the research review's inherent limitations. First, like with other reviews, the research papers that are included are determined by the search terms and tactics. Using alternate search criteria could have produced more papers that could have been included in the review, even though the purpose was to conduct a comprehensive and

methodologically rigorous search. Furthermore, relevant empirical material for this study review was found by searching a few research databases. Limiting the search for research to a pre-established list of academic, peer-reviewed publications would have been an alternate methodological approach

This approach might have resulted in a lower sample of literature for inclusion. To the greatest extent possible, however, further control over validity, dependability, and trustworthiness was sought during the search and inclusion procedures. Finally, it's possible that we overlooked any grey literature that wasn't indexed in the databases and archives we used, like dissertations and conference proceedings.

Conclusion

The study's findings suggested that AI-assisted instruction improved biology students' performance. Students in the experimental group outperformed those in the control group on the pre- and post-tests. Additionally, the experimental group's students demonstrated higher levels of drive and interest in biology. the consequences, viewpoints, and challenges related to integrating artificial intelligence (AI) into science instruction. Our research uncovered a landscape brimming with opportunities and challenges. The application of AI in science education has continuously shown positive effects on student learning results.

It boosts students' motivation, enhances their comprehension of the subject matter, and encourages participation in the learning process. Both educators and learners were pleased with AI's application and effectiveness. They both concurred that it might enhance educational prospects. However, issues were brought on by AI's poor understanding of particular subjects, its inability to adjust to various learning contexts, and the variations in performance amongst AI models. Responsible use's ethical ramifications also appeared to be a major concern. A systematic approach that considers careful evaluation and context-specific modification is needed to get over these challenges.

To fully utilize AI's potential in science education, educators and governments must negotiate these challenges while maintaining moral standards and optimizing the technology's influence on students' educational paths across the globe.

REFRENCES

1. Adams, C., Pente, P., Lemermeyer, G., Turville, J., & Rockwell, G. (2022). Artificial intelligence and teachers' new ethical obligations. *The International Review of Information Ethics*, *31*(1). https://doi. org/10.29173/irie483.
2. Alharbi, S. M., Elfeky, A. I., & Ahmed, E. S. (2022). The effect of e-collaborative learning environment on development of critical thinking and higher order thinking skills. *Journal of Positive School Psychol- ogy*, *6*(6), 6848–6854.
3. Almasri, F. (2021). *Collaborative learning in science education: effects of student's gender attitudes and achievement in science education* University of Warwick, Retrieved from http://webcat.warwick.ac.uk/ record=b3853208.
4. Almasri, F. (2022a). The impact of e-learning, gender-groupings and learning pedagogies in biology under-
5. graduate female and male students' attitudes and achievement. *Education and Information Technolo- gies*, *27*, 8329–8380. https://doi.org/10.1007/s10639-022-10967-z.
6. Almasri, F. (2022b). Simulations to teach science subjects: Connections among students'

engagement, self- confidence, satisfaction, and learning styles. *Education and Information Technologies*, *27*(5), 7161– 7181. https://doi.org/10.1007/s10639-022-10940-w.

7. Bozkurt, A., Karadeniz, A., Baneres, D., Rodríguez, M. E., & Rodríguez, M. E. (2021). Artificial intelligence and reflections from educational landscape: A review of AI studies in half a century. *Sustainability*, *13*(2), 800. https://doi.org/10.3390/su13020800.
8. Burton, E., Goldsmith, J., Koenig, S., Kuipers, B., Mattei, N., & Walsh, T. (2017). Ethical considerations in artificial intelligence courses. *AI Magazine*, *38*(2), 22–34. https://doi.org/10.1609/aimag.v38i2.2731.
9. Cathrin, S., & Wikandaru, R. (2023). The future of character education in the era of artificial intelligence.
10. *Humanika Kajian Ilmiah Mata Kuliah Umum*, *23*(1). https://doi.org/10.21831/hum.v23i1.59741.
11. Chiu, T. K., Xia, Q., Zhou, X., Chai, C. S., & Cheng, M. (2023). Systematic literature review on opportuni- ties, challenges, and future research recommendations of artificial intelligence in education. *Computers and Education: Artificial Intelligence*, *4*, 100118. https://doi.org/10.1016/j.caeai.2022.100118.
12. Cooper, G. (2023). Examining science education in chatgpt: An exploratory study of generative artificial intelligence. *Journal of Science Education and Technology*, *32*(3), 444–452. https://doi.org/10.1007/ s10956-023-10039-y.
13. Dai, Y. (2023). Negotiation of epistemological understandings and teaching practices between primary teach- ers and scientists about artificial intelligence in professional development. *Research in Science Educa- tion*, *53*(3), 577–591. https://doi.org/10.1007/s11165-022-10072-8.
14. Grinnell, F. (2021). Scientific Inquiry, pluralism and complementarity. *Scientific Inquiry Pluralism and Com- plementarity*. https://doi.org/10.31235/osf.io/gejwv.
15. Hermansyah, M., Najib, A., Farida, A., Sacipto, R., & Rintyarna, B. S. (2023). Artificial intelligence and ethics: Building an artificial intelligence system that ensures privacy and social justice. *International Journal of Science and Society*, *5*(1), 154–168. https://doi.org/10.54783/ijsoc.v5i1.644.
16. Holmes, W., Bialik, M., & Fadel, C. (2023). *Artificial intelligence in education*. Globethics.
17. Holme, T. A. (2021). *Considering the call to action for science education* (Vol. 98, pp. 2739–2740). ACS.
18. Hong, F., Dou, W., & Chen, S. (2022). *Research on the impact of artificial intelligence on government public service quality*. Paper presented at the 2022 2nd International Conference on Public Management and Intelligent Society (PMIS 2022).
19. Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review.
20. *Computers & Education*, *123*, 109–123. https://doi.org/10.1016/j.compedu.2018.05.002.
21. Irez, S. J. S. E. (2006b). Are we prepared? An assessment of preservice science teacher educators' beliefs about nature of science. *90*(6), 1113–1143.
22. Kiemde, S. M. A., & Kora, A. D. (2022). Towards an ethics of AI in Africa: Rule of education. *AI and Ethics*, *2*(1), 35–40. https://doi.org/10.1007/s43681-021-00106-8.
23. Kola, A. J. (2013). Importance of science education to national development and problems militating against its development. *American Journal of Educational Research*, *1*(7), 225–229. https://doi.org/10.12691/ education-1-7-2.
24. Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of con- troversial socioscientific issues. *Science Education*, *85*(3), 291–310. https://doi.org/10.1002/sce.1011.
25. Mavroudi, A., Giannakos, M., & Krogstie, J. (2018). Supporting adaptive learning pathways through the use of learning analytics: Developments, challenges and future opportunities. *Interactive Learning Environ- ments, 26*(2), 206–220. https://doi.org/10.1080/10494820.2017.1292531

26. Tang, K. S., & Cooper, G. (2024). The role of materiality in an era of generative artificial intelligence. *Science & Education*, 1–16. https://doi.org/10.1007/s11191-024-00508-0.
27. artificial intelligence applications in higher education–where are the educators? *Journal of Educational Technology in Higher Education*, *16*(1), 1–27. https://doi.org/10.1186/s41239-019-0171-0.
28. Zhai, X., Haudek, C., Shi, K., Nehm, L. H., R., & Urban-Lurain, M. (2020a). From substitution to redefinition: A framework of machine learning-based science assessment. *Journal of Research in Science Teaching*, *57*(9), 1430–1459. https://doi.org/10.1002/tea.21658.
29. Zhai, X., He, P., & Krajcik, J. (2022). Applying machine learning to automatically assess scientific models.
30. *Journal of Research in Science Teaching*, *59*(10), 1765–1794. https://doi.org/10.1002/tea.21773.
31. Zhai, X., Shi, L., & Nehm, R. H. (2021). A Meta-analysis of machine learning-based Science assessments: Factors impacting machine-human score agreements. *Journal of Science Education and Technology*, *30*(3), 361–379. https://doi.org/10.1007/s10956-020-09875-z.
32. Zhai, X., Yin, Y., Pellegrino, J. W., Haudek, K. C., & Shi, L. (2020b). Applying machine learning in science assessment: A systematic review. *Studies in Science Education*, *56*(1), 111–151. https://doi.org/10.108 0/03057267.2020.1735757.
33. Zulyusri, Z., Elfira, I., Lufri, L., & Santosa, T. A. (2023). Literature study: Utilization of the PjBL model in science education to improve creativity and critical thinking skills. *Jurnal Penelitian Pendidikan IPA*, *9*(1), 133–143. https://doi.org/10.29303/jppipa.v9i1.2555.