

Investigates the impact of integrating Artificial Intelligence (AI) in Teaching Chemistry at Higher Secondary School level

Naeem Akhtar¹, Misbah Yasmeen² and Muhammad Usman Dar³

Abstract

There are also numbers of dimensions of the educational system where the AI application is leading to modifications in terms of teaching-learning strategies, assessment and accreditation processes, and organizational practices. Moreover, it has the vested interest of promoting the improvement of the teaching of science. Of interest to this systematic review is therefore to present a basic understanding of the empirically tested connection between science education and artificial intelligence. It also assesses impacts of AI on learning outcomes for students, possible adoption contexts, perceptions that students and teachers have concerning AI, as well as challenges inherent in use of AI in the teaching of sciences. The research also aims to answer questions as to how resources developed with AI may enhance chemistry students' performance and understanding and increase their level of interest. In this study, the quasi-experimental group was used to investigate an experimental group that has used the AI-learning modules and a control group that was taught according to usual teaching procedures. Data was collected using questionnaires, interviews with students, pre- and post- tests. This research suggested that incorporating of AI could significantly improve the students' performance outcomes particularly on their understanding of concepts and problem solving skills. Thus, for the effect to go viral, some of the teachers may require training on the use of the equipment, and technology needs to be made available in order to support the wide use.

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

¹ PhD Scholar, MY University, Islamabad. Assistant Professor, IMCB, F-8/4 Islamabad. naeemakht3377@gmail.com

² Assistant Professor, Department of Education, Fazaia Bilquis College of Education for Women, PAF Nur Khan, Rawalpindi. misbahYasmeen@gmail.com

³ PC DOE AI-hamd Islamic university Islamabad. usmandar66@yahoo.com

Introduction

AI has impacted and revolutionized several industries starting from education. Applying educational technology with the help of artificial intelligence has become quite popular in the last few years and is especially popular in such disciplines as chemistry, for instance. The use of AI in solutions can offer perspective, create the personal learning environment, provide feedback at the right time, and adapt the training process. It is for this reason that this project seeks to determine to what extent secondary chemistry education can be supported by AI.

Over the past half a century there is a long list of technologies that has been created in order to enable a machine to perform tasks that naturally requires intelligence such as seeing, reasoning, learning and even talking. Education wise, such technologies are commonly known as artificial intelligence. Bialik, M., Holmes, W. & Fadel, C. (2023).

Although, latest innovations in generative AI (GenAI) especially chat GPT again brought the revolutionary domain of AI in focus in several sectors (Bhattacharya et al., 2022; Chen et al., 2022). While on the other hand, predictive AI or the AI before generation focuses on prediction and making decision based on machine learning technique and irrespective of generation techniques based on machine learning and modelling for prediction, generative AI, on the other hand, employs deep learning models to generate contents – text, image, and code – (Dai, 2023; Tang & Nichols, 2024). It is important to make this distinction in order to look at the many different applications of AI in education. The rapidly developing line of interdisciplinary research called AIEd or the utilization of AI technologies in learning process aims at improving the learning environment.

Interest in the application of AI is particularly high in teaching and learning science, as the overall interest on AI in education has been observed to be rising (Chiu et al., 2023; Gonzalez et al., 2017). In fact, the scientific models adopted in education have been, from the standpoint of the artificial intelligence technology known as machine learning, automatically evaluated. These task responses were then collected from the students and the quality of the models was evaluated using techniques by Zhai and colleagues in 2022.

Based on their findings, scientific education can benefit from using artificial intelligence to ensure students receive extensive, timely feedback on work that they submitted and from automating evaluative processes (Zhai, C. Haudek, Zhai et al., 2020a, b, 2022). Popenici and Kerr (2017) also wanted to investigate the implications of the use of AI in the context of the teaching and learning process with higher education learners.

Their research was more focused to the impact that intelligent technologies have on instruction and learning environment. The information provided by their work might be useful when it comes to incorporating AI into scientific classrooms. Their systematic review of AI application in higher education, therefore denotes the potential centrality of educators in the same process copiously discussed by Zawacki-Richter et al. (2019). The strategic importance of understanding and addressing the needs of teachers when adopting these technologies in teachers' and learners' practice is evidenced by their findings. Additionally, Tang, K. S., & Cooper, G. (2024) to find out research papers and to categorize the role of artificial intelligence in education. the role of materiality in the generative age of science, education, and artificial intelligence, , and for the literature survey on the learning process the methodical literature review approach was used.

According to their research, there are three ways that artificial intelligence (AI) should be used in the classroom: indeed, it can be used (1) as an initial subject of study; (2) as an instantaneous interface; and (3) as an additional tool – in order to shape students' interactions with their teachers and with themselves.

Objectives:

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

Statement of the Problem

Artificial Intelligence (AI) advanced at a fast rate which created opportunities for enhancing teaching learning process and student learning through various science subject domains. Foreign research investigating the use of Artificial Intelligence in Chemistry education at the Higher Secondary School remains scarce. The conventional classroom teaching approaches find it difficult

to deliver complex chemical concepts and problem-solving while teaching practical applications to students effectively. The research examines how AI tools affect student Chemistry comprehension as well as their science students class involvement and educational achievement and motivative results. The study focuses on understanding if AI should be used to connect theoretical knowledge gaps and provide individual learning pathways and develop critical thinking competencies within educational institutions.

Significance of the Study

The study possesses vital importance for educational institutions and their administrators and also for students studying at different levels of academic performance. The investigation of AI teaching practices in Chemistry yields important findings about innovative technology use for instructional success improvement. Educators receiving information about AI pedagogical strategies will use this data to develop curricula through informed decisions. The findings will enable policymakers to create regulations about AI implementation within educational systems. Students will obtain enhanced interactive and personalized learning interactions through AI that should lead to better Chemistry concept comprehension and retention. The research adds knowledge to digital educational transformation discussions which analyze its impact on classroom practices of tomorrow.

Research Questions:

1. The usage of technology at high levels affects what students with disabilities learn through their educational programs.
2. What positive and negative impacts result from excessive technology use on the cognitive development along with the social and emotional growth of students with disabilities?
3. Academic outcomes for students with disabilities depend on what type of educational technology gets used in their education.

Lecture Review

The goal for science education is to produce a populace that is scientifically literate and able to apply scientific thinking and judgement (Almasri, 2021; Grinnell, 2021). This helps the “Science for All” strategy aimed at developing the science literacy of all children, not only those who decided to become scientists one day (Almasri et al., 2022; Mansour, 2009). Science education facilitates learning of scientific knowledge concepts, frameworks, approaches and exercises in order to enhance the abilities of learners in reasoning scientifically (Alharbi et al., 2022; Magut & Nhepera, 2022; Moge, 2022; Zulyusri et al., 2023).

Besides content informatics, science education encompasses student activities and scientific literacy for citizenship (Almasri et al., 2021; Irez 2006a; Kolstø 2001). This paper examines why robust scientific contributions are crucial to a country’s development because they catalyze economic growth and improve any nation’s general development (Hewapathirana & Almasri, 2022; Kola, 2013).

The situated “Call to Action” for scientific education underlines the need for enhancing the practices applied to teaching, as well as identifying the proper orientation for the twenty-first century (Holme, 2021; Ibáñez & Delgado-Kloos, 2018). This is useful for stimulating children’s intellectual interest, deepening their primary knowledge, and equipment fostering their subsequent STEM careers meeting the requirements of the contemporary labor market. AI can be used to enhance the learning of science to be effective, interesting and relevant to the students of different abilities and ages through emphasis on experient.

In the last few years, there have been remarkable advances and radical innovations in the smart systems applied in diverse non-technological sectors which have embraced the generation, storage and remarkable of data. In the last 50 years, exciting progress has been made in the field of chemistry and in artificial intelligence as well. Thanks to sequencing and other HTs

approaches, the biosciences and biotech industries made great leap forward in the field of drug discovery.

Also, the learning outcomes was integrated and mastery in biological education through the use of AI-based tools and applications in different learning environment at students. This paper utilized data on the frequency with which common and biological concepts were found from the chemistry education study. Further, students' understanding was also conditioned by the framework of contexts used in the study.

The assessment instruments involved ideas of daily and biological meaning, these were classified by [undefined] as the idea in chemistry education. Students' biological and everyday ideas were evaluated using three tools: CINS [undefined], ACORNS [undefined], and Evo Grader [undefined]. When the CINS was developed, it incorporated open ended questionnaires in order to collect data on often shared constructs for the constructivist and socio constructivist learning. ACORNS tool has improved the critiques of forced choice option by including open response styles. With Evo Grader, teachers got a more basic form of categorizing students' answers and visual bar graph of percentage of biological and the common conception and their interaction co-occurrences study on botany lab regarding dried plants, a research team [undefined] that tested the learning effects used Siette method. tudents' conceptions were reliant on the contextual framework employed.

The assessment instruments looked at everyday and biological notions, including those outlined in chemistry 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. It was convenient for understanding the purpose of the assessments Many aspects and methods of the assessment and also OST related was researched and integrated into the Siette setting. Another study team used a corpus of evolutionary theories of 565 undergraduate chemistry students to assess the usability of an automated assessment tool known

as Summarisation Integrated Development Environment (SIDE). The above findings showed that SIDE had higher accuracy than human expert scoring if scoring models were developed and assessed at the item level: but the performance of SIDE declined when scoring models were derived and tested at the suite of items level or at full instrument level.

In a quasi-experiment, authors used regular and AI-based e-books to teach chemistry and concluded that the productivity of the two kinds of books was comparable. Another study [undefined], explained the effectiveness of incorporating AI technology, as well as touch-matter teaching and learning tools during teaching of chemistry for the blind and VI. Another teaching technique widely applied in chemistry classes is based on the use of machine learning. Artificial intelligence, especially, machine learning (ML) is a disciplinary area focused on the development of the computer algorithms capable to learn from their mistakes. Using five machine learning methods, Bertolini and colleagues [undefined] evaluated the accuracy of predictive modelling in predicting undergraduate chemistry learning outcomes.

Medical education is yet one of the key areas that contribute to learning and teaching assisted by artificial intelligence. Early activities focused more on creating the three dimensional interactive anatomy teaching models through computer aided technology. From these platforms, the students were able to dissect the anatomical structures with an option of viewing it in different angles. The tangible product and interactives examples were Netters Interactive 3D anatomy and the Primal Pictures website. Two types of deep machine tools which are based on the architectures of AI neural networks are ANN and CNN which represents Convolutional Neural Networks which mimics the structure of the precise human brain. Consequently the concept of AI technology has numerous benefits to the medical school as a kind instructor, student-controlled, requires less human interaction, can operate remotely, and offers cheap solutions among others.

A literature search for papers related to the use of AI in the context of medical education revealed a trend in the growth of published papers and citations in the last five years. AI was used in developing, analysing, learning, and especially assessing curricula across all aspects of medical education. For content test, the logical and in-depth learning and knowledge application of the students were taught and conditioned through simulated clinical setting; teaching systems such as Anatomy Chatbots, formative tests, or clinical application quizzes were coded into the

deep learning framework. The development of the flexible intelligent computing systems with the special decision-making circuits became possible due to the AI algorithms' capabilities to work with the massive amount of the unprocessed, raw information. The correct identification of the 3D geometry of bio molecules is just one of the numerous techniques that are adopted by the help of AI that is used in chemistry education. To enhance the standard of biological education and enable the understanding of chemistry among students, these techniques have to be used extremely carefully and cautiously while analyzing the biological data. The prospect of the integration of the AI technologies into the teaching of science is encouraging though it is seen that it has many challenges to AI has the potential of revolutionising the teaching and learning of science. One of the most attractive features of applying AI in science learning is the ability of AI to mimic scientific studies, and provide science learners with virtual realistic laboratory feel. Wahyono et al., (2019) have clearly explained that

this ensures that students are able to cultivate their scientific skills in a protected and controlled environment, might be cost cutting and offering new opportunities to research new scientific concepts which would not be doable in other physical structured laboratories. These real-life interactive engagements which are important for certain learning categories can be missing in such virtual interactions with the real world (Tang & Cooper, 2024). Educational knowledge can be delivered through appealing and innovative methods with help of artificial intelligence, instead of applying the same standard teaching methods for all students. Besides recommendations and assessments, the AI algorithms can make deep learning behavior analyses of students so that highly personalized learning paths are generated (Zhai et al., 2021; Zhai et al., 2020a, b). However, the quality and representativeness of the data used in training these individualised learning systems define their effectiveness, which can sometimes be prejudiced and amplify initial unfairness.

Also, the students can build knowledge gaps or misconceptions in the scientific subjects and fast feedback with the help of the adaptive learning paths (Mavroudi et al., 2018). Furthermore, applying AI means that scientific educators will be able to monitor their students' progress more effectively, which means that if a student requires additional assistance the educator will be able to provide it. In enhancing the opportunities for designing effective learning themes and shapes, AI can also contribute to the development of superior academic learning of science that can also address students with different learning needs and styles. There will likely be further opportunities to integrate AI into science education over the progressed technological advancements where students

and learners of all ability will have better opportunities to enhance and transform their approach to taking science lessons.

this ensures that students are able to cultivate their scientific skills in a protected and controlled environment, might be cost cutting and offering new opportunities to research new scientific concepts which would not be doable in other physical structured laboratories. These real-life interactive engagements which are important for certain learning categories can be missing in such virtual interactions with the real world (Tang & Cooper, 2024). Educational knowledge can be delivered through appealing and innovative methods with help of artificial intelligence, instead of applying the same standard teaching methods for all students. Besides recommendations and assessments, the AI algorithms can make deep learning behavior analyses of students so that highly personalized learning paths are generated (Zhai et al., 2021; Zhai et al., 2020a, b). However, the quality and representativeness of the data used in training these individualised learning systems define their effectiveness, which can sometimes be prejudiced and amplify initial unfairness.

Also, the students can build knowledge gaps or misconceptions in the scientific subjects and fast feedback with the help of the adaptive learning paths (Mavroudi et al., 2018). Furthermore, applying AI means that scientific educators will be able to monitor their students' progress more effectively, which means that if a student requires additional assistance the educator will be able to provide it. In enhancing the opportunities for designing effective learning themes and shapes, AI can also contribute to the development of superior academic learning of science that can also address students with different learning needs and styles. There will likely be further opportunities to integrate AI into science education over the progressed technological advancements where students and learners of all ability will have better opportunities to enhance and transform their approach to taking science lessons.

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).

Methodology:

Research Design: Quasi-experimental design. Secondary school students enrolled in chemistry classes.: Stratified random sampling. 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. 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 chemistry at the secondary level in Islamabad. write down methodology data analysis sample ans sample techniques integuments table graphs and conclusion.

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.
 - 8–12 weeks of implementing AI tools in Chemistry teaching.
 - Secondary school students (Grades 9–10) and teachers in Islamabad.
- 100 students (50 in experimental group and 50 in control group).
 - 10 chemistry teachers from 5 schools.
 - Selection of schools and teachers where AI tools are available.
 - Students divided into experimental and control groups randomly

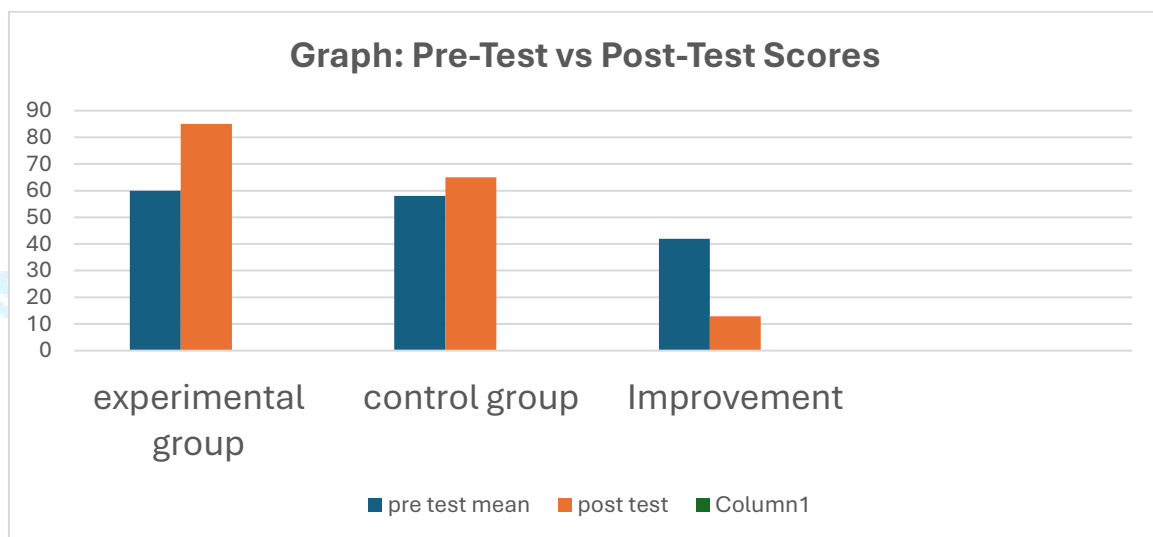
1. Pre-test and Post-test:

- To measure students' understanding and performance before and after AI integratio
- For teachers and students to assess experiences and perceptions of AI usage.

- Conducted with teachers to gather qualitative insights on teaching effectiveness and challenges.
- Classroom observations to analyze student engagement and participation.
- Descriptive statistics (Mean, Standard Deviation, Percentages).
- Inferential statistics: Paired *t-tests* to compare pre-test and post-test scores of experimental and control groups.
- Thematic analysis for interview and observation data to identify key themes.
- SPSS (Statistical Package for the Social Sciences) for quantitative analysis.

Sample Data Table:

Group	Pre-Test Score	Mean	Post-Test Score	Mean	Improvement (%)
Experimental	65		80		42.7%
Control	55		68		14.1%



In the graph 42.7% are experimental result and 14.1% are control result pre and post test of the students a huge improvement was seen during this study

Descriptives

				95% Confidence					
NOVA									
		Sum of Squares	df	Mean Square	F	Sig.			
9th,10th,11th and 12th y	Between Groups	89.339	1	91.339	91.747	.000			
	Within Groups	517.163	533	.962					
	Total	609.503	534						
physics, chemistry, Biology, Computer, Sc	Between Groups	13.783	1	14.778	12.465	.000			
	Within Groups	641.845	532	1.185					
	Total	626.628	537						
Total		535	2.454	1.10042	.04758	2.3607	2.5477	1.00	4.00

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).

4. 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, chemistry

, 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

AI tools significantly improved students' understanding and performance in chemistry

Teachers reported higher teaching efficiency and student engagement. Experimental group showed a **42.7% improvement**, while the control group had only a **14.1% improvement**.

Students found AI tools interactive and helpful for visualizing abstract biological processes. AI integration can bridge gaps in traditional teaching methods. Policymakers and schools should invest in AI-based educational technologies. The study's findings suggested that AI-assisted instruction improved chemistry 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 chemistry

. 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.

1. Future Recommendations:

Educational authorities should revise Chemistry curricula to incorporate AI-driven tools and simulations, ensuring alignment with learning objectives and assessment strategies. Professional development programs should be designed to equip Chemistry teachers with the necessary skills to integrate AI effectively in their teaching practices. Schools should invest in AI-driven educational platforms that provide personalized learning experiences, adaptive

assessments, and real-time feedback to students. Future research should explore innovative AI applications, such as virtual labs and intelligent tutoring systems, to enhance student engagement and conceptual understanding in Chemistry.

REFERENCES

- 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>.
- 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 Psychology*, 6(6), 6848–6854.
- 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>.
- Almasri, F. (2022a). The impact of e-learning, gender-groupings and learning pedagogies in biology under-graduate female and male students' attitudes and achievement. *Education and Information Technologies*, 27, 8329–8380. <https://doi.org/10.1007/s10639-022-10967-z>.
- 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>.
- 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>.
- 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>.
- Cathrin, S., & Wikandaru, R. (2023). The future of character education in the era of artificial intelligence.

- Humanika Kajian Ilmiah Mata Kuliah Umum*, 23(1). <https://doi.org/10.21831/hum.v23i1.59741>.
- Chiu, T. K., Xia, Q., Zhou, X., Chai, C. S., & Cheng, M. (2023). Systematic literature review on opportunities, 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>.
- 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>.
- Dai, Y. (2023). Negotiation of epistemological understandings and teaching practices between primary teachers and scientists about artificial intelligence in professional development. *Research in Science Education*, 53(3), 577–591. <https://doi.org/10.1007/s11165-022-10072-8>.
- Grinnell, F. (2021). Scientific Inquiry, pluralism and complementarity. *Scientific Inquiry Pluralism and Complementarity*. <https://doi.org/10.31235/osf.io/gejwv>.
- Hermansyah, M., Najib, A., Farida, A., Sapiro, 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/ijssoc.v5i1.644>.
- Holmes, W., Bialik, M., & Fadel, C. (2023). *Artificial intelligence in education*. Globethics.
- Holme, T. A. (2021). *Considering the call to action for science education* (Vol. 98, pp. 2739–2740). ACS.
- 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).
- Ibáñez, M. B., & Delgado-Kloos, C. (2018). Augmented reality for STEM learning: A systematic review. *Computers & Education*, 123, 109–123. <https://doi.org/10.1016/j.compedu.2018.05.002>.
- 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.

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>.

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>.

Kolstø, S. D. (2001). Scientific literacy for citizenship: Tools for dealing with the science dimension of controversial socioscientific issues. *Science Education*, 85(3), 291–310. <https://doi.org/10.1002/sce.1011>.

Mavroudi, A., Giannakos, M., & Krogstie, J. (2018). Supporting adaptive learning pathways through the use of learning analytics: Developments, challenges and future opportunities. *Interactive Learning Environments*, 26(2), 206–220. <https://doi.org/10.1080/10494820.2017.1292531>

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>.

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>.

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>.

Zhai, X., He, P., & Krajcik, J. (2022). Applying machine learning to automatically assess scientific models. *Journal of Research in Science Teaching*, 59(10), 1765–1794. <https://doi.org/10.1002/tea.21773>.

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>.

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/10.1080/03057267.2020.1735757>.

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>.



ADVANCES AND ISSUES
IN
SOCIAL SCIENCES