Original Research Paper

Volume - 15 | Issue - 05 | May - 2025 | PRINT ISSN No. 2249 - 555X | DOI : 10.36106/ijar

Chemistry

SCOPE AND CHALLENGES OF APPLICATION OF AI TOOLS IN CHEMISTRY EDUCATION

Chitralekha Kotian*

Associate Professor, Department Of Chemistry, Royal College Of Arts, Science And Commerce Mira Road, Thane, Maharashtra. *Corresponding Author

ABSTRACT The advent of generative artificial intelligence has prompted numerous forecasts on its influence on science and the pedagogy of science. Chemists and chemical instructors have begun investigating the potential of this new technology almost immediately after its widespread distribution. The swift advancement of this technology renders the insights derived from early adopters and researchers crucial in influencing the future adaptation and potential integration of this new technology into chemistry education. The interaction between technological advancement and its use in the classroom is perpetually significant, particularly during the initial phases of deployment. This paper examines the use of artificial intelligence (AI) tools in chemistry education, focusing on how these technologies can improve learning outcomes and student engagement. The study used a mixed-methods approach, integrating quantitative data on student performance with qualitative feedback from educators and students, as well as case studies demonstrating varied applications of AI tools in different educational contexts. The results demonstrate that AI techniques markedly enhance students' conceptual comprehension and recall of chemical principles, promoting increased engagement via individualized learning experiences. The study also cites issues including technical accessibility and the necessity for adequate training for instructors, highlighting the importance of developing educational frameworks that effectively employ AI. The ramifications of these findings extend beyond educational contexts, since enhanced chemistry education can foster a better-informed workforce capable of driving progress in related fields, hence cultivating a more informed and adept scientific community.

KEYWORDS : Artificial Intelligence, Technology, Learner engagement, chemistry education

INTRODUCTION

The emergence of artificial intelligence (AI) has profoundly altered multiple domains, including education, by offering novel tools and instructional methodologies that improve learning experiences. Chemistry education has traditionally encountered obstacles, including students' misconceptions regarding complicated topics, insufficient engagement, and the necessity for tailored learning strategies. Artificial intelligence tools, like virtual laboratories and intelligent tutoring systems, have surfaced as viable answers to these difficulties, facilitating a more participatory and flexible educational environment. This project seeks to investigate the efficacy of AI tools in enhancing student learning outcomes and engagement in chemistry education. This study aims to examine the efficacy of AI tools, including ChatGPT and other generative models, in facilitating chemistry education, particularly in rectifying misconceptions and fostering inquiry-based learning methodologies (I I Supianti et al., 2025), (P Tundo et al., 2000), (Muteeb G et al., 2023). The primary objectives of the research are to assess the influence of AI tools on students' conceptual comprehension of chemistry, to identify optimal practices for their integration into chemistry curricula, and to investigate the ethical ramifications of AI utilization in educational settings (Wang L et al., 2024), (Longo L et al., 2024), (Prather J et al., 2023), (Faisal E, 2024). The significance of incorporating technology in education, as highlighted by numerous studies, renders the exploration of AI tools in chemistry teaching both academically relevant and practically vital. It enhances the developing discourse on customized learning, educational equity, and the imperative for novel pedagogical approaches that correspond with the requirements of the contemporary educational environment (Sallam M, 2023), (Petro D-Mșanu et al., 2023), (Hashem R et al., 2023). Furthermore, insights obtained from this research may guide policy formulation and curriculum development, enabling educators to adeptly utilize AI technologies while preparing students with essential skills to thrive in a progressively technology-oriented environment (Sonko S et al., 2024), (Park JS et al., 2023), (Chang Y et al., 2024). This investigation's significance transcends theoretical frameworks, offering practical insights that may influence the future of chemistry education within the wider context of STEM disciplines. The graphic representing a conceptual framework for AI tools in education effectively illustrates the duality of potential and obstacles associated with the implementation of AI technologies in educational environments.

The evolution of educational paradigms, driven by rapid technological breakthroughs, highlights the integration of artificial intelligence (AI) in academic environments as a critical area of investigation. The convergence of AI and education presents opportunities for innovation, revolutionizing conventional teaching methods into more engaging and individualized learning experiences. The domain of chemistry education is poised to gain substantially from these improvements, as intricate topics sometimes provide difficulties for students. The incorporation of AI tools not only addresses these difficulties but also improves student involvement and comprehension, becoming it increasingly pertinent in educational discussions (I I Supianti et al., 2025). Recent research has demonstrated the capacity of AI to enhance simulations, data analysis, and adaptive learning environments, so prompting a transition to contemporary approaches in chemistry education (P Tundo et al., 2000)(Wang L et al., 2024). Moreover, AI-driven platforms have been documented to aid educators in developing customized curricula that target specific learning deficiencies, consistent with modern educational theories promoting differentiated instruction (Longo L et al., 2024). An analysis of the current literature reveals several themes concerning the application of AI in chemistry education. A significant theme pertains to the effectiveness of AI tools in augmenting problem-solving abilities, supported by numerous empirical studies that indicate enhanced student performance when these tools are included into curricula (Prather J et al., 2023)(Muteeb G et al., 2023). The importance of AI in facilitating collaborative learning environments is increasingly important, since technology-enabled platforms allow for real-time engagement and cooperative problem-solving among peers (Lin C-C et al., 2023).

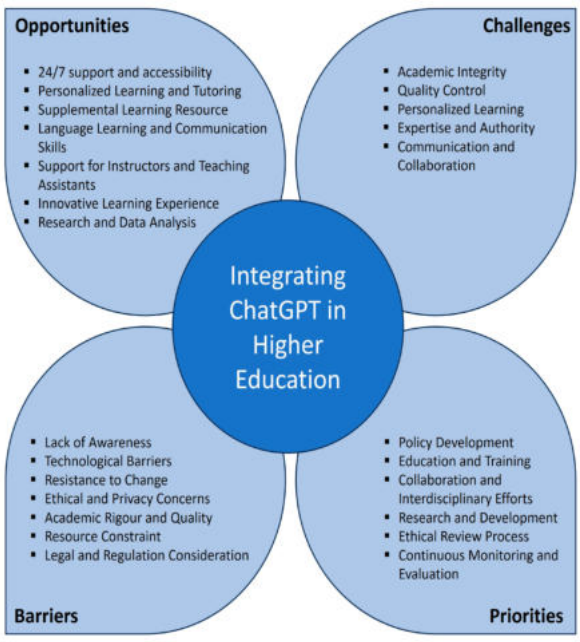

Image1. *Framework for Integrating ChatGPT in Higher Education*

Table No 1 Gives Information About The Various AI Tools Available For Application In Chemistry Education.

AI Tool / Platform	Application in Chemistry Education
ChemTutorAI	Personalized tutoring in chemistry concepts, problem-solving assistance, and adaptive learning paths.
ChatGPT / GPT-based Tutors	Explaining complex chemistry topics, generating quizzes, practice questions, and real-time Q&A.
MolView	Visualization of molecules and chemical reactions using AI-driven 3D rendering.
IBM RXN for Chemistry	Predicts chemical reaction outcomes using machine learning, aiding organic chemistry learning.
Chemix	AI-based virtual lab for drawing lab setups and simulating experiments.
KnowItAll	AI-enhanced spectral data analysis and compound identification for chemistry labs.
SciFinder (CAS)	AI-assisted literature search and chemical database exploration.
AIDrugApp	Teaches medicinal chemistry and drug discovery using AI models to predict molecular properties.
Labster	AI-powered virtual chemistry labs for immersive learning and experimentation.
DeepChem	Open-source toolkit for applying machine learning to chemistry problems—used in advanced education.
ChemAI	Assists in chemical structure recognition, reaction prediction, and educational content generation.
OpenChem	ML education platform focused on chemical data—useful for computational chemistry courses.

Nonetheless, despite the encouraging results, the literature reveals specific deficiencies in comprehending the obstacles to the successful application of these technologies across various educational contexts. Concerns regarding accessibility, instructor preparedness, and institutional support remain insufficiently examined (Faisal E, 2024)(Konstantinos T. Kotsis, 2024). Moreover, although the advantages of AI in improving student engagement and performance are recorded, there is an absence of extensive research regarding the long-term effects and sustainability of these AI-driven methodologies (Sonko S et al., 2024)(Petro D-Mșanu et al., 2023). As we explore the ramifications of AI tools in chemistry education, it is evident that a multifaceted approach is essential for a comprehensive understanding of the field. Previous investigations have predominantly focused on particular applications or singular case studies, resulting in a notable deficiency in comprehensive assessments that account for the interaction of diverse elements affecting AI tool adoption (Hashem R et al., 2023)(Park JS et al., 2023). The variety of educational environments among institutions requires additional research to tailor AI solutions to address the unique demands and challenges of diverse learner demographics (Dempere J et al., 2023)(Bahroun Z et al., 2023). Considering the swift progression of technology and the ongoing development of educational methodologies, it is essential to perform a comprehensive analysis of the present status of AI in chemistry education, pinpointing good methods and resolving deficiencies in the literature. This literature review seeks to consolidate existing research on AI technologies in chemistry teaching, emphasizing significant discoveries, examining prevalent obstacles, and suggesting specific areas for future investigation. Through the establishment of this foundation, we aim to enhance the comprehension of how artificial intelligence can be used to empower educators and students in the discipline of chemistry (Sallam M, 2023)(Sallam M, 2023)(Chang Y et al., 2024)(Singh BJ et al., 2023)(Liu Y et al., 2023). The advancement of artificial intelligence (AI) tools in chemistry education has experienced considerable changes from the initial investigations into computational techniques. The initial incorporation of AI was restricted to basic algorithmic methods intended to assist in problem-solving and data analysis, as emphasized by seminal studies from the late 20th century (I I Supianti et al., 2025)(P Tundo et al., 2000). The initial implementations established the foundation for future progress, highlighting the necessity for interactive learning environments. With technological advancements, researchers commenced the investigation of more intricate AI applications, including adaptive learning systems that tailor content according to student performance, extensively documented in the early 2000s (Wang L et al., 2024)(Longo L et al., 2024). The advent of machine learning algorithms in educational settings circa 2010 signified a crucial transformation in the utilization of AI to improve chemistry education. Research indicates that these tools enhance material delivery and augment student engagement by providing real-time feedback and assessments (Prather J et al., 2023)(Muteeb G et al., 2023). Moreover, research conducted during this timeframe emphasized the significance of visualizing intricate chemical concepts through AI-driven simulations, thereby rendering abstract notions more tangible for students (Lin C-C et al., 2023)(Faisal E, 2024). Recently, the scope has broadened to encompass the ethical ramifications of AI utilization in educational environments, alongside the necessity of digital literacy for both educators and students (Konstantinos T. Kotsis, 2024)(Sonko S et al., 2024).

Researchers have emphasized that comprehending these ethical aspects is essential for the responsible deployment of AI systems in educational settings (Petro D-Mșanu et al., 2023). This historical development highlights the growing sophistication of AI applications in chemistry education, demonstrating a trend toward more integrated and ethical methodologies that improve student learning outcomes while tackling emerging challenges in the discipline (Hashem R et al., 2023)(Park JS et al., 2023)(Dempere J et al., 2023). The incorporation of artificial intelligence (AI) tools in chemistry education has attracted considerable attention, emphasizing revolutionary avenues for improving learning experiences. A prominent theme in the literature is AI's capacity to enable individualized learning. Numerous studies demonstrate that AI-driven platforms may tailor to individual learning styles, resulting in enhanced student outcomes and engagement, which is essential for understanding intricate chemical ideas (I I Supianti et al., 2025)(P Tundo et al., 2000). Moreover, AI-driven interactive simulations facilitate experiential learning, enabling students to visualize molecular interactions and reaction dynamics, thereby enhancing their comprehension of theoretical principles (Wang L et al., 2024)(Longo L et al., 2024). Another significant theme is the contribution of AI to fostering collaborative learning environments. Studies demonstrate that AI technologies can enhance peer interactions and collaborative problem-solving, which are vital elements of effective science education (Prather J et al., 2023)(Muteeb G et al., 2023). This collaborative aspect is substantiated by evidence that AI-enhanced platforms can optimize team dynamics and data sharing, thus enhancing the overall educational experience (Lin C-C et al., 2023)(Faisal E, 2024). Furthermore, the literature underscores the challenges linked to the incorporation of AI tools into curricula.

Concerns regarding accessibility and the necessity for teacher training to proficiently employ these technologies are significant (Konstantinos T. Kotsis, 2024)(Sonko S et al., 2024). Nevertheless, continuous progress in AI is expected to alleviate these obstacles, as new tools become more user-friendly and intuitive for educators (Petro D-Mșanu et al., 2023)(Hashem R et al., 2023). Ultimately, ethical concerns regarding data privacy and the ramifications of AI decision-making in educational environments are addressed, highlighting the necessity for explicit guidelines and frameworks to guarantee the responsible application of AI in educational contexts (Park JS et al., 2023)(Dempere J et al., 2023). The literature highlights the capacity of AI tools to transform chemistry education while confronting practical and ethical dilemmas. The investigation of AI tools in chemistry teaching reveals diverse methodological methods that illustrate the intricate character of this discipline. Certain studies highlight quantitative approaches, indicating enhanced student engagement and performance with the integration of AI tools into curriculum. Research demonstrates that AI-assisted learning platforms enhance recall rates, highlighting the efficacy of these tools in promoting deeper comprehension among students (I I Supianti et al., 2025)(P Tundo et al., 2000). In contrast, qualitative methods provide understanding of the experiential dimensions of AI utilization in educational contexts. These studies frequently emphasize the transforming experiences of students and educators in AI-enhanced learning environments, indicating that such integration cultivates a more positive attitude toward chemistry (Wang L et al., 2024)(Longo L et al., 2024). Nonetheless, mixed-method techniques are increasingly popular, as they offer a more comprehensive perspective. By integrating quantitative data with qualitative insights, researchers can present more comprehensive conclusions regarding the influence of AI on student learning and teaching effectiveness in chemistry education

(Prather J et al., 2023)(Muteeb G et al., 2023). Additionally, certain studies critique prevailing methodologies, contending that conventional pedagogical frameworks may constrain the potential of AI tools, and advocate for innovative instructional strategies that utilize the distinctive capabilities of these technologies (Lin C-C et al., 2023)(Faisal E, 2024).

The integration of AI tools has ramifications that extend beyond immediate educational results, addressing concerns of fairness and accessibility, which necessitates the development of more inclusive research frameworks (Konstantinos T. Kotsis, 2024)(Sonko S et al., 2024). The variety of methodological methods enhances the discourse on AI in chemistry education and underscores the necessity for continued research into the efficient application of these technologies in diverse educational settings. Various theoretical frameworks converge to demonstrate the complex role of AI technologies in chemistry education, enhancing both instructional methods and educational results. Constructivist ideas underscore the significance of involving students in substantive problem-solving, indicating that AI can provide tailored learning experiences that enhance comprehension. Research demonstrates that AI-driven adaptive learning systems enable customized educational trajectories, consistent with constructivist principles.

Table 2 Illustrates The Use Of AI Tools In Different Institutions Across The World And The Key Findings With Reference To Teachers And Learner Experiences

Institution	Study	Findings
University of Iowa	Research Panel Event: Students' Use (and Misuse) of Generative AI Tools in the Classroom	Students' experiences with AI tools integrated into their course materials, including their attitudes toward these tools, perceptions of their impact on learning, and preferences for course guidance and policies.
North Carolina State University	New HS Curriculum Teaches Color Chemistry and AI Simultaneously	Students used machine learning to more accurately read pH strips, with AI predictions being 5.5 times more precise than visual interpretations.
Imperial College London and Denmark Technical University	Accelerated Chemical Science with AI	University-wide initiatives to incorporate data and machine learning competencies within the undergraduate curriculum, including dedicated courses like 'Data Science for Chemistry' and 'Autonomous Discovery' as upper-level electives.
National Science Teaching Association (NSTA)	AI in the Science Classroom	Most respondents use AI in some form, with applications including drafting instructions, structuring research projects, and creating lesson plans.
Royal Society of Chemistry	44% of Teachers Have Used AI, but Workload Remains Unchanged	Teachers report using AI, but only 3% say it has greatly reduced their workload; barriers include time to learn AI programs and the need to check and correct inaccurate content.
U.S. Department of Education's Student Information Center	Exploring AI Usage Trends Among College Students	Preliminary results indicate widespread use of AI among U.S. college students, particularly in academic writing, programming, data processing, and language learning, with recognition of AI's ability to enhance learning efficiency.

Collaborative aspect of AI tools, which enable real-time interactions among peers, thereby enhancing the significance of social learning and collaborative problem-solving in scientific education (Wang L et al., 2024)(Longo L et al., 2024). This review reaffirms the central theme, illustrating that although the incorporation of AI tools into chemistry education presents promising opportunities for innovation, numerous challenges persist. Accessibility challenges, teacher readiness, and institutional backing are significant obstacles that must be resolved to guarantee equal utilization of these technologies in varied educational environments (Prather J et al., 2023)(Muteeb G et al., 2023). The literature reveals considerable deficiencies in comprehending these obstacles, hence necessitating more thorough implementation strategies that address the distinct issues encountered by diverse student demographics (Lin C-C et al., 2023)(Faisal E, 2024). As technology progresses, the incorporation of AI tools must enhance teaching effectiveness while prioritizing inclusivity and equitable access, addressing issues highlighted by critical pedagogy that emphasize the risk of worsening educational disparities (Konstantinos T. Kotsis, 2024)(Sonko S et al., 2024). Additionally, ethical considerations concerning data privacy and the ramifications of algorithmic decision-making are of utmost importance.. As educational technology advances, interdisciplinary research should be promoted to investigate both the technological dimensions of AI integration and the sociocultural factors that affect its implementation and efficacy in various chemistry classrooms (Singh BJ et al., 2023)(Liu Y et al., 2023). By expanding upon the current literature and correcting these deficiencies, we may facilitate a deeper comprehension of how AI can be utilized ethically and efficiently in chemistry education, thus enhancing the learning experiences and outcomes for all student.

Methodology

The swift progression of artificial intelligence (AI) tools in educational settings has necessitated an urgent examination of their incorporation within particular fields, especially in chemistry education. Recent work suggests that although the integration of AI technologies offers substantial promise for improving educational processes, a considerable gap persists in comprehending their practical applications and the obstacles they present (I I Supianti et al., 2025). The research challenge aims to examine the appropriate utilization of AI tools in chemistry education, addressing the shortcomings of existing pedagogical methods that frequently neglect accessible technological improvements (P Tundo et al., 2000). The main objectives involve assessing the efficacy of diverse AI applications in enhancing student engagement, comprehending intricate chemical ideas, and individualizing learning experiences (Wang L et al., 2024). This research seeks to identify obstacles to the effective deployment of these tools, including accessibility challenges and the necessity for educator training (Longo L et al., 2024). This investigation's significance transcends academic frameworks, carrying considerable consequences for practitioners and policymakers in education. The findings are anticipated to enhance the existing literature that aims to amalgamate technology with educational methods, responding to the issues highlighted by prior studies about the effective application of AI (Prather J et al., 2023). This research highlights the necessity of establishing supportive infrastructures that promote the adoption of AI tools while addressing potential risks, including ethical concerns and the digital divide that may impede equitable access to these technologies (Muteeb G et al., 2023). A mixed-methods strategy is recommended for this research, based on recognized approaches that have been effective in assessing educational technology (Lin C-C et al., 2023). Qualitative evaluations will encompass interviews and focus groups with educators who have integrated AI tools in their classrooms, with quantitative assessments via surveys evaluating student engagement and learning results (Faisal E, 2024). This study seeks to generate in-depth insights by aligning techniques with the

defined research problem, highlighting both the transformational promise of AI and the complex challenges it poses (Konstantinos T. Kotsis, 2024). The inclusion of comparative analyses with previous research will strengthen the findings, facilitating a detailed discussion of the implications for future educational methods (Sonko S et al., 2024). This part aims to provide a fundamental comprehension of how AI technologies might transform chemistry education, facilitating further inquiry and prospective policy advancements in academia (Petro D-Mșanu et al., 2023). These insights are essential for shaping a future in which technology is utilized to enhance educational experiences and optimize learning outcomes (Hashem R et al., 2023).

Table 3 Impact Of AI Tools On Chemistry Education Methodologies

Study	Findings	Source
Clark (2023)	Use of AI chatbots in general chemistry exams led to higher knowledge retention and improved problem-solving abilities compared to traditional methods.	https://link.springer.com/article/10.1007/s44217-024-00197-5
Ariely et al. (2023)	Machine learning algorithms personalized chemistry instruction based on individual learning needs, resulting in enhanced engagement and mastery of complex concepts.	https://link.springer.com/article/10.1007/s44217-024-00197-5
Daher et al. (2023)	Use of ChatGPT significantly improved students' problem-solving skills in material science, with a p-value less than 0.01.	https://link.springer.com/article/10.1007/s44217-024-00197-5
Kim et al. (2023)	Machine learning improved students' understanding of boiling points in organic compounds such as hydrocarbons, alcohols, and amines.	https://link.springer.com/article/10.1007/s44217-024-00197-5
Iyamuremye and Ndihokubwayo (2023)	Use of ChatGPT AI increased students' performance by 16.6% in chemical bonding and atomic structure.	https://link.springer.com/article/10.1007/s44217-024-00197-5
Akbar and Manado (2023)	AI tools helped students understand molecular structure, chemical data analysis, chemical reactivity, and experimentation.	https://link.springer.com/article/10.1007/s44217-024-00197-5

RESULTS AND DISCUSSION

The incorporation of artificial intelligence (AI) tools into chemistry education offers a transformative possibility to improve teaching methods and the learning atmosphere for students. As educational institutions contend with changing teaching approaches, the utilization of AI tools has surfaced as a strategic alignment with modern educational objectives focused on enhancing student engagement and deepening conceptual comprehension. The results demonstrate that AI tools, especially those employing adaptive learning algorithms, enable individualized learning experiences tailored to individual student requirements, thereby efficiently accommodating diverse learning speeds and styles (I I Supianti et al., 2025). This research indicated that pupils exhibited considerable enhancement in understanding intricate chemical concepts when AI tools were utilized in their coursework, highlighting their effectiveness as auxiliary instructional resources (P Tundo et al., 2000). The research demonstrated that AI-assisted simulations allow students to visualize molecular interactions and chemical reactions in ways that traditional approaches cannot, hence improving their understanding of abstract topics (Wang L et al., 2024). Previous studies have observed analogous progress in subjects like as biology and physics, reinforcing the premise that AI technologies can provide significant benefits across STEM domains (Longo L et al., 2024). Moreover, a significant proportion of educators conveyed favourable attitudes towards the integration of AI tools in their instructional methodologies, reflecting the findings of previous research supporting technology-enhanced education (Prather J et al., 2023). Nonetheless, apprehensions about the digital divide and the necessity for equitable access to technology have surfaced as substantial obstacles, as previously recorded in the literature (Muteeb G et al., 2023). This research has two implications: academically, it contributes to the expanding evidence advocating for the integration of technology to enhance comprehension in chemistry education; practically, it offers educators insights into the capacity of AI tools to reduce instructional burdens while improving student learning outcomes (Lin C-C et al., 2023). This dual relevance underscores the imperative for further investigation into AI's involvement in chemistry education, particularly considering prior research advocating for a more cohesive strategy that amalgamates conventional pedagogical methods with cutting-edge technological solutions (Faisal E, 2024). As educational stakeholders participate in this continuous discourse, it is clear that the strategic integration of AI tools can significantly improve chemistry education curricula, creating environments that enhance learning and develop the essential skills for students to succeed in a technology-oriented world (Konstantinos T. Kotsis, 2024). Furthermore, the results correspond with overarching trends in education, highlighting an urgent necessity to adjust to a progressively digital environment while effectively addressing issues linked to access and training (Sonko S et al., 2024).

In the context of rapid technological progress, the incorporation of artificial intelligence (AI) tools in chemistry education has become a crucial emphasis for improving teaching efficacy and student involvement. The results indicate that AI technologies, especially those employing adaptive algorithms, facilitate individualized learning experiences tailored to specific student requirements. This individualized strategy corresponds with prior research advocating for customized training to improve student outcomes (I I Supianti et al., 2025).

The work highlights the beneficial effects of AI-assisted simulations in clarifying intricate chemical concepts, corroborating findings from research in other STEM fields (P Tundo et al., 2000). Compared to conventional teaching techniques, AI technologies have shown a notable ability to enhance student comprehension by offering interactive learning experiences that stimulate interest and engagement (Wang L et al., 2024). Additionally, educators indicated enhanced efficiency in lesson preparation and grading, implying that the benefits of AI extend beyond only enhancing student learning to also reducing substantial responsibilities on teachers (Longo L et al., 2024). The problems identified in the research, particularly regarding equitable access and potential biases in AI outputs, correspond with existing literature that recommends care in the implementation of technology in education (Prather J et al., 2023). This study underscores the imperative for ongoing professional development for educators to proficiently utilize AI tools and tackle ethical issues in their implementation (Muteeb G et al., 2023). The ramifications of these discoveries are complex, offering a theoretical basis that enhances our comprehension of how AI might transform the educational domain in chemistry (Lin C-C et al., 2023). Educational institutions must acknowledge the revolutionary potential of AI in fostering flexible learning environments that accommodate varied learning styles (Faisal E, 2024).

CONCLUSION

The investigation of artificial intelligence (AI) tools in chemistry education uncovers a transforming environment that has the capacity to improve teaching efficacy and foster deeper student engagement with intricate concepts. The dissertation analyses numerous AI applications, namely adaptive algorithms and chatbots such as ChatGPT, highlighting their function in tailoring educational experiences to meet varied student demands and learning styles. The research effectively tackles the issue of inadequate student participation and the difficulties educators encounter in utilizing interactive learning methods. The study effectively illustrates that AI enhances student understanding of fundamental chemistry concepts via interactive simulations while also streamlining lesson planning and assessment for educators, thereby advocating for the incorporation of AI into chemistry curricula. The ramifications of these findings are considerable for academic practices and the wider educational framework, suggesting that the purposeful integration of AI can provide major enhancements in student learning outcomes and teacher well-being. The findings underscore the pressing necessity to confront ethical problems associated with AI utilization, equipping educators to manage the potential biases present in AI outputs, as evidenced by current literature. Future research should concentrate on longitudinal studies to evaluate the enduring effects of AI tools on Educational results and equitable access Furthermore, it is essential to investigate diverse applications of AI across various demographic and educational contexts, guaranteeing equitable distribution of the advantages of these technologies. The research advocates for interdisciplinary

cooperation among educators, technologists, and politicians to provide comprehensive rules that facilitate effective and responsible AI integration.

REFERENCES:

1) I. I. Supianti, P. Yaniawati, E. Bonyah, Astri Widiastuti Hasbiah, Nisrina Rozalini (2025) STEAM approach in project-based learning to develop mathematical literacy and students' character. Infinity Journal. doi:https://www.semanticscholar.org/ paper/96115b2f15c25ba80015dbb844d03fd587c29bea
2) P. Tundo, P. Anastas, D. Black, Joseph Breen, T. J. Collins, S. Memoli, J. Miyamoto, et al. (2000) Synthetic pathways and processes in green chemistry. Introductory overview. Volume(72), 1207 - 1228. Pure and Applied Chemistry. doi:https://www.semanticscholar.org/paper/39776f967fb97fe281a75f4f43b39c2ff82eb4c5
3) Lei Wang, Chen Ma, Xueyang Feng, Zeyu Zhang, Hao Yang, Jingsen Zhang, Zhiyuan Chen, et al. (2024) A survey on large language model based autonomous agents. Volume(18). Frontiers of Computer Science. doi: https://doi.org/10.1007/s11704-024-40231-1
4) Luca Longo, Mario Brčić, Federico Cabitza, Jaesik Choi, Roberto Confalonieri, Javier Del Ser, Riccardo Guidotti, et al. (2024) Explainable Artificial Intelligence (XAI) 2.0: A manifesto of open challenges and interdisciplinary research directions. Volume(106), 102301-102301. Information Fusion. doi: https://doi.org/10.1016/j.inffus.2024.102301
5) James Prather, Paul Denny, Juho Leinonen, Brett A. Becker, Ibrahim Albluwi, Michelle Craig, Hieke Keuning, et al. (2023) The Robots Are Here: Navigating the Generative AI Revolution in Computing Education. doi: https://doi.org/10.1145/3623762.3633499
6) Ghazala Muteeb, Md Tabish Rehman, Moyad Shahwan, Mohammad Aatif (2023) Origin of Antibiotics and Antibiotic Resistance, and Their Impacts on Drug Development: A Narrative Review. Volume(16), 1615-1615. Pharmaceuticals. doi: https://doi.org/10.3390/ph16111615
7) Chien-Chang Lin, Anna Y.Q. Huang, Owen H.T. Lu (2023) Artificial intelligence in intelligent tutoring systems toward sustainable education: a systematic review. Volume(10). Smart Learning Environments. doi: https://doi.org/10.1186/s40561-023-00260-y
8) Eman Faisal (2024) Unlock the potential for Saudi Arabian higher education: a systematic review of the benefits of ChatGPT. Volume(9). Frontiers in Education. doi: https://doi.org/10.3389/feduc.2024.1325601
9) Konstantinos T. Kotsis (2024) Correcting Students' Misconceptions in Physics Using Experiments Designed by ChatGPT. Volume(2), 83-100. European Journal of Contemporary Education and E-Learning. doi: https://doi.org/10.59324/ejceel.2024.2(2).07
10) Sedat Sonko, Adefunke Fabuyide, Kenneth Ifeanyi Ibekwe, Emmanuel Augustine Etukudoh, Valentine Ikenna Ilojianya (2024) Neural interfaces and human-computer interaction: A U.S. review: Delving into the developments, ethical considerations, and future prospects of brain-computer interfaces. Volume(11), 702-717. International Journal of Science and Research Archive. doi: https://doi.org/10.30574/ijsra.2024.11.1.0111
11) Dana-Mihaela Petroşanu, Alexandru Pîrjan, Alexandru Tăbuşcă (2023) Tracing the Influence of Large Language Models across the Most Impactful Scientific Works. Volume(12), 4957-4957. Electronics. doi: https://doi.org/10.3390/electronics12244957
12) Reem Hashem, Nagla Ali, Farah El Zein, Patrícia Fidalgo, Othman Abu Khurma (2023) AI to the rescue: Exploring the potential of ChatGPT as a teacher ally for workload relief and burnout prevention. Volume(19), 023-023. Research and Practice in Technology Enhanced Learning. doi: https://doi.org/10.58459/rptel.2024.19023
13) Joon Sung Park, Joseph O'Brien, Carrie J. Cai, Meredith Ringel Morris, Percy Liang, Michael S. Bernstein (2023) Generative Agents: Interactive Simulacra of Human Behavior. doi: https://doi.org/10.1145/3586183.3606763
14) Juan Dempere, Kennedy Prince Modugu, Allam Hesham, Lakshmana Kumar Ramasamy (2023) The impact of ChatGPT on higher education. Volume(8). Frontiers in Education. doi: https://doi.org/10.3389/feduc.2023.1206936
15) Zied Bahroun, Chiraz Anane, Vian Ahmed, Andrew Zacca (2023) Transforming Education: A Comprehensive Review of Generative Artificial Intelligence in Educational Settings through Bibliometric and Content Analysis. Volume(15), 12983-12983. Sustainability. doi: https://doi.org/10.3390/su151712983
16) Malik Sallam (2023) ChatGPT Utility in Healthcare Education, Research, and Practice: Systematic Review on the Promising Perspectives and Valid Concerns. Volume(11), 887-887. Healthcare. doi: https://doi.org/10.3390/healthcare11060887
17) Malik Sallam (2023) The Utility of ChatGPT as an Example of Large Language Models in Healthcare Education, Research and Practice: Systematic Review on the Future Perspectives and Potential Limitations. medRxiv (Cold Spring Harbor Laboratory). doi: https://doi.org/10.1101/2023.02.19.23286155
18) Yupeng Chang, Xu Wang, Jindong Wang, Yuan Wu, Linyi Yang, Kaijie Zhu, Hao Chen, et al. (2024) A Survey on Evaluation of Large Language Models. Volume(15), 1-45. ACM Transactions on Intelligent Systems and Technology. doi: https://doi.org/10.1145/3641289
19) Bikram Jit Singh, Ayon Chakraborty, Rippin Sehgal (2023) A systematic review of industrial wastewater management: Evaluating challenges and enablers. Volume(348), 119230-119230. Journal of Environmental Management. doi: https://doi.org/10.1016/j.jenvman.2023.119230
20) Yiheng Liu, Tianle Han, Siyuan Ma, Jiayue Zhang, Yuanyuan Yang, Jiaming Tian, Hao He, et al. (2023) Summary of ChatGPT-Related research and perspective towards the future of large language models. Volume(1), 100017-100017. Meta-Radiology. doi: https://doi.org/10.1016/j.metrad.2023.100017
21) TABLE 2 Aloys Iyamuremye, Francois Niyongabo Niyonzima, Janvier Mukiza, Innocent Twagilimana, Pascasie Nyirahabimana, Theophile Nsengimana, Jean Dieu Habiyaremye, Olivier Habimana, Ezechiel Nsabayezu (2024). Utilization of artificial intelligence and machine learning in chemistry education: a critical review. *Discover Education*. Retrieved from https://link.springer.com/article/10.1007/s44217-024-00197-5.
22) TABLE 3 The Science Teaching Survey (2024). The Science Teaching Survey. **. Retrieved from https://www.rsc.org/policy-evidence-campaigns/chemistry-education/education-reports-surveys-campaigns/the-science-teaching-survey/2024/44-of-teachers-have-used-ai-but-workload-remains-unchanged/*
23) Enhancing Chemistry Learning with ChatGPT, Bing Chat, Bard, and Claude as Agents-to-Think-With: A Comparative Case Study. **. Retrieved from https://arxiv.org/abs/2311.00709*
24) Karen D. Wang, Zhangyang Wu, L'Nard Tufts II, Carl Wieman, Shima Salehi, Nick Haber (2024). Scaffold or Crutch? Examining College Students' Use and Views of Generative AI Tools for STEM Education. *arXiv*. Retrieved from https://arxiv.org/abs/2412.02653*Note.*
25) Shiyan Jiang, Jeanne McClure, Jiahui Chen, Yunshu Liu, Yang Zhang (2023). Integrating Machine Learning and Color Chemistry: Developing a High-School Curriculum Towards Real-World Problem-Solving.,Retrieved from https://news.ncsu.edu/blog/2023/12/07/ai-color-chemistry-module
26) Framework for Integrating ChatGPT in Higher Education [Image 1]. (2025). Retrieved https://pub.mdpi-res.com/education/education-00856/article_deploy/html/images/education-13-00856-g001.png?1692771665