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Exploring The Role of ChatGPT in Chemistry Learning: A Systematic Literature Review

Danang Priyadi[1*], Suyanta[1], Suwardi[1], Illyas Md. Isa[2]

[1]Faculty of Mathematics and Natural Sciences, Yogyakarta State University, Yogyakarta, Indonesia
[2]Department of Chemistry Faculty of Science & Mathematics, Universiti Pendidikan Sultan Idris, Perak, Malaysia

*Corresponding author's email: danangpriyadi.2024@student.uny.ac.id

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Abstract. This study used the systematic literature review method to analyze the contribution of chatGPT in chemistry education by reviewing 30 related articles. The results showed that chatGPT assists in various learning tasks, such as preparing lesson plans, assessing students' critical thinking and self-regulation skills, guiding practical sessions, and supporting scientific report writing. In addition, chatGPT plays a role in the development of technology-based teaching materials and explaining complex chemical concepts. However, there are challenges in its implementation, such as the potential for students to rely on AI and the need for information verification to ensure the accuracy of scientific concepts. Therefore, in order for chatGPT to remain a useful tool in chemistry learning, it must be accompanied by the right strategy. With appropriate guidance, this technology can increase student interaction and engagement, thereby contributing to improving the quality of chemistry teaching in the digital era.
Keywords: ChatGPT, artificial intelligence, chemistry learning

Introduction

In many spheres of human life, including the sphere of education, the digital revolution has brought significant changes (Akavova et al., 2023). Challenges such as the increasing number of students, limited teacher resources, and the need for more personalized learning drive innovation in education (Gupta et al., 2024; Cheng & Wang, 2023). With its capacity to offer more individualized and adaptive learning, artificial intelligence (AI) has become one of the interesting remedies (Kavitha et al., 2024; Hepp et al., 2015). In recent years, advancements in artificial intelligence (AI) have had a significant impact in various fields, including education. AI technology offers the possibility to enhance the way we teach and learn by creating more personalized learning experiences tailored to students' needs. ChatGPT, a huge language model competent for engaging with people intelligently and naturally, is one of the AI technologies under current focus (Chen et al., 2023; Alshahrani, 2023; Hatmanto & Sari, 2023).

Developed by openAI, chatGPT (generative pre-trained transformer) is an artificial intelligence model grounded on natural language processing (natural language processing). This model uses a deep learning architecture to understand, respond to, and generate text in various contexts in a contextual and relevant manner. This technology was released for public use on November 30, 2022, and since the publication of this communication, chatGPT has been free for public use (Fergus et al., 2023; Roumeliotis & Tselikas, 2023 Rajala et al., 2023). Using extensive text data from several sources, chatGPT has been trained to respond to inquiries, offer explanations, and support many text-based activities, particularly in the field of education (Javaid et al., 2023; Seo et al., 2021). Its ability to understand natural language and provide context-based responses makes it a potential tool for supporting the learning process (Hasrod et al., 2024).

Given that chemistry is sometimes regarded as a difficult and abstract subject, chatGPT has a lot of potential to be a useful teaching tool. More thorough explanations of chemistry ideas, practice questions catered to each student's needs, and immediate, individualized feedback are all possible with this language paradigm (Taagepera & Arasasingham, 2013; Leite, 2023; Fonseca, 2024). Students can independently research fascinating subjects and receive prompt, accurate responses to their queries thanks to chatGPT's capacity to access and interpret vast volumes of data. Additionally, through interactive discussions, text-based simulations, and the distillation of difficult ideas into simpler forms, chatGPT can assist students in comprehending chemical phenomena (Ardyansyah et al., 2024).

Though chatGPT has several advantages, its application in chemistry education is still quite fresh and calls for more study. The veracity of the data generated, the model's possible bias, and the morality of utilizing AI in education are a few issues that must be taken into account (Araújo & Saúde, 2024) . Furthermore, it's critical to think about how to use chatGPT with current teaching strategies and make sure that this technology enhances rather than replaces the job of teachers. To successfully integrate AI technology into education, several stakeholders, including educators and educational institutions, must be prepared in terms of training and technological knowledge (Yue et al., 2024; Bettayeb et al., 2024).

This research aims to fill that gap by conducting a systematic review of the existing literature, thereby obtaining a more comprehensive understanding of the role of chatGPT, particularly in chemistry education. This study will identify the different applications of chatGPT in chemistry teaching, as well as the problems and opportunities that arise during implementation. By answering these questions, this research is expected to provide broader insights into the utilization of chatGPT in chemistry education and offer recommendations for educators and researchers in developing effective and ethical AI-based learning innovations.

Methods

This study investigates the use of chatGPT in chemistry education using a methodical literature review approach. This method was used because it enables a thorough examination of numerous earlier research projects, offering a thorough summary of chatGPT's application in the context of chemical instruction.

The literature selection process was conducted by collecting articles from the scopus database, with inclusion criteria that included discussions on the application of chatGPT in education, specifically in chemistry learning, as well as publications within the last five years (2020–2025). Articles that did not pertain to chemistry or scientific education, for example, were not included in the analysis. To make sure that only reliable and pertinent studies are incorporated in the synthesis of the literature review, the literature that cuts is next assessed according to the calibre of the methodology and the precision of the research findings.

The following are guidelines for inclusion and exclusion criteria in selecting journals to be analyzed:

Table 1. List of inclusion and exclusion criteria guidelines for journal selection

Criteria Inclusion	Criteria Exclusion
Articles focused on the application of chatGPT (science)	Articles that focus outside on the implementation of chatGPT (science)
Articles that can be accessed	Articles that cannot be accessed
Full article	Articles that do not include empirical data or implementation descriptions.

Following data collection, thematic analysis and narrative synthesis techniques were used to examine the chosen articles (Liu, 2024). As part of this procedure, publications about the use of chatGPT in chemistry teaching are grouped according to their subjects, approaches, and key conclusions. A review of the literature is done to determine the quality and applicability of the research as well as chatGPT's potential to improve chemistry education. 30 pertinent journals were chosen from the selection results for additional examination to offer comprehensive insights into the incorporation of chatGPT into the chemistry curriculum and its effects on student comprehension.

The following is a description of the stages in the systematic literature review (SLR) research in this study (Pati & Lorusso, 2018):

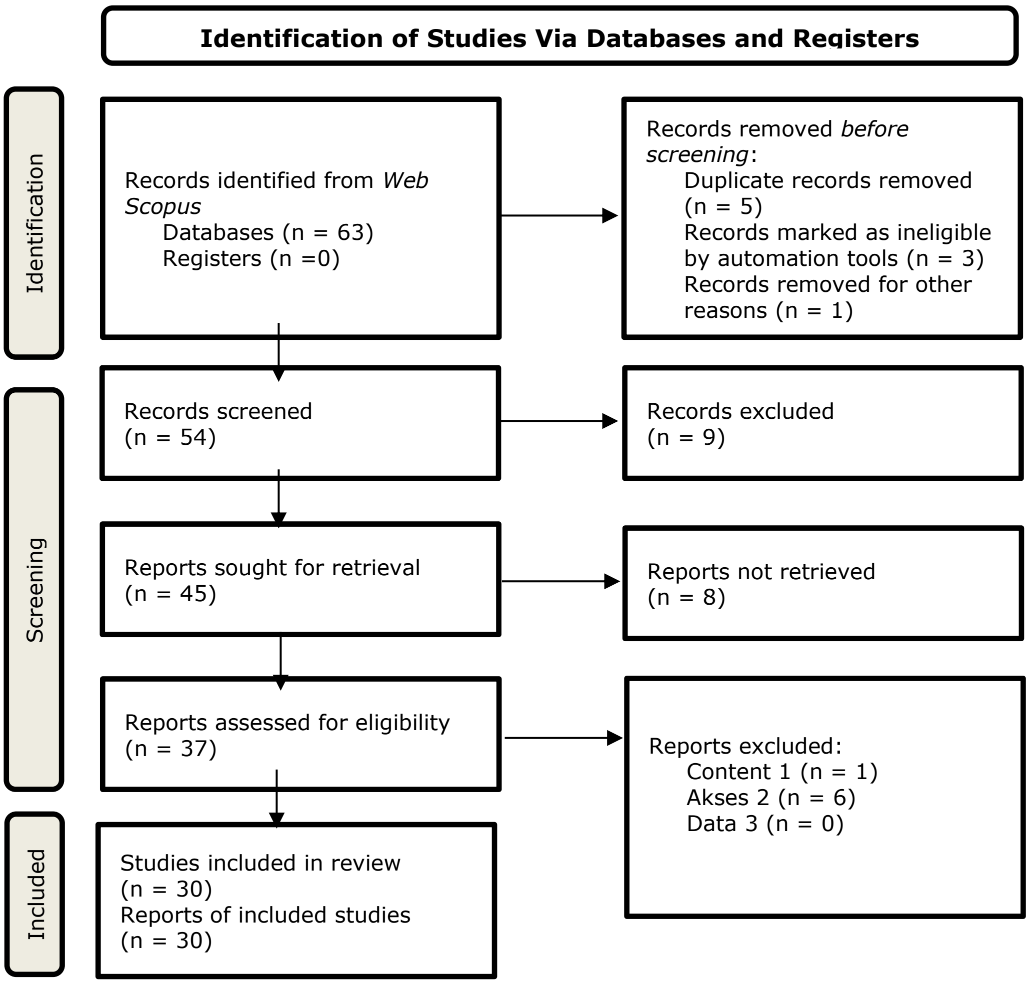

Figure 1. Prisma flow diagram of the study selection process

Results and Discussion

The results of this study present findings that address the problem formulation related to the use of chatGPT in the researched context. This research evaluates how chatGPT provides answers, the level of accuracy, and its limitations in supporting the learning or analysis conducted. These findings are also compared with previous literature to understand the advantages and challenges in the application of chatGPT in the studied field. Here is the list of research journals reviewed, detailed in Table 2.

Table 2. List of reviewed articles

Code	Writer	Focus ChatGPT Discussion
A1	(Bazzari & Bazzari, 2024)	Evaluation of GPT-4o in recognizing drugs and providing patient education.
A2	(Elmas et al., 2024)	Analysis of the validity of chatGPT answers to biochemical questions and its limitations.
A3	(Lee et al., 2024)	Evaluation of GCLA in supporting SRL and HOTS with hints, not direct answers, in blended learning chemistry.
A4	(Nascimento et al., 2024)	Evaluation of the accuracy of text and chemical image recognition of chatGPT 4.0 compared to other GAIs.
A5	(Ruff et al., 2024 a)	Evaluation of the accuracy of the chatGPT chemistry method, especially green chemistry, and its impact on students' critical thinking.
A6	(Ramos & Condotta, 2024)	Evaluation of chatGPT's role in the provision of data and scenarios simulation for PBL in engineering chemistry.
A7	(Sorenson & Hanson, 2024)	Analysis of chatGPT behaviour in exams using Rasch models to identify patterns of AI use in chemistry education.
A8	(Bruno Silva, 2024)	Testing the capabilities of chatGPT, gemini, and copilot in defining basic chemistry concepts and assessing their potential as digital resources in education.
A9	(Ruff et al., 2024b)	Assessing the effectiveness of chatGPT in revising chemistry texts and improving students' understanding of report structure.
A10	(Yik & Dood, 2024)	Assessing the accuracy of chatGPT explanations of chemical reaction mechanisms and the influence of prompt engineering on their quality.
A11	(Araújo & Saude, 2024)	Evaluate chatGPT's ability to develop scientific, safe, and sustainable chemistry laboratory plans for students.
A12	(Geetha et al., 2024)	Assessing the performance of chatGPT in clinical pathology and anatomy and its effectiveness in answering questions of varying difficulty levels.
A13	(Hasrod et al., 2024)	ChatGPT for GUI feedback and Anaconda-Jupyter guidance for chemistry students.
A14	(Park & Martin, 2024)	Limitations of chatGPT in scientific concepts, critical thinking development, and AI ethics in science classrooms.

A15	(Taniguchi & Lindsey, 2024)	Chatbot limitations in answer accuracy, especially related to dyes and fluorophores, and the need for domain expert expertise.
A16	(Yuliia & Babenko, 2024)	ChatGPT is suitable for simple tasks but weak in complex chemical concepts and logic.
A17	(Sallam et al., 2024)	Evaluation of chatGPT 3.5 and 4 performance in clinical chemistry exam and comparison with bing and bard in higher education.
A18	(Fonseca, 2024)	Application of chatGPT in chemistry education and the challenges of answer accuracy and verification.
A 19	(Lee & Zhai, 2024)	ChatGPT integration in science lesson plans, evaluation with TPACK rubric, and pre-service teachers' perceptions and concerns regarding students' accuracy and dependability.
A20	(Farhat et al., 2024)	Comparison of the performance of GPT-3.5 and GPT-4 in the NEET exam, assessing accuracy, consistency of answers, and the potential of GPT-4 in education.
A21	(Akhtom et al., 2023)	ChatGPT's ability to generate titles according to criteria and the influence of synonyms on the diversity and relevance of cross-disciplinary titles.
A22	(West et al., 2023)	Analysis of chatGPT's capabilities in generating laboratory reports and its impact on education.
A23	(Janamala et al., 2023)	ChatGPT's potential in medical telecommunications efficiency and sustainability.
A24	(Leon & Vidhani, 2023)	Analysis of chatGPT's effectiveness in responding to various prompt formats and assessing its accuracy, consistency, and reliability.
A25	(Tyson, 2023)	Evaluation of chatGPT as a literature search tool in chemistry education and its limitations in concept and calculation.
A26	(Humphry & Fuller, 2023)	Analysis of the use of chatGPT in writing practical report discussions and its detection methods.
A27	(Fergus et al., 2023)	Assessing chatGPT's capabilities in terms of understanding the application and its limitations in non-text.
A28	(Kunitsu, 2023)	Assessing the capabilities of GPT-4 in pharmacy exams and its limitations on diagrams, specialist questions, and calculations.
A29	(Hallal et al., 2023)	Assessing chatGPT's performance on organic chemistry tasks and comparing it with Bard and GPT-4.
A30	(Leite, 2023)	Assessing chatGPT in chemistry teaching and its role in supporting critical thinking and ethical use.

Based on the results of the analysis of 30 journals studied, several key findings were found that show the role of chatGPT in chemistry and chemistry learning. From the 30 journals analyzed, here are the details of the findings related to the role of chatGPT based on the results of the review conducted:

Identification of the Use of ChatGPT in Chemistry Learning

In the current digital era, the use of artificial intelligence technology, particularly chatGPT, has permeated the world of education, including the field of chemistry. Based on the review that has been conducted, the use of chatGPT in chemistry education is divided into two groups. Various studies (with codes A3, A5, A6, A7, A9, A10, A11, A12, A14, A16, A19, A22, A28, and A30) demonstrate how chatGPT can be integrated into various aspects of learning to support teaching and enhance student understanding.

Based on the journal classification, ChatGPT has been used in various aspects of chemistry learning. Research A3 by Lee et al., (2024) shows that chatGPT can support independent learning skills and HOTS in blended learning. Further studies on guidance-based chatGPT assisted learning aid (GCLA) confirm that this guidance-based approach effectively enhances self-regulated learning (SRL) and HOTS. By encouraging students to solve problems independently before seeking help from ChatGPT, GCLA creates a more interactive and in-depth learning experience, thereby enhancing students' critical thinking skills and self-regulation. Additionally, research A5 by Ruff et al. (2024a) also reveals that chatGPT is capable of presenting innovative approaches in chemistry education, particularly in the application of green chemistry concepts that encourage students to think critically. Although chatGPT still provides less accurate answers and minimal references, its use remains a valuable exercise in helping students critically evaluate experimental methods and AI outputs. Additionally, the anonymous survey accompanying this research indicates that students' perceptions of chatGPT and AI technology vary depending on the purpose of its use. Thus, this is the same as the research conducted by Sharma (2024) and Qawqzeh (2024) that chatGPT not only acts as an aid, but also as a means to equip students with the critical thinking skills needed to face challenges in the real world.

ChatGPT also plays a role in material development and activity planning. Research A19 by Lee & Zhai (2024) discusses the integration of chatGPT in science lesson planning and its evaluation using the TPACK rubric. This study reveals that although chatGPT can assist in creating more structured and interactive lesson plans, prospective teachers still have concerns regarding the accuracy of information and the potential for student dependency. These findings indicate that chatGPT can be an effective supportive tool in lesson planning, but it still requires monitoring to ensure the quality and validity of the generated materials (Hashem et al., 2023; Elsayary, (2024).

Evaluation in the context of exams is also one of the aspects that receive attention through the integration of chatGPT. Study A7 by Sorenson & Hanson (2024) uses the rasch model to detect usage behaviour patterns of chatGPT during exam administration, providing a clear picture of how AI technology can be integrated into formal evaluation systems. This is important to ensure that the use of chatGPT in exams does not disrupt the integrity of the assessment process. Additionally, chatGPT is also utilized in answering test questions. In the A12 study by Geetha et al. (2024), it was shown that chatGPT can be used to answer test questions, where the research results indicate that chatGPT's effectiveness in answering questions varies greatly based on the level of difficulty, with the highest score on easy questions (68.47%), decreasing on medium questions (52.88%), and the lowest on difficult questions (37.21%). These findings indicate that chatGPT can function as an aid in creating more interactive and relevant materials, but it still requires supervision to ensure the accuracy of the information provided.

In the context of chemistry practicals, the application of ChatGPT increasingly demonstrates its advantages by assisting in the preparation of scenarios and providing real-time technical feedback.Research A11 by Araújo & Saúde (2024) emphasizes chatGPT's ability to develop safe and sustainable laboratory activity plans, which is crucial in the context of responsible chemistry education. Through A6 by Ramos & Condotta (2024), chatGPT is used to provide data and simulation scenarios that support problem-based learning (PBL) in the field of chemical engineering. Research A16 by Yuliia & Babenko (2024) emphasizes that chatGPT is capable of providing feedback during the use of software such as anaconda navigator and jupyter notebook, thereby helping students overcome technical obstacles without needing deep programming expertise. Furthermore, the integration of chatGPT in chemistry education also includes the preparation of laboratory reports and understanding of reaction mechanisms. Research by Ruff et al. (2024) shows that chatGPT can assist students in revising and structuring chemistry lab reports more systematically, which in turn enhances their understanding of the concepts being studied. Additionally, research by Yik & Dood (2024) highlights the role of chatGPT in explaining chemical reaction mechanisms, where the quality of the generated responses highly depends on the prompt engineering strategy. With proper utilization, chatGPT can become an effective tool in facilitating the understanding of complex chemistry concepts, especially in interpreting experimental data and presenting information more systematically. However, it is important to ensure that its use remains directed and supported by scientific validation to avoid conceptual errors (Ghazali, 2024).

In addition, chatGPT has also been widely used in various fields, not only in chemistry education but also in broader applications including clinical chemistry, biochemistry, and even the medical field. Various studies (with codes A1, A2, A4, A8, A15, A19, A20, A25, A29, A30, A34, A35, and A36) show that this technology has great potential in assisting data analysis, solving complex problems, and improving efficiency in various chemistry-based processes. Overall, the integration of chatGPT in chemistry education opens up great opportunities for innovation in the world of education. With roles that include material development, concept comprehension enhancement, practical application, and exam evaluation, chatGPT is capable of making significant contributions to creating a more interactive and adaptive learning process. This technology enables educators to design more engaging and relevant teaching materials, as well as provide students with access to information and assistance in real time. This is very beneficial in supporting independent learning, where students can explore topics in-depth and seek answers to their questions at any time (Alnaim et al., 2024).

ChatGPT also is a useful tool for organizing events and offering insightful comments. With its ability to generate curriculum-aligned content, chatGPT can assist educators in designing safe and sustainable laboratory activities, as well as support students in revising and improving their reports. Thus, chatGPT not only enhances the quality of teaching but also enriches students' learning experiences, making it a valuable tool in chemistry education in the digital era (Vargas-Murillo et al., 2023).

Challenges in ChatGPT Implementation

Accuracy of Information and Verification by Teachers

One of the main challenges in using chatGPT in learning is the need to verify the accuracy of the information generated. Although AI can provide quick and easily accessible responses, the accuracy of the generated answers remains a primary concern. Research conducted by Park & Martin (2024) emphasizes that educators need to validate the information provided by chatGPT before using it in the learning process. This is important because chatGPT still has limitations in distinguishing between valid and inaccurate information, especially in complex scientific concepts.

In line with that research, Osama et al., (2023) found that although chatGPT can present scientific data quickly, there are still errors in the interpretation of deeper concepts. Additionally, study A18 by Fonseca (2024) highlights that although chatGPT is capable of providing accurate answers to questions with low to moderate difficulty levels, this technology still faces limitations in solving problems that require deeper conceptual understanding. This indicates that the role of educators remains crucial in ensuring the accuracy of the information provided by AI and in guiding students in interpreting and confirming the generated answers (Osama et al., 2023). Thus, the application of chatGPT in chemistry education requires a strategy that prioritizes systematic verification and evaluation of answers so that its use can truly support learning effectively (Dimeli & Kostas, 2025).

With the presence of this challenge, appropriate mitigation strategies are needed, such as using chatGPT as an exploratory tool that is still supervised by instructors, as well as developing artificial intelligence systems that are more transparent in presenting information sources. Furthermore, further research is needed to enhance chatGPT's ability to provide more accurate and evidence-based answers, so that this technology can be more reliable in the context of formal education.

ChatGPT in Academic Evaluation and Integrity

In addition to the challenges in information accuracy, the use of chatGPT in academic evaluation also raises debates regarding the integrity of the assessment process. Sorenson & Hanson (2024) research used the rasch model to analyze the usage patterns of chatGPT during exams. The results of this study indicate that there are signs of AI utilization that could affect the validity of evaluations, especially in tasks based on higher-order thinking skills (HOTS). This raises concerns about the extent to which chatGPT can be integrated into formal evaluation systems without compromising the objectivity of the assessment.

As a comparison, the study by Patac & Patac (2025) also found that the use of chatGPT in exams can enhance students' understanding of solving problem-based questions, but on the other hand, there is a potential increase in dependence on AI. This is in line with the findings reported by A19 Lee & Zhai (2024), where although ChatGPT can assist in lesson planning and completing simple tasks, there are still limitations in handling questions that require deep understanding.

A number of research offers answers to this problem, such as the creation of adaptive assessment tools that can gauge students' comprehension of the subject matter without unduly depending on artificial intelligence (Duque-Méndez et al., 2020). Furthermore, project-based learning and performance evaluations prove to be more successful options than only depending on text-based tests or multiple-choice questions (Zhang & Ma, 2023). A more well-rounded strategy would allow chatGPT to continue serving as a helpful assessment tool without sacrificing students' academic integrity or the uniqueness of their responses.

Ethics of Using ChatGPT in Education

In addition to issues of accuracy and evaluation integrity, ethical aspects of using chatGPT in academic settings are also a major concern. Yuliia & Babenko (2024) research emphasizes that the use of AI in learning must be conducted with full responsibility and ethics. One of the main challenges is how to ensure that students do not just use chatGPT as a tool to complete tasks instantly without understanding the underlying concepts. In another study, Hung & Chen (2023) found that although chatGPT can help improve learning efficiency, there is a risk of misuse, especially in academic tasks that require critical thinking and originality. This is reinforced by the findings of (Matsubara, 2024), which show that some students tend to use chatGPT to compose essays and reports without further reflection or analysis. Therefore, clear policies regarding the limitations and guidelines for the use of AI in the educational world are necessary (Ogugua et al., 2023).

As a solution, several studies suggest that educational institutions should develop an AI usage code of ethics that includes transparency in its use, limitations on certain academic tasks, and encouragement to use chatGPT as a learning support tool, not as a substitute for critical thinking (Contreras & Jaimes, 2024). Additionally, an AI literacy-based approach is also important to implement so that students understand how AI works and the consequences of excessive dependence on this technology (Nganji et al., 2024). Thus, chatGPT can be utilized optimally without violating academic ethical principles.

The Need for Clear Guidelines for Using ChatGPT in Learning

With the increasing use of chatGPT in the field of education, clear guidelines are needed so that this technology can be utilized effectively and responsibly. Yulia & Babenko (2024) research emphasizes that without proper regulations, the use of chatGPT can create gaps in understanding among students, especially if there is insufficient guidance from educators.

In another study, Talaue (2023) highlighted that the lack of clear policies can lead to significant variations in how students use chatGPT, potentially resulting in academic unfairness. Some students might use chatGPT only as an aid, while others rely on it entirely to complete tasks without any further effort to understand. This is reinforced by the research of Funa & Gabay (2025), which found that educational institutions that implement specific guidelines in the use of AI tend to have better learning outcomes compared to institutions that do not have strict regulations.

As a mitigation step, several studies recommend the development of policies that include restrictions on the use of chatGPT in various types of academic tasks, monitoring strategies by educators, and the integration of AI literacy into the curriculum (Cotton et al., 2024; Ghimire & Edwards, 2024). Additionally, training for educators is necessary so that they can optimally utilize chatGPT in supporting learning without compromising academic principles (Ratten & Jones, 2023). With clear regulations in place, chatGPT can become a tool that enriches the learning process without replacing the primary role of educators and direct interaction in the classroom (Ghimire & Edwards, 2024). Overall, although the implementation of chatGPT in education faces various challenges, such as information accuracy, student dependency, and ethical and regulatory aspects, this technology still offers great opportunities in enhancing learning and evaluation. The accuracy of information that still needs to be verified by educators demands stricter oversight strategies, while the challenge related to student dependency indicates the need for an approach that encourages the critical use of chatGPT and not as the sole learning resource. Additionally, clear regulations and guidelines are crucial to ensure that the use of chatGPT remains within the bounds of ethical and fair academic practices.

As a recommendation, educational institutions need to develop policies that ensure the use of chatGPT supports the learning process without replacing students' analytical thinking. Educators can utilize this AI as an aid in interactive learning, such as providing feedback on lab reports or helping students understand complex chemistry concepts. In addition, training for teachers in AI literacy is also necessary so that they can optimize its use while maintaining control over the learning process.

With the right approach, chatGPT can become a valuable tool in chemistry education, helping students develop critical thinking skills and creating a more adaptive and innovative learning environment. Therefore, educators and researchers need to continue exploring the best strategies for effectively and ethically integrating AI. Through further research and sharing best practices, the utilization of chatGPT in education can be optimized, providing significant benefits to students and educators, and fostering a more dynamic educational transformation in the digital era (Kim & Adlof, 2024).

Conclusion

Based on the analysis of 30 reviewed journals, it can be concluded that chatGPT plays a significant role in chemistry education, ranging from enhancing students' critical thinking and self-regulation skills, lesson plan preparation, exam evaluation, to assisting in practical sessions and scientific report writing. ChatGPT also helps in explaining complex chemistry concepts and supports the development of technology-based teaching materials. However, its implementation still faces challenges, particularly regarding the accuracy of the information provided, necessitating validation by educators to ensure alignment with correct scientific concepts. Additionally, there are concerns about the potential dependency of students on AI, so a balanced usage strategy is needed to ensure that this technology remains an effective tool without diminishing learning independence. Overall, with proper supervision and usage, chatGPT in chemistry education offers great opportunities for innovation in the field of education. This technology can be a solution that supports more interactive, adaptive, and technology-based learning, thereby enhancing the quality of chemistry education in the digital era.

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