AT-TAKLIM : Jurnal Pendidikan Multidisiplin E-ISSN : 3062-9489
https://journal.hasbaedukasi.co.id/index.php/at-taklim
Halaman: 38-46

INTEGRATION OF CHATGPT IN HIGH SCHOOL CHEMISTRY EDUCATION: AN EXPLORATORY STUDY ON THE USE OF AI BY TEACHERS AND STUDENTS

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Keywords

Artificial Intelligence, ChatGpt, Chemistry Learning, Prompt Engineering.

Abstract

The rapid development of artificial intelligence technology has opened new opportunities for transforming learning in various disciplines, including chemistry. Given the urgency of increasing digital literacy and the need for adaptive learning resources, the utilization of ChatGPT as a learning tool at the high school level is an important topic to examine. This study explores how teachers and students use ChatGPT in the chemistry learning process, identifying the benefits, challenges, and pedagogical applications of its use. An exploratory qualitative case study design was used, involving two teachers and ten students. Data were collected through semi-structured interviews, observation, and documentation and analyzed thematically. The results showed that ChatGPT was used as a partner for clarifying concepts, a tool for preparing questions, and a medium for reflecting on learning. However, optimal use was limited by students' low skill level in composing appropriate prompts and teachers' limited ability to validate information from AI. This study concludes that integrating ChatGPT into chemistry education positively impacts concept understanding and independent learning but requires pedagogical intervention, such as AI literacy training and developing critical and reflective learning strategies. This study contributes to the theoretical development of AI integration in science education, offering practical recommendations for developing teacher and student competencies in effectively and responsibly utilizing technology.

1. INTRODUCTION

In the digital age, high school chemistry education often faces challenges such as the complexity of abstract concepts, time constraints, and limited interaction between teachers and students (Prastika et al., 2024). Globally, generative AI, such as ChatGPT, is being integrated into STEM classrooms, including chemistry, to provide real-time explanations, personalized feedback, and reinforcement of conceptual understanding (Disciplinary and Interdisciplinary Science Education Research [DISER], 2025; dos Santos, 2023). For instance, a pilot program at David Game College in London revealed that ChatGPT improves independent learning in GCSE chemistry (Business Insider, 2024). In Indonesia, although AI implementation is in its early stages and faces infrastructure challenges and limitations in teacher training, its potential to enrich students' learning experiences in an adaptive and interactive manner is significant (Prastika et al., 2024). Djarwo et al. (2024) emphasize that students' digital literacy significantly influences chemistry learning outcomes and that the use of technologies like ChatGPT must be critically and structurally guided to meaningfully contribute to scientific understanding.

Several studies have revealed the positive impact of ChatGPT on the motivation and understanding of chemistry concepts among African students (Babalola et al., 2023) and on chemistry teaching through AI storytelling in tenth-grade classes in Bandung (Nugraha & Harsono, 2024). However, research on the critical use of ChatGPT by Indonesian high school teachers and students is still very limited. While Dos Santos's (2023) study found ChatGPT to be effective as an "agent to think with" in a constructivist context, it has yet to examine the pedagogical interactions between teachers and students and the prompt engineering strategies used in the learning process in detail. Conversely, Lee and Zhai (2024) demonstrate that prospective science teachers can integrate TPACK into ChatGPT-based lesson planning; however, the focus is not on its implementation in the classroom. These gaps highlight the importance of researching how ChatGPT is utilized in chemistry classrooms and how technological literacy determines its effectiveness.

This study aims to explore how high school teachers and students use ChatGPT for chemistry learning, analyze the prompt engineering strategies they use to optimize learning, and convey their perceptions and the challenges they face when integrating AI into learning. The study primarily focuses on observing actual practices and user interactions with technology in the context of secondary school learning.Theoretically, this research contributes to the development of an AI-based TPACK model in the context of secondary-level chemistry learning while enriching the literature on agent-to-think-with and prompt-based learning approaches (dos Santos, 2023; Lee & Zhai, 2024). In practice, the findings of this study are expected to inform educational policies related to teacher training, AI literacy curriculum development, and technology integration in science education. Thus, schools, teachers, and policymakers can use the results of this research to develop adaptive, ethical, and contextual AI-based chemistry learning strategies.

LITERATURE REVIEW

TPACK and Expansion Towards AI TPACK

The TPACK (Technological Pedagogical Content Knowledge) model, developed by Mishra and Koehler (2006), posits that teachers' effectiveness in utilizing learning technology hinges on the integration of three key knowledge domains: pedagogy, content, and technology. The TPACK model is widely used in science and chemistry education to evaluate teachers' preparedness for adopting educational technology (Ali et al., 2024; Ning et al., 2024). Recently, this framework has expanded to include AI TPACK, incorporating elements of artificial intelligence literacy, AI ethics, and prompt engineering skills (Xie & Luo, 2025; Ning et al., 2024).

GenAI as an "Agent to Think With" and Constructivist Learning

Within the constructivist framework, ChatGPT can serve as an agent to think with, helping students build understanding through reflective dialogue and concept exploration. Dos Santos (2023) demonstrated that using ChatGPT and Bing Chat in chemistry encourages critical thinking and active knowledge construction through prompt-based interactions. Polverini et al. (2024) added that ChatGPT can strengthen the Socratic dialogue approach in science teacher education, indicating the role of AI as a thinking partner in the learning process.

Social Learning Theory and Collaborative Learning

According to Vygotsky's (1978) theory of the Zone of Proximal Development (ZPD), effective learning occurs through social interaction between learners and individuals who are more knowledgeable. In the context of AI-assisted learning, ChatGPT can serve as digital scaffolding, supporting collaboration and facilitating two-way dialogue. As the study by Ali et al. (2024) explains, using generative AI reinforces the principles of technology-based collaborative learning (Computer-Supported Collaborative Learning/CSCL). In this model, students interact with machines as mediators to understand chemistry concepts.

Inquiry-Based Learning and Strengthening Core Chemistry Competencies

Meaningful chemistry learning requires an inquiry-based approach, especially when building an understanding of microscopic concepts, symbolic representations, and scientific skills. Wei et al. (2025) developed a chemistry learning model based on three domains—ontological, epistemological, and axiological—which emphasizes the importance of developing core chemistry competencies, such as chemical thinking, scientific practice, and scientific values. In this context, integrating ChatGPT helps students formulate questions, test hypotheses, and reflect on results independently and critically.

2. RESEARCH METHOD

This study employs an exploratory, qualitative approach. This approach allows for an in-depth analysis of how high school chemistry teachers and students use ChatGPT. Data were collected through source triangulation (interviews, observations, and documentation) to enrich the context and credibility of the findings (Creswell & Creswell, 2018).

The study population includes chemistry teachers and students from two of the top high schools in Jayapura City. The sample was selected using non-probability purposive sampling with the following criteria: (a) teachers with at least five years of experience using digital technology and (b) 11th grade students who have used ChatGPT actively for at least one month. The sample size consisted of two teachers and ten students.

Data collection was conducted through:

1. Semi-structured interviews developed from previous studies with 15–20 items and validated for content validity by a panel of chemistry education experts (Gill et al., 2008).
2. Participatory observation of students' ChatGPT interactions in a chemistry class.
3. Documentation of prompt artifacts, ChatGPT responses, and instructional materials.

The data were analyzed using a thematic procedure involving transcription, open coding, axial coding, and identification of main themes (Braun & Clarke, 2006). NVivo 15 was used to facilitate coding, theme network visualization, and query coding. The findings were reviewed through peer debriefing and member checking to ensure the confirmability and credibility of the research results (Lincoln & Guba, 1985). This procedure was conducted systematically, from instrument design to final reporting, in accordance with standards for qualitative academic research.

3. RESULTS AND DISCUSSION

This study explores the use of ChatGPT for chemistry learning among high school teachers and students. Based on interviews with two teachers and ten students, as well as observations and documentation, several key findings were obtained regarding how users interact with ChatGPT, their perceptions of its benefits and challenges, and its impact on the chemistry learning process.

First, all students utilize ChatGPT as a source of clarification for challenging topics such as chemical bonding, redox reactions, and molecular structure. ChatGPT is considered capable of simplifying explanations and providing varied example questions, thereby helping students understand concepts taught by teachers more deeply. These results reinforce the social constructivist framework (Vygotsky), which emphasizes the importance of scaffolding in learning. In this context, ChatGPT acts as an "agent to think with" (dos Santos, 2023). Teachers also stated that ChatGPT expands learning resources and supports developing teaching materials, especially variations of questions and scenario-based learning simulations. However, both teachers emphasized the importance of validating information from AI because some of the responses were scientifically inaccurate, a phenomenon known as AI hallucination (Morgan et al., 2024).

Second, there was a gap in skills related to creating prompts or commands for ChatGPT. Only three out of ten students could create specific, contextual prompts; the rest copied questions from teaching materials without adjusting them. This indicates low prompt engineering literacy among students, consistent with Woo et al.'s (2024) finding that this skill is not widely taught explicitly in secondary schools. This limitation hinders the optimization of AI potential because the quality of prompts greatly affects the depth and relevance of the system's responses. Therefore, prompt engineering training should be included in digital or AI literacy curricula, especially in science education.

Third, reflective interaction patterns were observed among students in collaborative learning groups. These students used ChatGPT to find answers, test their understanding, and reflect on the consistency of AI answers with scientific logic. These findings suggest that dialogically using AI can foster higher-order cognitive abilities, which is consistent with Polverini et al.'s (2024) findings on the advantages of integrating AI into Socratic dialogue-based learning. In this context, teachers play a crucial role as facilitators, guiding the reflective process and directing students' interactions with AI in a critical and productive manner.

However, this study also identified several challenges. In addition to limitations in prompting skills, the AI has difficulty presenting visualizations of abstract and complex chemical concepts. Additionally, ChatGPT's responses sometimes do not align with the national curriculum or the technical language commonly used in Indonesian education. If not properly addressed, these discrepancies can lead to misconceptions. This underscores the need for teacher involvement in every AI-based learning process to ensure quality.

Theoretically, these findings contribute to the development of an AI-based TPACK framework (AI-TPACK), particularly by strengthening the role of technology pedagogy (TPK) in teacher-AI-student interactions. In practice, the results of this study provide recommendations for teacher training on AI integration in chemistry classrooms and for developing an AI literacy curriculum that includes prompt engineering, information verification, and ethical use of artificial intelligence technology. Further research should explore broader contexts, including diverse school backgrounds and student characteristics. Additionally, it should develop AI-based learning models that integrate visual and experimental elements to support a more holistic understanding of chemistry concepts.

4. CONCLUSION

Based on the research findings, it can be concluded that integrating ChatGPT into high school chemistry education positively contributes to improving conceptual understanding, especially for abstract topics. Students use ChatGPT as a learning partner to clarify material and practice problems, and teachers use it as an alternative resource when designing learning activities. However, ChatGPT's effectiveness heavily depends on students' ability to formulate appropriate prompts and teachers' ability to facilitate reflective and critical interactions with the information generated by AI. Low prompt engineering skills and a lack of information verification literacy pose significant challenges to optimizing AI use in the classroom. Therefore, teachers and students need systematic support in the form of AI literacy training, particularly regarding prompting strategies, scientific validation, and the ethics of AI use in the context of learning.

It is suggested that the use of ChatGPT be pedagogically designed and integrated into student-centered, collaborative learning plans. Teachers must have adequate technopedagogical skills to guide students in using AI productively and responsibly. The curriculum is expected to incorporate basic AI literacy competencies to prepare students for the digital transformation of education.

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