Bulletin of Education and Language

Publisher: Standout Press

E-ISSN: XXXX-XXXX
Homepage: https://standoutpress.org/bel
Volume 1, Issue 1, January–April 2026, pp. 1–15

Review Article

The Impact of ChatGPT on Students' Problem-Solving Abilities in Chemistry Education: A Review Study

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Received: January 10, 2026 **Accepted:** February 03, 2026 **Published:** February 09, 2026

Abstract
This review synthesizes current conceptual, theoretical, and empirical literature on the impact of ChatGPT on students' problem-solving abilities in Chemistry education. The findings indicate that ChatGPT possesses significant potential to function as a cognitive scaffold by enhancing conceptual understanding, analytical reasoning, and procedural fluency in complex Chemistry tasks. Through instant feedback, step-by-step explanations, and personalized guidance, the tool can reduce extraneous cognitive load and support learners within their Zone of Proximal Development, particularly in resource-constrained educational contexts. However, the literature also reveals substantial pedagogical concerns. Excessive and uncritical reliance on ChatGPT may foster cognitive dependency, superficial learning, weakened metacognitive regulation, and diminished independent analytical reasoning. Such outcomes risk undermining the development of higher-order problem-solving skills essential for scientific inquiry and professional competence. The review emphasizes that the effectiveness of ChatGPT depends largely on structured pedagogical integration, guided usage models, and strong digital literacy frameworks. It recommends the adoption of AI integration policies that prioritize critical engagement, ethical use, and assessment strategies focused on reasoning rather than answer reproduction. Ultimately, a blended human–AI partnership is proposed as the most sustainable pathway for strengthening independent problem-solving competence in Chemistry education.
Keywords: ChatGPT, Problem-Solving Abilities, Chemistry Education, Artificial Intelligence in Education, Digital Literacy.

Introduction

As digital technologies continue to impact teaching and learning, education systems around the globe are undergoing discernible changes (Mhlongo et al., 2023; Zou et al., 2025). Technology-supported platforms that enable more flexibility, personalized learning paths, and more interactive classroom experiences are now being used to supplement approaches that previously relied almost exclusively on in-person instruction and printed textbooks (Zawacki-Richter et al., 2019). Within this broader digital transition, Artificial Intelligence (AI) has become one of the most impactful developments, altering the ways students locate information, process ideas, and build understanding in modern classrooms (Holmes et al., 2019). In science education in particular, AI-based tools are gradually being introduced as potential means of strengthening students' reasoning abilities and improving their approach to complex problem-solving tasks (Kim & Kim, 2022).

Among recent AI innovations, ChatGPT developed by OpenAI has attracted considerable academic attention. It operates as a conversational system capable of producing detailed explanations, clarifying challenging concepts, supplying examples, and offering structured responses to academic prompts (Kasneci et al., 2023). Because it can simulate interactive dialogue and respond to subject-specific questions, many students now view it as a form of digital study companion across various disciplines. In educational settings, it may support learning by unpacking abstract ideas, outlining stepwise solutions, and encouraging independent exploration of subject matter. These characteristics are particularly relevant for disciplines such as Chemistry, where deep cognitive engagement is required (Baidoo-Anu & Ansah, 2023; Rudolph et al., 2023).

Chemistry education presents unique cognitive demands due to its abstract nature and multi-level representational structure. Students are required to interpret phenomena across macroscopic observations, submicroscopic particle interactions, and symbolic chemical representations (Popova, 2024). This triadic complexity often leads to conceptual misunderstandings and difficulties in applying theoretical knowledge to quantitative and real-world problems. Mastery in Chemistry therefore depends not only on memorization but also on well-developed problem-solving abilities, critical thinking skills, and analytical reasoning. Persistent learning challenges in Chemistry classrooms have prompted educators to explore alternative pedagogical strategies and digital supports that can enhance conceptual clarity and procedural competence (Iyamuremye et al., 2024; Utetiwabo et al., 2025).

Emerging global research suggests that AI-supported learning tools may improve student participation, interest, and academic performance when implemented carefully and within structured pedagogical frameworks (Kasneci et al., 2023; Rudolph et al., 2023). For example, research efforts led by Stanford University's SCALE Initiative in partnership with OpenAI are currently investigating how ChatGPT influences learning performance and cognitive development in educational contexts (StanfordReport, 2025). Additional studies (Vieriu & Petrea, 2025; Li & Wilson, 2025; Wang & Fan, 2025) suggest that the integration of ChatGPT can increase classroom interaction and learner engagement (Blahopoulou & Ortiz-Bonnin, 2025). Collectively, these findings imply that AI systems may function as structured academic supports, helping students manage demanding tasks while maintaining active involvement in the learning process (Li & Wilson, 2025).

Although interest in ChatGPT continues to grow, its use in formal education is still widely debated. The platform can generate quick explanations and organized answers, yet scholars have questioned how accurate those responses always are, how ethically the tool is used, and whether students may become too comfortable relying on automated help (Dwivedi et al., 2023). This issue is particularly sensitive in science subjects. In Chemistry, solving a problem involves more than producing a final answer. Students must interpret conditions, consider different reaction pathways, test assumptions, and defend their reasoning. There is a genuine chance that independent analytical development will slow down if too much of that thinking is delegated to a digital system.

Within the Nigerian context, interest in AI tools in Nigerian schools is growing (Adeleke, 2022; Adebayo & Johnson, 2023; Güngören et al., 2026). Howlader et al. (2025) suggest that students are more likely to adopt ChatGPT when they believe it is useful, easy to operate, and socially accepted. However, other factors that influence real usage include students' technological confidence, institutional support, access to digital gadgets, and internet reliability (Ezurike & Akinsulire, 2024). Even though many undergraduates increasingly use online learning platforms, the consistency of their use is still impacted by differences in infrastructure and connectivity (Okoye & Nwachukwu, 2022).

Chemistry education in Nigerian tertiary institutions continues to face persistent challenges, including limited laboratory facilities, overcrowded classrooms, inadequate instructional materials, and reduced student motivation (Nkiko, 2021). These constraints can hinder effective conceptual understanding and problem-solving development. Consequently, students may turn to supplementary digital tools such as ChatGPT to bridge instructional gaps. While such tools offer opportunities for personalized academic assistance, their actual contribution to measurable improvements in problem-solving competence remains insufficiently documented. Anecdotal evidence further suggests that many students struggle with mastering abstract chemical principles, which may negatively influence academic performance (Nkiko, 2021).

The dual nature of ChatGPT as both a supportive learning aid and a potential source of cognitive dependency raises critical pedagogical questions. On one hand, ChatGPT can clarify complex calculations, provide immediate explanations, and guide structured reasoning processes, thereby enhancing efficiency and understanding. On the other hand, excessive reliance may reduce originality, weaken critical thinking, and diminish intellectual rigor if students prioritize convenience over analytical engagement (Dwivedi et al., 2023). The central concern is whether ChatGPT functions as a scaffold that strengthens independent problem-solving abilities or as a substitute that displaces essential cognitive effort.

Although broader research on AI in education highlights transformative potential (Holmes et al., 2019; Zawacki-Richter et al., 2019), there remains limited consolidated evidence focusing specifically on its impact within Chemistry education, particularly regarding students' problem-solving abilities. Adewale et al. (2024), Bello and Hassan (2022), and Kokol et al. (2023) examined engagement, perception, or general academic performance, but fewer investigations critically synthesize findings related to higher-order cognitive outcomes in science disciplines. This gap appears more pronounced in developing educational systems, where infrastructural inequalities may shape the extent to which AI tools deliver consistent benefits (Okoye & Nwachukwu, 2022).

Given the growing reliance on AI-driven tools and the central importance of problem-solving competence in Chemistry education (Alli, 2025), a comprehensive review of existing literature is timely and necessary.

Understanding the extent to which ChatGPT enhances or hinders students' analytical reasoning and independent thinking is crucial for informing evidence-based pedagogical practices. Furthermore, synthesizing current findings can guide policymakers and educational stakeholders in designing frameworks that promote responsible and effective AI integration in science classrooms. Therefore, this review study critically examines the impact of ChatGPT on students' problem-solving abilities in Chemistry education. By analyzing emerging empirical evidence and theoretical perspectives, the study seeks to identify patterns of enhancement, areas of concern, and contextual factors influencing its effectiveness. The ultimate goal is to contribute to scholarly discourse on AI-assisted learning while offering informed recommendations for balanced and pedagogically sound implementation in Chemistry education.

Concept of ChatGPT

ChatGPT is a language-based computer programme developed by OpenAI that can respond to written questions in a way that feels close to normal human conversation (Gupta et al., 2023; Roumeliotis & Tselikas, 2023). It is built on what is called the Generative Pre-trained Transformer (GPT) model and was trained on large amounts of text so it can recognize patterns in language and produce meaningful replies. In everyday terms, it works like a digital helper. It can explain topics, answer questions, summarize materials, and assist with different types of academic work (King & ChatGPT, 2023).

In schools and universities, ChatGPT is mostly used as an extra support tool, not as a replacement for teachers (Phokoye et al., 2025). Students can ask questions whenever they want and get quick feedback, which can be useful especially outside lecture hours (Kasneci et al., 2023). Unlike textbooks that only present fixed information, ChatGPT allows interaction. Until the concept becomes obvious, a student can repeat a question in a different way, ask for more explanation, or seek simpler examples. This back-and-forth approach can help make complex ideas easier to understand, especially in a topic like chemistry where many concepts are abstract and occasionally hard to visualise. Additionally, some researchers contend that the use of these tools might motivate students to assess their comprehension and think more deeply about what they are learning (Dwivedi et al., 2023).

Historical Background of ChatGPT

ChatGPT is part of a longer story in the development of artificial intelligence (AI) and natural language processing (NLP). It is the outcome of multiple phases of technological advancement over time (Gupta et al., 2023).

Early Developments in AI and NLP

Before modern systems like ChatGPT, earlier AI programs depended mainly on strict rules or simple statistical methods. They were able to perform certain activities, such interpreting sentences or providing brief, factual answers, but they frequently faltered when the situation became more complicated (Roumeliotis and Tselikas, 2023). The introduction of the "transformer" paradigm by Vaswani et al. (2017) marked a significant turning point. This design helped computers pay attention to how words relate to each other across an entire sentence or paragraph. That development later became the foundation for the GPT series.

Evolution of the GPT Models

GPT-1 (2018): This was the first model in the series. It showed that a system trained on a large body of text could later be adjusted to perform different language tasks. It showed encouraging results, albeit being smaller than later iterations (Gozalo-Brizuela & Garrido-Merchan, 2023).

GPT-2 (2019): This version was much larger and could produce more natural and connected text. Its complete public dissemination was initially restricted due to worries about potential abuse (Khan et al., 2024)**.**

GPT-3 (2020): GPT-3 was a significant advancement. It could compose essays, solve problems, and even help with coding chores because it had a lot more parameters than previous iterations. Many observers noted that it performed surprisingly well with minimal instructions (Roumeliotis and Tselikas, 2023).

Birth of ChatGPT (2022)

On November 30, 2022, OpenAI introduced ChatGPT, which was based on GPT-3.5 but specially refined for conversation using Reinforcement Learning from Human Feedback (RLHF). This training method aimed to improve how the system responded in interactive dialogue. It was one of the fastest-growing digital sites at the time, apparently gaining over a million users globally in just five days (Goodman et al., 2023).

Subsequent Advancements

GPT-4 (2023): Along with the addition of text and image processing capabilities, GPT-4 improved reasoning and accuracy. This expanded its possible use in academic and professional settings (Ray, 2023).

Continuous Updates (2023–2024): OpenAI enhanced ChatGPT with features such as conversation history, plugins, web browsing, and integration with productivity tools, expanding its application in education, research, and professional sectors (Ray, 2023).

GPT-5 (2025): By mid-2025, OpenAI released GPT-5, which further improved contextual understanding, accuracy, and personalization. It incorporated real-time model switching and optimized responses for different use cases, making it more adaptable in academic environments, including science education (Al-Jahwari and Yousif, 2024; OpenAI, 2025; Shalawati et al., 2026). The Table 1 below shows the timeline for evolution of ChatGPT.

Table 1. Summary timeline of ChatGPT's development.

Year	**Milestone**
2017	Transformer architecture introduced by Vaswani et al.
2018	GPT-1 released (117M parameters)
2019	GPT-2 released (1.5B parameters), initially restricted
2020	GPT-3 launched (175B parameters) with few-shot learning
November 2022	ChatGPT released based on GPT-3.5 with RLHF
March 2023	GPT-4 integrated into ChatGPT (multimodal, improved reasoning)
2025	GPT-5 launched with improved accuracy and personalization
Source: Vaswani et al. (2017); Ray, 2023; Al-Jahwari and Yousif, 2024; OpenAI, 2025; Shalawati et al., 2026). This table shows the accuracy level of the latest version of GPT-5 from the transformer architecture introduced above to the efficacy of ChatGPT in education.	

ChatGPT in Education

Since ChatGPT came out, it is really started to change how students' study. At first, many teachers were not sure about it, but students and researchers began noticing that it can be a useful helper - someone to guide them through tricky topics, give explanations, and work through problems (Kasneci et al., 2023). It gives answers quickly, explains complicated ideas, and can adjust to what a student asks, which makes it handy for subjects like Chemistry that need thinking, reasoning, and problem-solving.

Merits of ChatGPT in Chemistry Education

Uninterrupted Access: Students can ask questions anytime, not just in class. This is helpful for completing homework, getting ready for tests, or even practice teaching (Ray, 2023).

Explains in Various Ways: If a step is unclear to a student, it may be explained in a different way. Organic reactions, for instance, can be perplexing, but ChatGPT can explain them step-by-step until they make sense (Kasneci et al., 2023).

Makes Hard Topics Easier: Chemistry has abstract ideas like atoms, bonds, and reaction speeds. ChatGPT can put them in simple words, give examples, or even generate practice questions to help students get it (Alli, 2025).

Assists With Calculations: It can demonstrate how to solve stoichiometry, titration, and chemical equilibrium problems by providing students with worked examples.

Promotes Self-Study: Students can verify information on their own without waiting for the next lesson and take charge of their learning (Shalawati et al., 2026).

Gives Extra Resources: It can suggest articles, summarize research, or give project ideas, which is useful for final-year students doing projects or literature reviews (Abdelghani et al., 2024).

Maintains Student Engagement: Studying feels less tedious since it functions as a dialogue. Students may be inspired to study more regularly as a result (Aktay et al., 2023).

Aids Where Resources Are Limited: Textbooks are frequently out of date and classrooms in Nigeria can be overcrowded. To fill in the blanks, ChatGPT can provide additional explanations (Dwivedi et al., 2023).

Demerits of ChatGPT in Chemistry Education

Risk of Inaccurate or Fabricated Information: ChatGPT sometimes provides scientifically incorrect or fabricated references. For Chemistry students, even minor inaccuracies in equations, constants, or experimental procedures can lead to misconceptions (Rahman and Watanobe, 2023).

Overdependence and Reduced Critical Thinking: If students rely excessively on ChatGPT for answers, they may neglect critical problem-solving skills, creativity, and analytical reasoning, which are essential in higher education and future teaching careers (Saurini, 2023).

Academic Integrity and Plagiarism: Some students may misuse ChatGPT to generate assignments, term papers, or project drafts without genuine understanding. This undermines academic integrity and prevents actual learning (Zhai, 2022).

Lack of Human Emotional and Pedagogical Understanding: Unlike human lecturers, ChatGPT cannot identify students' emotional needs, encourage them during frustration, or adjust teaching styles to suit personality differences (Yu, 2024).

Digital Divide and Infrastructure Challenges: Limited internet access, poor electricity supply, and low digital literacy levels in some parts of Nigeria may hinder equitable access to ChatGPT among students (Dwivedi et al., 2023).

Ethical and Privacy Concerns: Students may unknowingly share sensitive personal or academic information with ChatGPT, raising concerns about privacy and ethical usage of AI systems (Khalil & Er, 2023).

Potential to Undermine Teacher Authority: If students begin to value ChatGPT responses over lecturers' input, it may reduce classroom discipline, undermine teacher authority, and affect teacher-student relationships (Amjad, 2024).

Concept of Problem-Solving Abilities

Problem-solving abilities is widely recognized as a fundamental adaptable cognitive process and a core 21st-century skill in education (Adeoye & Jimoh, 2023), involving the identification, analysis, and resolution of challenges through systematic thinking, reasoning, and application of knowledge (Prabawati & Agustika, 2021). In educational contexts, particularly in higher education and STEM disciplines like Chemistry, problem solving abilities is defined as the ability to understand a problem situation, devise effective strategies, execute solutions, and evaluate outcomes, often in complex, ill-structured, or novel scenarios (Ventura-León et al., 2025). It encompasses both cognitive (e.g., analytical reasoning, pattern recognition) and metacognitive elements (e.g., planning, monitoring, reflection), enabling students to navigate real-world issues where straightforward answers are absent (Chen et al., 2025).

OECD (2026) emphasize that problem solving goes beyond rote application of formulas or procedures; it requires higher-order thinking skills such as critical analysis, creativity, evaluation of alternatives, and adaptation to new information (For instance, in higher education, problem solving is viewed as essential for building metacognitive awareness, self-efficacy, and independent learning, allowing students to tackle ambiguous tasks with confidence and persistence (Akgun & Sharma, 2023). In the era of AI integration, problem solving is increasingly seen as a hybrid human-AI process, where tools like ChatGPT can support strategy generation and exploration but may risk diminishing independent critical evaluation if over-relied upon (Nasr et al., 2025; Saurini, 2023).Problem solving ability in students is closely linked to academic performance, creativity, innovation, and future employability, as it equips learners to handle uncertainty, make evidence-based decisions, and adapt to dynamic challenges in fields like Chemistry (Chen et al., 2025). Educational researchers stress that fostering this skill requires deliberate instructional design, including real-world tasks, reflective practices, and scaffolding to develop both domain-specific expertise and general transferable competencies (OECD, 2026).

Types of Problem Solving

Problem solving in educational and psychological contexts is categorized into several distinct types, each reflecting different cognitive demands, contexts, and strategies. These classifications help explain how students, particularly in Chemistry, approach challenges ranging from routine calculations to complex experimental design.

Well-Structured (Routine) Problem Solving: Well-structured problems are clearly defined, have known solution paths, and usually possess a single correct answer. In Chemistry education, these include standard stoichiometric calculations, balancing chemical equations, or predicting reaction products using established rules (Hagos, 2025). Students apply memorized algorithms or formulas with minimal ambiguity (Jamil et al., 2024). This type relies heavily on procedural knowledge and is common in textbook exercises and examination questions.

Structured (Open-Ended) Problem Solving: Structured problems are characterized by unclear goals, multiple possible solutions, incomplete information, and subjective evaluation criteria. Examples in Chemistry include designing an experiment to identify an unknown compound, optimizing reaction conditions for maximum yield, or troubleshooting unexpected results in a practical session. This type demands higher-order thinking, creativity, critical evaluation of evidence, and integration of conceptual understanding with real-world constraints (Raman et al., 2024).

Domain-Specific vs. Domain-General Problem Solving: Domain-specific problem solving involves applying specialized knowledge within a particular field (e.g., using Le Chatelier's principle to predict equilibrium shifts in Chemistry), while domain-general problem solving relies on transferable strategies such as means-ends analysis, analogy, or trial-and-error that apply across disciplines (Sarwari & Kakar, 2023). In Chemistry education, effective problem solvers blend both using domain-specific content knowledge with general metacognitive strategies.

Collaborative vs. Individual Problem Solving: Collaborative problem solving occurs when students work in groups to share ideas, negotiate solutions, and divide tasks, often leading to richer outcomes in complex scenarios such as group practical investigations. Individual problem solving, by contrast, emphasizes personal reasoning and self-regulation (Aziza, 2021; Hurrel, 2021). Kokol et al. (2023) shows that AI tools like ChatGPT can influence both modes by providing instant suggestions, potentially altering group dynamics or reducing independent effort.

Importance of Problem-Solving Ability

Problem-solving ability is widely regarded as one of the most valuable competencies in 21st-century education, especially in STEM disciplines like Chemistry, where it underpins both academic success and real-world application. Sarwari and Kakar (2023) consistently emphasize its critical role that students who can solve problems effectively move beyond rote memorization to integrate concepts such as atomic structure, bonding, thermodynamics, and kinetics into coherent mental models (Bayarcal & Tan, 2023). This leads to better retention, transfer of knowledge to novel situations, and success in complex tasks like experimental design or data interpretation.

Secondly, problem solving fosters higher-order thinking skills analysis, synthesis, evaluation, and creation as outlined in revised Bloom's taxonomy. In Chemistry education, it enables students to critique experimental methods, evaluate evidence, and innovate solutions to practical challenges, preparing them for scientific inquiry and research (Chen et al., 2025). It significantly boosts academic performance and self-efficacy. Adeoye and Jimoh (2023) and Shanta and Wells (2022) posited that students with well-developed problem-solving abilities perform better in Chemistry examinations, practical assessments, and project work, while also reporting greater confidence in tackling difficult tasks (Rahmawati et al., 2022). Problem-solving ability is essential for employability and lifelong learning. Employers in chemical industries, research, and education value graduates who can diagnose issues, adapt to new technologies, and innovate under uncertainty skills directly linked to effective problem solving (Kinge et al., 2020).

Moreso, in the means of emerging technologies like AI, strong problem-solving ability ensures students remain active learners rather than passive users of tools like ChatGPT. It equips them to critically evaluate AI-generated suggestions, verify accuracy, and integrate outputs meaningfully into their reasoning process (AlBlooshi, 2026; Walter, 2024).

Impact of AI on Problem-Solving Abilities

The emergence of generative artificial intelligence tools like ChatGPT has profoundly influenced students' problem-solving processes, with mixed effects documented in different research (Agnaou & El Asri, 2025; Alghamdi, 2025; Bai & Wang, 2025; Elhag et al., 2025; Nasr et al., 2025). While, AI offers powerful support, it also raises concerns about dependency and skill erosion (Gerlich, 2025; Macnamara et al., 2024). Positive impacts are well documented (Chaudhary et al., 2024; Klimova and Pikhart, 2025). ChatGPT and similar large language models (LLMs) serve as on-demand cognitive scaffolds, helping students break down complex Chemistry problems, generate multiple solution pathways, explain concepts in multiple ways, and provide instant feedback on reasoning steps (Studies show that when used strategically, AI enhances exploration of ideas, reduces cognitive load on routine tasks, and allows students to focus on higher-order aspects such as evaluation and synthesis (Chaudhary et al., 2024).

In Chemistry, students have reported improved understanding of reaction mechanisms, equilibrium problems, and experimental troubleshooting when using AI for initial guidance or alternative explanations. Over-reliance on AI can negatively affect independent problem-solving ability. Research indicates that frequent use of ChatGPT for direct answers or step-by-step solutions may weaken students' ability to engage in deep, effortful thinking, leading to shallower processing, reduced metacognitive monitoring, and diminished persistence when faced with difficult problems without AI support (Tsao and Loh, 2025; Ventura-León et al., 2025). Several studies such as Qadir (2023) and Vieriu and Petrea (2025) found that students who habitually copy AI-generated solutions without critical evaluation showed lower performance on unaided problem-solving tasks and reduced confidence in their own reasoning.

Additionally, AI can introduce biases or inaccuracies (hallucinations) in Chemistry explanations, potentially leading students to accept incorrect information if they lack sufficient domain knowledge to verify outputs (AlBlooshi, 2026). This necessitates the importance of critical AI literacy teaching students to question, cross-check, and refine AI suggestions. In general, the impact of AI on problem-solving ability appears to be moderated by usage patterns, instructional design, and student proficiency. When integrated thoughtfully (e.g., as a brainstorming tool rather than a final answer provider), ChatGPT can augment rather than replace human problem-solving skills in Chemistry education (Khalil & Er, 2023; Zou & Huang, 2023).

Factors Hindering Problem-Solving Abilities of Students
Several interrelated factors continue to impede the development and expression of problem-solving abilities among students, including those in Chemistry programmes.

Over-Reliance on Memorization and Algorithmic Approaches: Many educational systems, including in Nigeria, emphasize rote learning and plug-and-chug problem solving, which discourages flexible thinking and deep conceptual understanding essential for novel or ill-structured problems (Kehinde and Adeyemi, 2025).

Limited Exposure to Authentic, Open-Ended Problems: Curriculum and assessment practices often favor well-structured, single-answer questions, reducing opportunities for students to practice tackling ambiguity, multiple solutions, or real-world applications (Vincent-Lancrin et al., 2019).

Inadequate Metacognitive Training: Students frequently lack explicit instruction in planning, monitoring, and evaluating their own problem-solving processes, leading to inefficient strategies and poor self-regulation (Li et al., 2024).

Anxiety, Low Self-Efficacy, and Fixed Mindsets: High anxiety in Chemistry problem solving, low confidence in one's abilities, and belief that problem-solving skill is innate rather than developable significantly hinder persistence and risk-taking (Jayson & Orongan, 2025).

Over-Dependence on AI Tools: Excessive reliance on ChatGPT for instant solutions can reduce cognitive effort, weaken independent reasoning, and create a false sense of competence when AI is unavailable (Matueny & Nyamai, 2025).

Resource and Pedagogical Constraints: In resource-limited settings like many Nigerian Colleges of Education, insufficient laboratory facilities, large class sizes, and limited time for inquiry-based activities restrict hands-on practice and guided problem-solving experiences (Ngaine, 2026).

Empirical Review
The results of numerous studies examining the impact of digital learning aids on students' problem-solving abilities are inconsistent. It appears that the subject, the method of instruction, and the usage of the instruments all have a significant impact on the result. ChatGPT role in STEM education were investigated by Karani and Mwancha (2025). They sought to determine whether these resources could improve students' involvement, creativity, and problem-solving skills. They looked for studies published after November 2022 in databases like Google Scholar, PubMed, Scopus, and Web of Science using a PRISMA-guided systematic review. They discovered that with appropriate application, these resources can support students' independent thought processes and critical problem-solving. However, the advantages diminish if students depend on them excessively. The study highlighted both the good and the bad sides of using digital tools in STEM learning.

Hidayat-ur-Rehman and Ibrahim (2024) explored why teachers decide to adopt platform such as ChatGPT. They created a model called "Educators' Adoption of ChatGPT," combining ideas from the Unified Theory of Acceptance and Use of Technology and the Status Quo Bias framework. They discovered that teachers' motivation, simplicity of use, digital skills, and expectations of student engagement promoted uptake through interviews and a survey of 243 educators. However, use was discouraged by worries about students relying too heavily on the tools, content errors, and unfair grading. Interestingly, worries about cheating did not really stop teachers from adopting the tools.

Arroyo-Bello et al. (2025) looked at health sciences education. They examined 18 papers on digital learning platforms published between 2023 and the beginning of 2025. Students were using these tools to help with writing, understanding tricky concepts, making quizzes, designing simulations, and planning coursework. However, there were also challenges, such as content errors, moral dilemmas, unequal access, and inadequate teacher and student preparation. The review came to the conclusion that, when used appropriately, these tools can support teaching and learning by providing individualised assistance, prompt feedback, and additional resources. However, teachers and students must remain vigilant, verify the authenticity of the content, and ensure that the tools do not take the place of real learning.

Durgungoz and Kharrufa's (2025) longitudinal study investigates the use of Large Language Models (LLMs), namely ChatGPT, in students' self-directed learning practices. Quantitative research indicates that ChatGPT, as a discussion partner and a trustworthy source of academic assistance, fosters an engaging and instructive learning environment. ChatGPT demonstrated a special capacity to improve students' educational experiences through personalised help, cognitive load reduction, and conversational engagements that resembled those of a human. Fakour and Imani (2025) examined how ChatGPT and human tutors differed perceptually in encouraging students to think critically, emphasising the value of Socratic teaching techniques in contemporary educational settings. The study used a mixed-methods approach, including quantitative surveys and qualitative interviews, and involved 230 Taiwanese university students as a sample. The findings show that although a sizable percentage of student's value ChatGPT's nonjudgmental attitude and accessibility, human tutors are valued for their capacity to offer individualised feedback and emotional support. The study found important characteristics influencing student choices through threshold analysis using a Multilayer Perceptron (MLP) model, highlighting the necessity of a balanced mix of AI and human tutoring techniques. The results highlight how crucial it is to create hybrid learning models that improve student learning and critical thinking abilities by utilising both the advantages of human facilitators and the effectiveness of AI technologies.

The Study of ChatGPT in Academia: University students' attitudes towards the use of ChatGPT and plagiarism was conducted by Fajt and Schiller (2025). This mixed-methods study focused on ChatGPT's role in education and looked at how it was incorporated into scholarly discourse. ChatGPT, an AI chatbot that uses the GPT model, has several advantages, including better accuracy in academic work and improved plagiarism detection. The study examined how a sample of 607 university students in Hungary used and perceived ChatGPT in relation to gender, educational background, and past AI experience. Additionally, it looks at the possible connection between students' propensity to plagiarise and their readiness to use ChatGPT. The results showed that people had a generally favourable opinion of ChatGPT, but they also raised worries about possible abuse. By offering insights and suggestions to strike a balance between technological innovation and the maintenance of academic integrity, this helped to responsibly integrate AI in education.

Using insights from a meta-analysis, Wang and Fan (2025) investigated how ChatGPT affected students' learning performance, perceptions of learning, and higher-order thinking. The study especially examined how well ChatGPT works to enhance students' learning performance, perception of learning, and higher-order thinking by meta-analyzing 51 papers that were published between November 2022 and February 2025. According to the findings, ChatGPT significantly improves learning performance and has a fairly beneficial effect on raising learning perception and encouraging higher-order thinking. Course type, learning model, and duration all influenced ChatGPT's impact on learning performance; duration moderated its effect on learning perception; and ChatGPT's role and course type moderated its influence on the development of higher-order thinking. The study makes the following recommendations: (1) when using ChatGPT to help students develop higher-order thinking skills, suitable learning scaffolds or educational frameworks (such as Bloom's taxonomy) should be made available; (2) widespread use of ChatGPT across grade levels and course types should be promoted in order to accommodate a range of learning needs; (3) ChatGPT should be actively incorporated into various learning modes to improve student learning, particularly in problem-based learning; (4) ChatGPT should be used continuously to support student learning, with a recommended duration of 4–8 weeks for more stable effects; and (5) ChatGPT should be flexibly integrated into teaching as an intelligent tutor, learning partner, and educational tool. Lastly, future research with a wider focus should investigate how to use ChatGPT more successfully to foster students' learning perception and higher-order thinking because of the small sample size for learning perception and higher-order thinking and the somewhat beneficial effect.

The problems, prospects, and teacher perspectives of generative AI-enhanced stem education in Taiwan's secondary schools were examined by Tsao and Loh (2025). This study examined the main learning resources used by Taiwanese technology instructors and how they use Generative AI (GenAI) into STEM teaching. Only 8% of teachers use GenAI for student performance evaluation, while 44% of teachers use it primarily for lesson preparation and creative material, according to a quantitative survey of 67 technology teachers in Taiwan with students aged 13 to 15. Professional development classes, educational technology conferences, and online learning platforms are the main ways that teachers learn about GenAI; the latter is particularly important for its use in assessing student performance. These findings highlight the need for focused AI-driven tools to support a wider range of instructional tasks in STEM teaching and imply that increasing instructors' participation with GenAI through online platforms could greatly increase its successful use in assessment.

In a previous but significant study, Rahman and Watanobe (2023) examined ChatGPT for research and education: opportunities, risks, and solutions. According to their findings, AI greatly improved students' capacity to tackle poorly organised issues and their metacognitive regulation when it was employed as a dialogic partner-that is, by encouraging introspection, challenging presumptions, and offering counterexamples. However, it resulted in less learning transfer to other contexts and poorer cognitive engagement when utilised mainly as an answer key. These studies show that ChatGPT and related generative AI technologies have a great deal of promise to enhance problem-solving skills by increasing idea generation, providing scaffolding, and providing instant feedback-especially when carefully included into instructional design. However, the research continuously cautions about the dangers of over-reliance, such as impaired metacognitive abilities, diminished autonomous reasoning, shallow processing, and susceptibility to AI errors. The results emphasise the value of teaching methods that encourage critical, reflective, and active interaction with AI outputs as opposed to passive consumption. This collection of data offers a solid empirical foundation for investigating the precise impacts of ChatGPT on students' problem-solving skills.

Theoretical Review

The theoretical framework for this study leans on two ideas that work well together: Vygotsky's Zone of Proximal Development (ZPD) and Sweller's Cognitive Load Theory (CLT). They help explain how tools like ChatGPT can either help or sometimes get in the way of students learning to solve problems.

Vygotsky's Zone of Proximal Development Theory

Vygotsky's Zone of Proximal Development (ZPD) theory of 1978 represents the gap between what a learner can accomplish independently and what they can accomplish with assistance (Panhwar et al., 2025). This theory posits that meaningful learning occurs most effectively when a learner engages with tasks that lie just beyond their current level of independent performance but can be accomplished successfully with appropriate guidance from a teacher, peer, or even a supportive tool such as ChatGPT. The ZPD represents the critical developmental space between what a student can do alone and what they can achieve with assistance (Times Higher Education, 2026).

The Application of This Theory in This Study: ChatGPT functions as a dynamic, digital scaffold within the student's ZPD. It provides immediate, personalized, and adaptive support by explaining complex Chemistry concepts such as reaction mechanisms, thermodynamics, or equilibrium shifts; breaking multi-step problems into manageable parts; offering hints, alternative solution pathways, or worked examples; prompting reflection on reasoning processes; and delivering real-time corrective feedback. Recent educational research has extended Vygotsky's original ideas to generative AI, demonstrating that tools like ChatGPT act as continuous, on-demand scaffolds that are accessible 24/7 and can adjust the level of guidance to match the learner's evolving needs. When students actively engage with ChatGPT by questioning its suggestions, refining prompts, and verifying outputs they operate within their ZPD, which fosters deeper conceptual understanding, greater confidence, and improved independent problem-solving capacity over time. However, the theory also cautions that if ChatGPT supplies complete solutions without requiring meaningful effort from the student, it effectively collapses the ZPD, bypassing the developmental zone and leading to dependency rather than genuine growth (Xi & Lantolf, 2021).

Complementing Vygotsky's framework is John Sweller's Cognitive Load Theory (CLT) emerged in 1988 as a theory that looks at how people process information in the brain (Martella et al., 2024), which explains how the human cognitive architecture processes information under three distinct types of cognitive load: intrinsic (the inherent complexity of the material, such as abstract concepts in Chemistry), extraneous (unnecessary cognitive demand caused by poor instructional presentation), and germane (effort devoted to schema construction and deep, meaningful learning) (Sweller et al., 2019). Sweller argues that working memory is limited, so effective instruction must minimize extraneous load, manage intrinsic load, and maximize germane load to promote schema acquisition and transfer of knowledge.

The Application of This Theory in This Study: In the context of ChatGPT use among Chemistry students, CLT provides a clear explanatory mechanism. When employed strategically, ChatGPT reduces extraneous cognitive load by delivering clear, step-by-step explanations, visual analogies, and worked examples for inherently complex topics, thereby freeing working memory resources for germane processing building robust mental schemas, making conceptual connections, and solving problems creatively. Conversely, when students habitually copy full AI-generated solutions without engaging deeply, this form of cognitive offloading prevents germane load, resulting in shallow processing, fragile knowledge structures, and poor transfer to unaided problem-solving situations. Recent applications of CLT to generative AI in STEM education have shown that when ChatGPT is used as a supportive partner offering hints, prompting reflection, and encouraging evaluation of outputs it optimizes cognitive load distribution and enhances problem-solving performance (Gkintoni et al., 2025; Lawson et al., 2024). In contrast, when it serves primarily as a direct answer provider, it risks increasing long-term extraneous load by reducing the student's active role in schema construction.

The integration of Vygotsky's ZPD/scaffolding theory and Sweller's Cognitive Load Theory forms a cohesive theoretical foundation for this investigation. ChatGPT operates as a dynamic scaffold within the student's Zone of Proximal Development, delivering just-in-time guidance that adapts to their current level of understanding in Chemistry. It manages cognitive load by minimizing extraneous demands on working memory, allowing students to allocate greater resources to germane processing and meaningful schema development processes central to building strong problem-solving ability. The core theoretical proposition guiding this study is that optimal, guided use of ChatGPT as a scaffold rather than a crutch will expand the ZPD, optimize cognitive load distribution, and significantly enhance students' independent problem-solving ability in both conceptual and practical Chemistry tasks. On the other hand, excessive dependence on ChatGPT for complete solutions will shrink the ZPD, misallocate cognitive resources, and lead to a measurable decline in unaided problem-solving performance. This dual theoretical perspective provides the conceptual structure for analysing how students utilize ChatGPT and how these usage patterns ultimately shape their ability to independently solve Chemistry problems.

Conclusion and Future Outlook

This review study has critically examined the impact of ChatGPT on students' problem-solving abilities in Chemistry education, synthesizing conceptual, theoretical, and empirical evidence across global and Nigerian contexts. The findings collectively suggest that ChatGPT holds substantial potential as a cognitive scaffold capable of enhancing conceptual understanding, analytical reasoning, and procedural fluency in Chemistry. Its ability to provide instant feedback, simplify abstract concepts, generate alternative solution pathways, and offer personalized explanations positions it as a powerful supplementary learning tool. When integrated strategically, ChatGPT can reduce extraneous cognitive load, expand students' Zone of Proximal Development, and promote active engagement in complex problem-solving tasks.

In resource-constrained environments, particularly within Nigerian tertiary institutions, it may also serve as a bridge to mitigate instructional gaps and improve access to academic support. However, the review equally underscores the risks associated with unregulated and excessive reliance on AI tools. Empirical evidence consistently highlights the possibility of cognitive dependency, superficial processing, diminished metacognitive regulation, and reduced independent analytical reasoning when students outsource problem-solving tasks entirely to ChatGPT. Such patterns threaten the development of higher-order thinking skills that are foundational to Chemistry education and scientific inquiry.

The central implication is therefore not whether ChatGPT should be adopted, but how it should be integrated pedagogically to preserve intellectual rigor while maximizing its benefits. Looking ahead, future research should move beyond perception-based studies to longitudinal and experimental designs that measure unaided problem-solving performance over time. There is a pressing need to investigate how different usage models such as AI as a brainstorming partner, reflective prompt generator, or evaluative assistant affect transfer of learning, retention, and creativity in Chemistry contexts.

Additionally, localized studies within developing educational systems are essential to understand infrastructural and curricular influences on AI effectiveness. From a policy and practice perspective, institutions should develop structured AI integration frameworks that incorporate digital literacy training, ethical guidelines, and assessment reforms that emphasize reasoning over reproduction. Rather than positioning ChatGPT as a replacement for human instruction, educators must leverage it as a guided scaffold that stimulates inquiry, reflection, and critical evaluation. Ultimately, the future of Chemistry education lies in a blended human-AI partnership where technological innovation enhances, rather than erodes, students' independent problem-solving competence and readiness for scientific practice in an increasingly digital world.

Declarations

Acknowledgments: The authors acknowledge with gratitude the contributions of previous researchers whose published works have provided a strong foundation for this review.
Artificial Intelligence (AI) Use Statement: The authors declare that no artificial intelligence (AI) tools were used in the preparation of this manuscript.
Author Contributions: AAO: Conceptualization, definition of intellectual content, implementation of study protocol, and manuscript review; AAO: Study design, data organization and interpretation, literature survey,

manuscript preparation, editing, and revision; AOM: Conceptualization, study design, literature review, and preparation of the initial manuscript draft; AEO: Conceptualization, literature review, and critical manuscript review.
Conflict of Interest: The authors confirm that there are no conflicts of interest associated with this publication.
Consent to Publish: All authors have read and approved the final manuscript and consent to its publication in Bulletin of Education and Language.
Data Availability Statement: This manuscript is based entirely on previously published studies, and no new data were generated or analyzed during this research.
Funding: The authors received no financial support for this research.
Institutional Review Board Statement: This study did not require ethical approval, as it is a review of existing literature and does not involve direct interaction with human or animal subjects.
Informed Consent Statement: Not applicable, as no primary data involving human participants were collected.
Research Content: The research content of manuscript is original and has not been published elsewhere.

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Citation: Alli, A. O., Adeyemo, A. O., Adebayo, O. M., & Abatan, E. O. (2026). *The impact of ChatGPT on students' problem-solving abilities in chemistry education: A review study*. *Bulletin of Education and Language, 1*(1), 1–15.