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THE ROLE OF CHATGPT IN STEM EDUCATION: ASSESSING ITS PROSPECTS, CHALLENGES, ETHICAL IMPLICATIONS, AND INFLUENCE ON STUDENT CREATIVITY AND INNOVATION COMPETENCIES

(Review Article)

Alex O.Karani [a1] , Cecilia N. Mwancha [b]

a Egerton University, Department of Agricultural Education and Extension, Egerton, , Kenya
b Egerton University, Department of Literature Language and Linguistics, Egerton, Kenya

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Abstract
This study aims to explore the role of ChatGPT in STEM education, specifically examining its impact on student creativity, innovation, and engagement. The study investigates both the prospects and challenges of using ChatGPT in educational contexts, as well as the ethical implications associated with its use. A systematic review following the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines was conducted. A comprehensive search was performed across multiple databases, including Google Scholar, PubMed, Scopus, and Web of Science, to identify empirical studies published after release of Chat GPT (30th November 2022). While some studies highlighted its ability to stimulate creative thinking and support problem-solving by offering diverse perspectives, others indicated that over-reliance on the AI tool might hinder creativity, leading to passive learning behaviors. Concerns about plagiarism, the risk of reduced critical thinking, and the potential for students to adopt unoriginal ideas were also raised. Ethical implications such as data privacy issues, the authenticity of student work, and the impact of AI on student independence were discussed. ChatGPT holds promise as a tool for enhancing creativity and innovation in STEM education, but its integration must be carefully managed to mitigate challenges such as bias and over-reliance on technology. The study recommends that educators incorporate ChatGPT in ways that encourage critical thinking and independent problem-solving. This study contributes to the understanding of how AI tools like ChatGPT can influence STEM education, offering insights into both the benefits and limitations of such technologies in fostering student engagement and creativity.

Keywords: *ChatGPT; STEM Education; Student Creativity; Innovation; Ethical Implications*

[1] Corresponding author: Alex O.Karani. ORCID ID.: *https://orcid.org/0000-0002-9113-2855*
E-mail: *ongakialex@gmail.com*
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1. Introduction

In the 21st century, advancements in technology have significantly reshaped numerous sectors, including education (Kalyani, 2024). Among these innovations, Artificial Intelligence (AI) has emerged as a transformative tool, influencing how we learn, teach, and interact with educational content. One of the most groundbreaking developments in the AI space is the creation of language models, such as OpenAI's ChatGPT. These sophisticated tools, which are capable of understanding and generating human-like text, have increasingly prominent role in modern education (Haleem et al., 2022). The application of AI, particularly ChatGPT, in educational settings offers exciting opportunities to enhance learning experiences, particularly within STEM (Science, Technology, Engineering, and Mathematics) fields. The rapid integration of AI tools, however, brings with it a set of challenges and ethical considerations that must be addressed to ensure their effective and responsible use in the classroom (Nguyen et al., 2023).

The rise of AI technologies, such as ChatGPT, within the context of STEM education marks a pivotal shift in how students approach learning and problem-solving. AI tools provide students with personalized learning experiences, adaptive feedback, and access to a wide array of resources that were once inaccessible or difficult to manage (Strielkowski et al., 2024). ChatGPT, as a conversational agent, has the unique ability to simulate real-time interactions with students, answering their questions, offering clarifications, and even assisting in problem-solving tasks that require a high level of cognitive engagement (Salem & Shaalan, 2024). This ability to support personalized, interactive learning is particularly valuable in STEM fields, where the complexity of content can be overwhelming for students. ChatGPT allows for a tailored approach, giving students the opportunity to explore topics in greater depth, ask questions freely, and receive immediate feedback on their understanding, thereby improving the overall educational experience.

While the prospects for ChatGPT in education are promising, the integration of such AI tools into classrooms is not without challenges. One significant barrier is the resistance from educators who may feel that the incorporation of AI into teaching undermines traditional pedagogical methods (Shankar et al., 2024). Teachers may also lack the necessary training to effectively integrate AI tools into their teaching practices, resulting in underutilization or ineffective application of technology in the classroom. Furthermore, there are concerns about the over-reliance on AI, with critics arguing that it may diminish students' critical thinking skills and creativity. If students begin to depend too heavily on AI for solutions, there is a risk that they might lose the ability to think independently or creatively, which are crucial skills in STEM disciplines (George et al., 2024). This challenge raises the need for balanced integration of AI, ensuring that it complements rather than replaces traditional methods of teaching and learning.

Additionally, ethical concerns surrounding the use of AI in education cannot be overlooked. Issues such as data privacy, algorithmic biases, and the potential for AI to perpetuate existing societal inequalities have raised alarms among researchers and educators alike (Kunjumuhammed, 2024). As AI systems are powered by vast amounts of data, the integrity and security of this data become paramount, particularly in a sensitive educational environment. These concerns necessitate a thoughtful approach to AI integration, ensuring that the benefits of these technologies are maximized while minimizing potential risks.

The role of ChatGPT in fostering creativity and innovation in STEM education is a key area of focus. STEM fields are inherently driven by problem-solving, innovation, and creativity (Rane, 2023a). The potential for ChatGPT to stimulate creative thinking among students lies in its ability to generate diverse ideas, offer alternative perspectives, and facilitate collaboration. In subjects like engineering,agriculture, mathematics, and computer science, where students often face complex problems with multiple possible solutions, ChatGPT can serve as an invaluable brainstorming tool, offering insights that might not have been considered. By leveraging ChatGPT's capabilities, students can experiment with different approaches to problem-solving, engage in creative thinking, and deepen their understanding of challenging concepts. However, the success of such an initiative hinges on how ChatGPT is incorporated into the curriculum and the degree to which it encourages independent thinking. If used correctly, ChatGPT could serve as a catalyst for innovation in STEM education, helping students develop the critical skills required for future careers in these fields. This study aims to fill a gap in research by looking closely at how ChatGPT is used in STEM education. It looks at both the good and the bad sides, and how it affects student's competencies like creativity and innovation. The study also gives useful ideas to teachers, school leaders, and curriculum planners on how to use AI tools like ChatGPT in the classroom in a smart and responsible way. This study aims to;

- Explore the role of ChatGPT in STEM education.
- Assess the prospects of ChatGPT in STEM education.
- Examine the challenges associated with AI integration.
- Analyze the ethical implications of ChatGPT in education.
- Evaluate ChatGPT's impact on student creativity and innovation.

To guide this study, the following Research Questions (RQs) are posed:

RQ1: What is the role of ChatGPT in STEM education?
RQ2: What are the prospects of ChatGPT in STEM education?
RQ3: What challenges are associated with the integration of AI, particularly ChatGPT, in STEM education?
RQ4: What are the ethical implications of using ChatGPT in education?
RQ5: How does ChatGPT impact student creativity and innovation?

2. Theoretical Underpinning

This study is based on Constructivist Learning Theory, primarily developed by Jean Piaget and further expanded by Lev Vygotsky in the early 20th century (Veraksa et al., 2022). Piaget's theory, particularly his focus on cognitive development, and Vygotsky's emphasis on social interactions as a key driver of learning, provide the foundation for understanding how students acquire knowledge and skills. Constructivist Learning Theory posits that learners actively construct their knowledge and understanding by engaging with their environment, making sense of new information through experiences and interactions (MacLeod et al., 2022). Vygotsky's social constructivism highlights the importance of social context and collaboration in learning, where learners build on their prior knowledge and engage in problem-solving activities, often with the help of more knowledgeable peers or tools (Vygotsky, 1978). According to Piaget, cognitive development occurs through stages, and students adapt their understanding by actively constructing knowledge from their experiences. The theory is particularly relevant to this study on ChatGPT's role in fostering student creativity and innovation in STEM education. ChatGPT, an AI tool, provides an environment where students actively engage with complex problems, generate ideas, and seek solutions, aligning with the core principles of constructivism. By using ChatGPT, students can explore different STEM concepts and create solutions independently, fostering deeper understanding and higher-order thinking. This interaction with AI tools promotes active learning, as students are not merely passive recipients of information but engage in critical thinking, reflection, and collaboration, key elements of constructivist learning. Moreover, ChatGPT supports Vygotsky's notion of scaffolding, where students can receive guidance and support tailored to their current level of understanding. The AI acts as a tool that aids in developing students' problem-solving skills and encourages creativity, which is essential in STEM fields. The personalized and interactive nature of ChatGPT also enhances students' autonomy, a central component of constructivist learning, by enabling them to explore knowledge at their own pace and level.

3. Conceptual Framework

Figure 1 depicts the conceptual framework for understanding the relationship between ChatGPT and student creativity and innovation in STEM education.

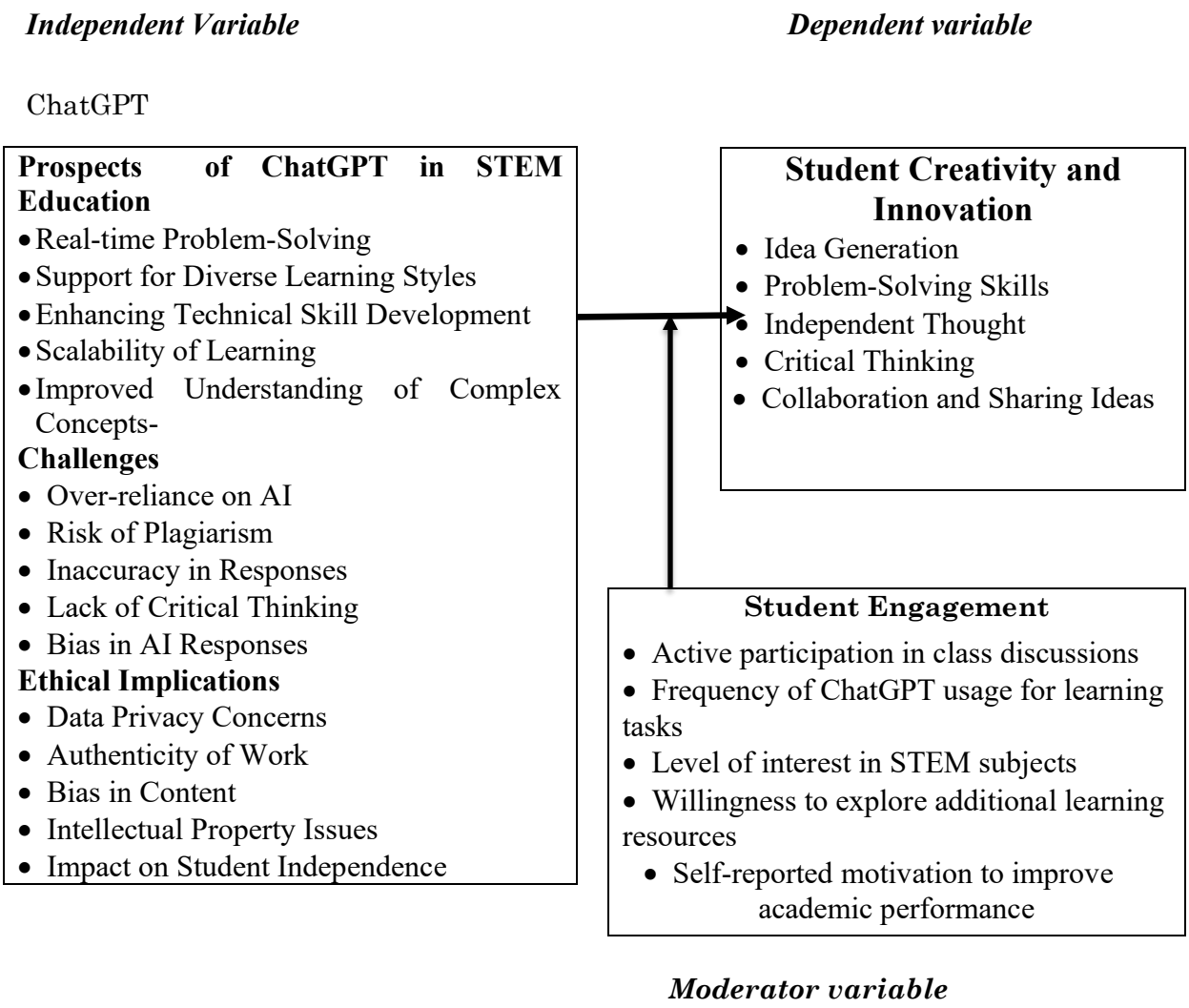

Figure 1. Conceptual Framework Illustrating the Relationship Between ChatGPT and Student Creativity and Innovation in STEM Education

In this study, ChatGPT and its prospects, challenges, and ethical implications are the independent variables, while student creativity and innovation is the dependent variable. The framework demonstrates how these independent variables directly influence student creativity and innovation and how student engagement moderates this relationship.

The relationship between ChatGPT and student creativity and innovation is grounded in the tool's ability to assist students in overcoming creative barriers, generating ideas, and enhancing problem-solving skills. ChatGPT can promote independent thought by providing prompts and examples that stimulate new ways of thinking, which helps students in STEM disciplines refine

their skills. It also fosters critical thinking as students engage with the AI to understand complex problems and solutions. Through collaboration and sharing ideas, ChatGPT facilitates a collaborative learning environment, encouraging students to brainstorm collectively, thus enhancing their creativity.

The prospects of ChatGPT, such as real-time problem-solving and support for diverse learning styles, further contribute to student creativity and innovation. Real-time feedback on tasks like coding or mathematical problems accelerates learning and helps students refine their approaches to complex concepts, which nurtures creativity. By offering tailored explanations and adjusting to different learning styles, ChatGPT enhances technical skill development and fosters a deeper understanding of STEM subjects. However, challenges such as over-reliance on AI, risk of plagiarism, and bias in AI responses may hinder creativity. If students excessively depend on ChatGPT for answers without engaging deeply with the subject matter, their problem-solving abilities and creativity could be stunted. Ethical implications like data privacy concerns and authenticity of work further complicate the use of AI, potentially stifling creativity by leading students to question the reliability of AI-generated content. Student engagement plays a crucial moderating role. Active participation in class discussions, frequency of ChatGPT usage, and interest in STEM subjects help ensure that students are engaging meaningfully with the content provided by ChatGPT. When students are highly engaged, they are more likely to use ChatGPT as a complementary tool rather than a crutch, which results in better creativity and innovation. Motivation to improve academic performance and a willingness to explore additional learning resources enhance the effectiveness of ChatGPT in fostering creativity.

4. Method

4.1. Research Design:

This study adopted a systematic literature review approach, guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines. The primary objective was to explore the role of ChatGPT in STEM education by assessing its prospects, challenges, ethical implications, and influence on student creativity and innovation. This method ensured a structured, transparent, and comprehensive analysis of current scholarly discourse on the integration of ChatGPT and similar large language models (LLMs) in STEM education. Figure 2 followed the Preferred Reporting Items for PRISMA guidelines to ensure the transparency and rigor of the review process as shown. Given the recent emergence of ChatGPT, the literature review focused on studies published after November 30, 2022, when ChatGPT was officially released by OpenAI. This ensures that the included studies reflect the capabilities and implications of contemporary LLMs, distinguishing them from earlier AI or chatbot models with significantly less advanced language comprehension and generation abilities.

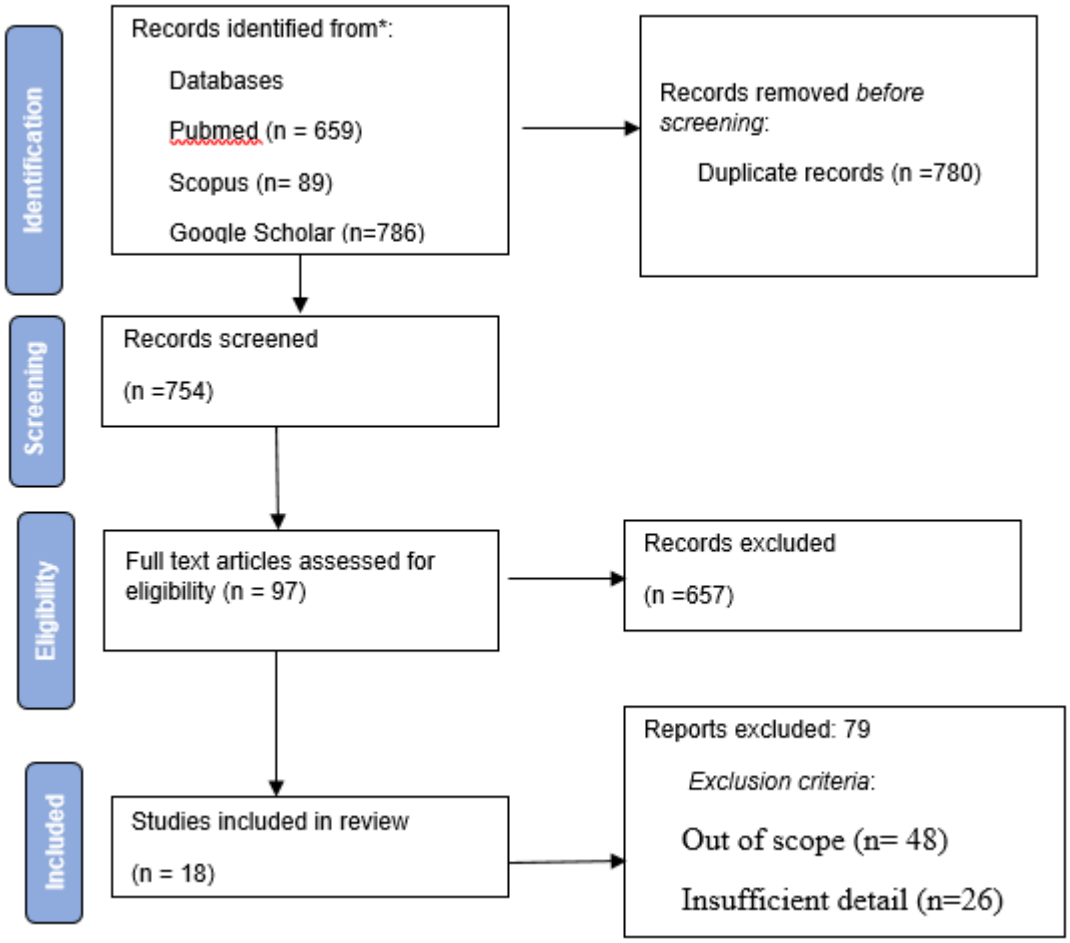

Figure 2. *PRISMA Flow Diagram Illustrating the Study Selection Process*

4.2. Procedure:

In the study, a systematic search of academic literature was conducted across multiple electronic databases, including Scopus, Web of Science, PubMed, and Google Scholar. Keywords such as "ChatGPT in education," "AI tools in STEM," "creativity and innovation in STEM," "ethical implications of AI in education," and "challenges of AI in classrooms" were used. Boolean operators (AND, OR, NOT) were applied to refine the search and ensure the inclusion of diverse yet relevant studies. The search was restricted to articles published in English between 2022 and 2024 to capture the most recent advancements in AI technologies.

4.3. Sampling:

Articles were included in the review if they focused on the integration of ChatGPT or similar AI tools in STEM education, discussed prospects, challenges, or ethical considerations of using AI in education, and explored the impact of AI on creativity and innovation in STEM disciplines. Additionally, the articles had to be published in peer-reviewed journals, written in English, and include empirical research, systematic reviews, or theoretical discussions. Studies were excluded if they did not center on STEM education or ChatGPT, were duplicate entries or preprints not peer-reviewed, or were published before 30th November 2022 when ChatGPT was officially released.

Table 1. *Inclusion and Exclusion Criteria for Study Selection*

Criteria	Inclusion	Exclusion
Focus Area	Studies focusing on ChatGPT or similar large language models (LLMs) in STEM education	Studies not centered on ChatGPT or not related to STEM education
Study Type	Empirical research, theoretical discussions, or systematic reviews	Opinion pieces, editorials, blog posts, or non-peer-reviewed sources
Publication Status	Published in peer-reviewed academic journals	Preprints, duplicates, or unpublished manuscripts
Language	English-language publications only	Non-English publications
Time Frame	Published from December 1, 2022, to 2024	Published before November 30, 2022
Content Relevance	Discusses prospects, challenges, ethical implications, or creativity impacts of ChatGPT	Lacks focus on ethical, pedagogical, or cognitive dimensions of ChatGPT use
Population/Setting	Studies involving educators, students, or educational settings in STEM fields	Studies focusing solely on general AI applications outside of education

4.4. Data Collection and Analysis

The review process began with an initial screening of article titles and abstracts to determine their relevance to the research objectives. Full-text articles of studies that passed this preliminary assessment were retrieved and subjected to a detailed evaluation based on the established

inclusion and exclusion criteria. Data extraction was conducted systematically, focusing on key aspects such as the authors and publication year, research aims and design, methodologies employed, sample characteristics, and findings related to ChatGPT's role in STEM education. Specific attention was given to insights on its prospects, challenges, ethical considerations, and its impact on creativity and innovation. A structured coding sheet was used to ensure consistency in data extraction. Each study was assessed for reliability, depth of analysis, and contribution to the field.

A matrix table was used to organize and analyze the data, summarizing key insights and thematic patterns across the selected studies. This synthesis provided a comprehensive understanding of the multifaceted role of ChatGPT in STEM education, highlighting areas of consensus and divergence in the literature. To support this analysis, a thematic framework was applied to group findings into categories such as pedagogical impacts, ethical concerns, and cognitive outcomes.

5. Results

The results and discussion are organized into themes based on the synthesis of the literature. Table 2 is a matrix table summarizing the key articles included in the systematic review.

Table 2. Matrix Summary of Key Articles Included in the Systematic Review on ChatGPT's Role in STEM Education

No.	**Author(s)**	**Year**	**Title of Article**	**Focus Area**	**Key Findings**
1	Adel et al.,	2024)	ChatGPT Promises and Challenges in Education: Computational and Ethical Perspectives	Personalized learning and ethical concerns	The study found that ChatGPT enhances personalized learning by providing dynamic, real-time feedback, improving teaching efficiency, and increasing learner engagement. However, it also poses challenges such as biases in AI algorithms that can distort educational content and the inability to replicate emotional and interpersonal teacher-student interactions. The study highlights the need for ongoing research to address these challenges and adapt educational strategies to the

					rapid evolution of AI technologies.
2	Elbanna and Armstrong,	2023	Exploring the integration of ChatGPT in education: adapting for the future	Personalized learning, assessment, and content creation	The study found that ChatGPT can automate routine tasks, enhance learning experiences, foster adaptive learning, and improve productivity in education. However, limitations such as factual inconsistencies, potential bias, lack of in-depth understanding, and safety concerns remain significant challenges.
3	Sain et al.,	2024	Exploring the ChatGPT Era: Finding Equilibrium between Innovation and Tradition in Education	Balancing AI innovation and traditional pedagogy	The study found that ChatGPT offers substantial benefits for personalized and interactive education, such as assisting in storytelling, generating writing prompts, and vocabulary improvement. However, challenges include potential biases, misunderstanding context, and risks of over-reliance on technology. Educators are advised to integrate ChatGPT responsibly through strategies like robust assessment methods, plagiarism detection, viva voce sessions, and ethics education.
4	Grassini,	2023	Shaping the Future of Education: Exploring the Potential and Consequences of AI and ChatGPT	AI's transformativ e impact on education	The study found that ChatGPT has significantly reshaped educational norms, offering opportunities like automated learning support and personalized education. However, concerns were raised

			in Educational Settings		about its potential to diminish analytical skills and encourage academic misconduct. While the paper acknowledges ChatGPT's impressive capabilities, such as passing the US bar law exam, it highlights the need for critical integration in educational practices to balance innovation with ethical and practical considerations.
5	Zeb et al.,	2024	Exploring the role of ChatGPT in higher education: opportunities, challenges and ethical considerations	AI tools in higher education	The study explores the opportunities and challenges of using ChatGPT in higher education. It highlights the difficulty in detecting academic dishonesty and discusses strategies universities can adopt to ensure ethical usage of these tools.
6	Alshahrani & Jameel Qureshi,	2024	Review the Prospects and Obstacles of AI Enhanced Learning Environments: The Role of ChatGPT in Education	AI in educational environments	This paper explores the transformative potential of AI, particularly ChatGPT, in enhancing education. It examines ChatGPT's ability to improve programming skills, foster creativity, and enhance student-teacher interactions. The study also highlights challenges such as academic integrity, ethical issues, and the need for balance with traditional methods.
7	Yu, 2024	2024	The application and challenges of ChatGPT in educational	AI in educational transformatio n	This paper discusses the potential of ChatGPT in promoting educational transformation, focusing on its

			transformation: New demands for teachers' role		role in answering questions and completing tasks. While recognizing its power, the study identifies challenges such as accuracy, data pollution, ethical concerns, and plagiarism risks.
8	Rane,	2023	Enhancing the Quality of Teaching and Learning through ChatGPT and Similar Large Language Models: Challenges, Future Prospects, and Ethical Considerations in Education	AI in teaching and learning	This paper examines the implications of integrating AI, specifically ChatGPT, into education. It highlights the benefits such as personalized learning, content creation, and performance analysis. However, concerns about plagiarism, academic integrity, and the authenticity of AI-generated content are discussed. The study stresses the importance of teacher involvement in mentorship, guidance, and feedback, which AI cannot replace.
9	Zhu et al.,	2024	Exploring the impact of ChatGPT on art creation and collaboration: Benefits, challenges and ethical implications	AI in art creation and collaboration	This paper investigates the role of ChatGPT in art creation, including poetry, prose, music, and literature, and its impact on collaboration between artists. Findings indicate that ChatGPT helps artists overcome creative blocks, generate new ideas, and enhance their work. However, ethical concerns regarding authorship, ownership, and authenticity were raised. Artists worry about losing their identity and control over their creations.

10	Uğraş & Uğraş,	2024	ChatGPT in early childhood STEM education: Can it be an innovative tool to overcome challenges?	AI in early childhood STEM education	The study examines teachers' perspectives on using ChatGPT to overcome challenges in early childhood STEM education. Findings suggest that ChatGPT can support teachers by guiding effective use of materials, designing student-specific activities, and filling knowledge gaps. However, concerns about potential negative effects, such as technological addiction, social skill regression, and misinformation, were also highlighted. Teachers believe ChatGPT could benefit students' education when used thoughtfully
11	Lazkani,	2024	Revolutionizing Education of Art and Design Through ChatGPT	AI in Art and Design Education	This chapter analyzes ChatGPT's role in transforming Art and Design education by offering personalized learning experiences, enhancing creativity, and streamlining portfolio reviews. It also promotes cross-disciplinary learning and acts as a lifelong career guide for students and alumni. The chapter emphasizes the integration of AI with traditional pedagogy while addressing ethical concerns about authenticity, originality, and data privacy.
12	Saurini,	2023	Creativity in Art and Academia: Analyzing the	AI and Creativity in	This thesis explores the impact of ChatGPT on human creativity, especially in art and academia. It

			Effects of AI Technology Through the Lens of ChatGPT	Art and Academia	argues that ChatGPT threatens creativity by potentially replacing human artistic expression and academic effort. The study discusses the benefits and drawbacks of using AI for tasks like homework assistance, proofreading, and essay outlines, stressing that overreliance on AI can hinder students' educational development and creativity. It highlights the importance of preserving human-created art and creativity in education.
13	Aithal & Aithal,	2023	Application of ChatGPT in Higher Education and Research – A Futuristic Analysis	AI in Higher Education and Research	This research critically examines the role of ChatGPT and similar AI language models in shaping the future of education and research. The study analyzes the potential benefits and challenges of AI integration in pedagogy, academic support, and scholarly inquiry. It highlights transformative opportunities while addressing ethical considerations and potential threats to the higher education industry.
14	(Silva et al.,	2024	ChatGPT: Challenges and Benefits in Software Programming for Higher Education	AI in Programming Education and Sustainability	While students recognized the tool’s potential for enhancing learning, concerns were raised about over-reliance on AI-generated code, which could hinder long-term understanding of programming fundamentals.
15	Taani & Alabidi,	2024	ChatGPT in Education:	AI in Mathematics	ChatGPT is frequently used for generating examples, assessing

			Benefits and Challenges of ChatGPT for Mathematics and Science Teaching Practices	and Science Education	difficulty, providing explanations, and aiding in test preparation. Teachers perceive it as enhancing student understanding and engagement but also report challenges related to accuracy, connectivity, and language limitations.
16	Jeyaraman et al.,	2023	ChatGPT in Action: Harnessing Artificial Intelligence Potential and Addressing Ethical Challenges in Medicine, Education, and Scientific Research	AI in Medicine, Education, and Research	ChatGPT's utility in medical education, radiology reporting, and research but stresses the importance of AI as an augmentation to human expertise. Challenges include limitations in critical thinking, false references, misuse, bias, privacy, and the need for cross-verification
17	Farhi et al.,	2023	Analyzing the Students' Views, Concerns, and Perceived Ethics About ChatGPT Usage	ChatGPT in Education	Results suggest that students see ChatGPT as a revolutionary tool that assists learning but also raise concerns about its impact on educational integrity.
18	Rahman & Watanobe,	2023	ChatGPT for Education and Research: Opportunities, Threats, and Strategies	ChatGPT in Education and Research	This study explores the opportunities and threats posed by ChatGPT in education and research, highlighting its potential for personalized feedback, interactive conversations, and lesson preparation. However, concerns such as cheating, diminished critical thinking, and challenges in evaluating AI-generated

					content are also discussed. The study further investigates ChatGPT's role in programming education through various experiments, demonstrating its effectiveness in code generation, pseudocode creation, and code correction.

6. Discussion

6.1 Explore the Role of ChatGPT in STEM Education

The integration of ChatGPT into STEM education offers substantial opportunities to enhance learning experiences, though challenges also arise. According to Adel et al. (2024), ChatGPT facilitates personalized learning, providing real-time feedback that can improve the learning process. This aligns with findings by Elbanna and Armstrong (2023), who also highlighted ChatGPT's potential in automating routine tasks, thus enabling educators to focus on more complex instructional needs. The interactive nature of ChatGPT allows students to engage more deeply with STEM subjects, particularly in fields like mathematics and science, where problem-solving skills are essential. Moreover, ChatGPT aids in simplifying complex STEM concepts by breaking them down into manageable steps. This echoes findings by Zeb et al. (2024), who discussed how AI tools can assist in creating adaptive learning environments tailored to individual student needs. However, some studies raise concerns about ChatGPT's role in STEM education. Saurini (2023) argues that over-reliance on AI may diminish students' understanding of fundamental principles. If students lean too heavily on AI tools, it could impede their critical thinking and ability to independently solve complex problems. As noted by Grassini (2023), while ChatGPT can enhance accessibility and engagement, there is a risk that students may miss out on the cognitive skills developed through traditional methods, such as manual problem-solving and deep learning through trial and error. ChatGPT's role in STEM education appears to be both beneficial and problematic. It offers immense potential in enhancing understanding and making STEM education more interactive. However, educators must strike a balance by ensuring that AI tools supplement rather than replace essential educational practices, as highlighted by studies like Grassini (2023) and Elbanna and Armstrong (2023).

6.2 Assess the Prospects of ChatGPT in STEM Education

The prospects of ChatGPT in STEM education are promising, yet they require careful consideration. As highlighted by Yu (2024), the application of ChatGPT in STEM education is transformative, particularly in programming and engineering fields, where real-time feedback and code correction are invaluable. Studies, such as those by Rahman & Watanobe (2023), have demonstrated ChatGPT's potential to assist in generating code and correcting errors, which can enhance students' technical skills. This capacity for real-time engagement allows students to actively participate in their learning, rather than passively absorbing content. ChatGPT's role in STEM is also enhanced by its ability to support a broad range of subjects. For instance, Taani & Alabidi (2024) highlighted the ability of ChatGPT to generate examples, provide test preparation, and offer explanations in complex subjects like mathematics and science. Furthermore, as noted by Aithal & Aithal (2023), ChatGPT's adaptability allows it to cater to various levels of student expertise, offering tailored support. This flexibility positions ChatGPT as a tool that can enhance both early and advanced stages of STEM education. However, the integration of ChatGPT into STEM education must be strategically planned. As discussed by Elbanna and Armstrong (2023), challenges remain, such as ensuring the tool's accuracy and addressing potential biases in its responses. Moreover, studies like those of Sain et al. (2024) suggest that while ChatGPT can enhance learning, its limitations must be addressed through ongoing research and adjustments in its application. Therefore, while the prospects of ChatGPT in STEM education are undoubtedly significant, they hinge on ongoing efforts to optimize its use and address its limitations.

6.3 Examine the Challenges Associated with AI Integration

The integration of ChatGPT into education, particularly in STEM disciplines, presents several challenges that must be navigated carefully. One major challenge highlighted by Grassini (2023) and Zeb et al. (2024) is the potential for students to misuse ChatGPT, leading to academic dishonesty. The ability of ChatGPT to generate human-like text raises concerns about plagiarism, as students may present AI-generated content as their own. This concern is echoed by Elbanna and Armstrong (2023), who stressed the need for universities to implement strategies to detect such misuse. Additionally, as highlighted by Rahman & Watanobe (2023), there are risks related to the diminishing development of critical thinking skills. If students rely too heavily on ChatGPT for answers or solutions, they may miss the opportunity to engage deeply with the subject matter and develop the problem-solving skills required in STEM education. The study by Saurini (2023) also emphasizes the risk of over-reliance, which could undermine students' capacity for independent thought and creativity in tackling real-world problems. Another challenge discussed by Jeyaraman et al. (2023) is the ethical use of AI. While ChatGPT

can significantly enhance learning, its integration into the classroom must be handled with care to ensure that it is used ethically. Teachers must be vigilant in addressing issues such as the fairness of AI-generated assessments and the potential for bias in AI responses. Thus, while ChatGPT offers considerable potential, it must be integrated thoughtfully to mitigate these challenges.

6.4 Analyze the Ethical Implications of ChatGPT in Education

The ethical implications of ChatGPT's integration into education are significant and multifaceted. Studies such as those by Grassini (2023) and Saurini (2023) have raised concerns about the authenticity of AI-generated content. As AI tools like ChatGPT become more prevalent, issues of authorship, intellectual property, and the ownership of ideas become increasingly complex. This concern is particularly relevant in creative fields like art and design, as discussed by Zhu et al. (2024), where ChatGPT's role in content generation may blur the lines between human creativity and machine-generated work. Furthermore, the ethical concern surrounding data privacy and security cannot be overlooked. As noted by Sain et al. (2024), the integration of AI tools requires the careful management of student data to avoid privacy breaches. There is also the issue of ensuring that AI systems do not perpetuate biases in education. Studies such as that of Adel et al. (2024) highlight that ChatGPT's algorithms may unintentionally reinforce societal biases, leading to unfair outcomes in education. Therefore, while ChatGPT offers transformative potential, its ethical integration into educational systems requires rigorous safeguards to ensure fairness and transparency. The ethical implications of ChatGPT in education demand careful consideration. The potential for bias, concerns over authorship, and the need for strict data privacy measures are critical issues that must be addressed as ChatGPT becomes more integrated into educational settings. These challenges underscore the need for ongoing dialogue and policy development to ensure that the use of AI in education remains equitable and ethically sound.

6.5 Evaluate ChatGPT's Impact on Student Creativity and Innovation

ChatGPT's impact on student creativity and innovation is a subject of ongoing debate in the literature. On one hand, as noted by Rahman & Watanobe (2023) and Adel et al. (2024), ChatGPT has the potential to enhance creativity by offering students new ways to approach tasks. In fields like writing, programming, and art creation, ChatGPT can assist students by providing ideas, suggestions, and examples, which can spark creative thinking. For instance, Zhu et al. (2024) found that artists using ChatGPT were able to overcome creative blocks and generate new ideas, thus enhancing their creative output. On the other hand, studies like those by Saurini (2023) argue that excessive reliance on AI tools like ChatGPT could stifle originality and independent creative thought. The concern is that students may begin to depend on AI-

generated ideas rather than developing their own unique concepts. This could result in a lack of innovation, as students may become accustomed to relying on AI for inspiration rather than exploring their own creative potential. Furthermore, as noted by Grassini (2023), over-reliance on AI in creative processes could diminish students' ability to engage in critical thinking and problem-solving, both of which are essential for fostering creativity and innovation. while ChatGPT has the potential to enhance creativity and innovation, its role in education should be carefully managed. Encouraging students to use AI as a tool for inspiration, rather than a crutch, can help ensure that creativity and innovation continue to thrive. As emphasized by studies like those of Rahman & Watanobe (2023) and Zhu et al. (2024), the key lies in striking a balance between utilizing AI to enhance learning and preserving the essential role of human creativity in education.

7. Conclusions

The integration of ChatGPT into STEM education presents both remarkable opportunities and significant challenges. On one hand, it holds the potential to enhance personalized learning experiences, facilitate real-time feedback, and support student engagement, particularly in technical fields such as programming and engineering. However, the over-reliance on AI tools like ChatGPT may hinder students' development of critical thinking skills and independent problem-solving abilities, which are crucial in STEM disciplines. Additionally, issues related to academic integrity, ethical use, and potential biases in AI responses necessitate careful consideration and management. The future of ChatGPT in STEM education hinges on striking a balance between leveraging its benefits while ensuring that it supplements, rather than replaces, traditional learning methods. Educators must be vigilant in addressing the ethical implications, such as data privacy concerns and the potential for reinforcing societal biases. Furthermore, it is essential to foster an environment where AI tools serve as aids to creativity and innovation, not as crutches that stifle students' independent thought and originality.

8. Limitations

While this review provides a comprehensive overview of the current literature, several limitations must be acknowledged. First, the inclusion criteria were restricted to studies published in English between December 2022 and 2024, which may have excluded valuable insights from non-English publications and grey literature. Second, the relatively short timeframe since ChatGPT's release means that much of the literature is still exploratory in nature, with a limited number of peer-reviewed empirical studies. Additionally, the focus on STEM education may have inadvertently excluded interdisciplinary perspectives or insights from related educational domains, and the potential for publication bias remains, given the novelty and popularity of the topic.

9. Future Directions

To address these limitations and build a more robust understanding of ChatGPT's role in education, future research should prioritize longitudinal, classroom-based studies that assess the long-term effects of AI tools on students' cognitive development, problem-solving skills, and creative thinking. Further studies should explore how ChatGPT can be integrated effectively across different educational contexts, including under-resourced and multilingual settings, to ensure inclusivity and equity. Moreover, researchers should investigate the development of guidelines and best practices for ethical AI use in classrooms, including teacher training programs, student AI literacy, and strategies for mitigating algorithmic bias. Such work will be essential to support the responsible and impactful integration of AI technologies in STEM education.

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Declaration of Conflicting Interests and Ethics

The authors declare no conflicting interests related to this study. Although this is a review study, all ethical considerations, including data privacy and responsible AI usage, were rigorously adhered to in the research process.

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