

IMPACT OF GENERATIVE AI ON CRITICAL THINKING SKILLS IN UNDERGRADUATES: A SYSTEMATIC REVIEW

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Abstract

Despite widespread acknowledgement of the significance of critical thinking skills for success in today's job market, higher education institutions face challenges in effectively nurturing these skills in students. Educational policies, reports, and employer demands emphasise the importance of critical thinking, yet a gap remains between its recognised value and the actual proficiency levels among university students. This study employs a systematic literature review approach to address a research question, "What is the impact of Generative AI on the critical thinking skills of undergraduates?" About half of the thirty selected papers suggest that Generative AI benefits undergraduate critical thinking, but limitations in study design prevent generalisation. Other inconclusive studies highlight the need for further research to address research gaps.

Keywords: Critical thinking, Generative AI, Higher education

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Introduction

Critical thinking is vital in higher education, influencing students' academic, professional, personal, and socio-political growth. Despite extensive research, there is no universally accepted definition, though it is recognised as a key academic skill that encourages students to question and reflect on knowledge (Moore, 2011; Davies, 2015). Research over the past four decades, particularly in Western contexts, highlights the increasing demand for critical thinking skills to meet the needs of a complex, technological society and the globalised economy (Moore, 2011). Philosophical perspectives emphasise argumentation, while psychological approaches focus on cognitive skills. Educational programs have been developed to cultivate logic, reasoning, and argumentation skills (Paul, 2011).

From a cognitive standpoint, critical thinking involves skills, attitudes, and knowledge, encompassing abilities like evaluation, synthesis, analysis, interpretation, inference, and explanation (Sternberg & Halpern, 2020). Critical thinkers excel in communication and teamwork, aiding in problem-solving. Paul and Elder (2006) define critical thinking as the skill of evaluating and improving thought processes, essential for professional success and active democratic participation.

Teaching critical thinking is vital in its contribution to a rational, civilised community, its value across professions, and its role as a lifelong skill (Wass, 2012). Higher education aims to develop critical thinking, a key concern for educators worldwide. Critical thinking enables graduates to participate actively in society, tackle global issues, and foster democracy (Stanford Encyclopedia of Philosophy, 2018). However, teaching critical thinking techniques alone is insufficient; students must learn to apply these skills in real-world situations. Instructors initially support learning through scaffolding but later adopt a facilitator role as students grow more independent. Critical thinking is a learned skill that must be taught, as it is not innate, emphasising the need for education to help students form independent opinions and judgments (Fahim & Masouleh, 2012).

The Dearing Report (1997) and the Hunt Report (2011) emphasise the importance of undergraduates acquiring skills such as "learning to learn," "critical analysis," and "independent thought," highlighting the need for these skills to address future societal needs. Tomlinson (2010) notes that technological advancements and new knowledge requirements have shifted employer expectations, making life skills and critical thinking essential for graduates.

Employees who adapt to changing conditions and technological advancements are crucial in today's dynamic workplace. Critical thinking skills enable graduates to think creatively, learn quickly, and solve problems. According to the World Economic Forum (2023), "critical thinking and problem-solving" are among the most essential skills for future employment.

Critical thinking and problem-solving are crucial skills in every job, as they involve analysing situations, identifying key issues, evaluating data, and making informed decisions. According to a NACE report (2021), these are the most sought-after skills among recent graduates. However, national assessments in the United Kingdom (UK) and the United States (US) indicate that university students' critical thinking abilities are not improving (Arum & Roksa, 2011; Huber & Kuncel, 2016). A survey found that only 39% of US employers believe graduates are well-prepared in critical thinking, highlighting a mismatch between workforce demands and educational outcomes (Y Fin Le Y. et al., 2021).

Despite the importance of critical thinking skills for undergraduates, some barriers hinder their development, as demonstrated by a study on South African undergraduates. (Eze. et al., 2022). The

main obstacles include lecturers' lack of proficiency, societal norms that discourage challenging authority, students' unfamiliarity and reluctance, and an education system focused on memorisation. Additional factors include confirmation biases, language proficiency, and an overreliance on lectures and teachers. In summary, critical thinking in higher education is vital, but it faces significant challenges due to various educational and societal factors (Utami et al., 2021).

Generative AI and Critical Thinking in Higher Education

Generative Artificial Intelligence (GenAI) is a type of artificial intelligence that can generate content in the form of text, image, audio, video, animation, and code (Chan & Hu, 2023). GenAI technologies like ChatGPT are revolutionising higher education by reshaping traditional teaching methods and enhancing learning experiences. GenAI, which uses machine learning and neural networks to generate content, has seen rapid adoption, exemplified by ChatGPT's massive user base shortly after its release in November 2022 (Lim et al., 2023). GenAI offers personalised tutoring, automated grading, language translation, and interactive learning (Chan & Hu, 2023). However, it also raises concerns about academic integrity, privacy, and the potential for students to rely too heavily on GenAI, undermining their critical thinking skills (Tamrat, 2022).

Integrating GenAI in higher education presents opportunities and challenges for fostering critical thinking. While AI tools can enhance problem-solving and creativity, they may also lead to a decline in higher-order cognitive skills if over-relied upon (Bhosale, 2023). However, the impact of GenAI on critical thinking remains a topic of debate. Critics argue that excessive dependence on GenAI may reduce students' motivation to conduct independent research and analysis (Farrokhnia et al., 2023). Therefore, it is crucial to integrate GenAI thoughtfully into educational systems to encourage inquiry, discussion, and critical evaluation rather than passive learning. This balance is essential to ensure that GenAI is a complement to, rather than a replacement for, traditional educational methods.

The impact of GenAI on undergraduate students' critical thinking remains underexplored, with significant gaps in empirical research, theoretical frameworks, and practical applications (Wang, 2024). Additionally, there is a need for more comprehensive studies on students' and teachers' perceptions of GenAI across various demographics and educational contexts (Chan & Lee, 2023). With the unprecedented interest in GenAI, it is essential to explore students' experiences and perceptions to understand how these technologies can be integrated into higher education to enhance critical thinking skills.

This literature review maps prior research on the influence generated by GenAI on undergraduate students' critical thinking. The result of this Systematic Literature Review is to map out possibilities for further research on the impact of GenAI on the development of critical thinking abilities among undergraduates.

Methodology

Systematic Literature Review

Systematic literature reviews aim to examine a specific research question comprehensively. Unlike standard literature reviews, which offer a general overview, systematic reviews are highly focused and involve a more structured and transparent process. This process includes clearly defined protocols, meticulous planning, and a detailed search strategy (Lame, 2019).

These reviews offer in-depth insights, making them exceptionally valuable to practitioners and researchers despite being more time-consuming and detailed than standard literature reviews. The focus, transparency, and comprehensive nature of systematic reviews ensure their reliability and relevance in research.

The steps in a systematic literature review typically involve (Lame, 2019):

1. Defining the research question
2. Developing a protocol
3. Conducting a comprehensive literature search
4. Selecting studies
5. Extracting data
6. Assessing study quality
7. Synthesising data
8. Interpreting and reporting results
9. Drawing conclusions and making recommendations
- 10.

Research Question

The following question is addressed in the systematic Review

- What is the impact of Generative AI on the critical thinking skills of undergraduates?

Literature Review Source

The literature sources that were used in this research are from several trusted and recognised quality publishers, such as:

- Emerald Insight (<http://emeraldinsight.com>)
- IEEE Explore (<http://ieeexplore.ieee.org>)
- Taylor & Francis Online (<http://tandfonline.com>)
- Digital Scholarship (<http://digital-scholarship.org>)
- Sage Publications (<https://us.sagepub.com>)
- Elsevier(<https://www.elsevier.com>)
- SpringerOpen(<https://www.springeropen.com>)
- ACM Digital Library (<https://dl.acm.org>)
- arXiv(<https://arxiv.org/>)
- Wiley Online (<https://onlinelibrary.wiley.com>)

The references were obtained from several sources of literature. These references were sorted using inclusion and exclusion criteria, which we will explain in subsequent sections.

Study Selection

Study selection is used to sort the references from various online publishing sources. Over a thousand articles were initially identified, and after sorting, 30 references were identified as relevant to the research. Two criteria were applied to the literature selection process to establish clear boundaries, as outlined in Table 1.

Table 1: Inclusion and Exclusion Criteria

Inclusion Criteria	● Papers published in English. ● Complete papers. ● Papers are available in electronic format. ● Papers published in Journals.
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	● Papers related to the search string terms. ● Papers published after November 2022 ● References that discuss the impact of GenAI in higher education
Exclusion Criteria	● References that discuss the general impact of GenAI in education ● References which are published before November 2022 ● Documents classified as tutorials, posters, panels, lectures, ● Round tables, theses, dissertations, book chapters and technical reports. ● Duplicate papers. ● Papers that cannot be located.

Initially, a search was conducted using the keywords "Generative AI" and "Higher Education." This search was subsequently refined by including "Critical Thinking" alongside the initial keywords. Research papers were searched using Google Scholar, Connected Papers, Research Rabbit, ResearchGate, and Semantic Scholar. Due to this filtering process, 68 journal articles were identified. From these, 30 articles were selected for Review following additional filtration focused on research questions. The selected papers were then critically examined to address the research questions.

Results and Discussion

Frequently Studied Educational Contexts

From the selected studies on the impact of GenAI on the critical thinking skills of undergraduates, approximately five studies (Berg & Plessis, 2023; Javaid et al., 2023; Farrokhnia et al., 2023; Lu et al., 2024; and Hsiao-Ping Hsu, 2023) focused on the field of education. Additionally, four studies (Jia & Tu, 2024; Shanto et al., 2024; Zaphir et al., 2024; and Fiialka et al., 2023) included undergraduates from various disciplines. Three studies (Yilmaz, 2023; Styve et al., 2024; and Elsayed, 2023) specifically investigated the development of critical thinking skills among computing students, particularly in programming. Two studies (Wang, 2024; and Hutson, 2024) examined the influence of GenAI in English language studies. Furthermore, there is one study each in the fields of business (Essien et al., 2024), social science (Taiye et al., 2024), applied science (Walter, 2024), and mathematics (Barana et al., 2023), all exploring the effects of GenAI on the critical thinking abilities of undergraduates.

Research Methods Employed for Analysis

In the systematic literature review on the impact of Generative AI on the critical thinking skills of undergraduates, various research methods were identified, with a dominant approach being the quasi-experimental study design. This method involved control and experimental groups, where the experimental groups utilised GenAI tools, while the control groups engaged in traditional methods that required critical thinking skills. This design was prevalent in the selected papers, including studies by Essien et al. (2024), Shanto et al. (2024), Barana et al. (2023), Lu et al. (2024), and Yilmaz (2023) as it allowed for a comparative analysis of the effects of GenAI on students' cognitive abilities. Additionally, qualitative methodologies were employed, notably through exploratory case studies and phenomenological research, which included document analysis to gain in-depth insights into participants' experiences and perceptions as well as thing ethnography in the studies of Berg and Plessis (2023), Wang (2024), Michel-Villarreal et al.(2023), (Elsayed,2023), Lancaster (2023), Walter (2024), and Zaphir et al. (2024). Online surveys were also used in studies such as Smolensky et al. (2023), Styve, Virkki, & Naeem (2024), and Fiialka et al. (2023) to gather quantitative data, providing a broader understanding of the trends and patterns in the data. Furthermore, structural equation modelling was employed (Jia & Tu, 2024) to examine the relationships between variables, offering a comprehensive

view of the factors influencing critical thinking skills. Also, mixed-method approaches, combining both quantitative and qualitative methods, were utilised in the studies of Ruiz-Rojas et al. (2024), Leiker et al. (2023), and Hsiao-Ping Hsu (2023) to provide a holistic understanding of the impact of GenAI on undergraduates' critical thinking skills, integrating diverse data sources for richer analysis and interpretation. In addition, there are a number of studies such as Sallam (2023), George et al. (2023), Lim et al. (2023), Kasneci et al. (2023), Farrokhnia et al. (2023), Thiga (2024), Rudolph, Tan, and Tan (2023), Javaid et al. (2023), Dai et al. (2023), and Hutson (2024) employed literature review or desk-based analysis. Also, a few unique approaches, such as Taiye et al. (2024) used Soft Systems Methodology, and Tenakwaha et al. (2023) applied Competency Based Analysis.

The Potential of GenAI in Enhancing Cognitive Abilities

GenAI can be used to develop students' critical thinking in the form of data generation (Berg & Plessis, 2023). However, contrary to the study of Smolansky et al. (2023), academics assume Artificial Intelligence (AI) will be used to encourage critical thinking. However, students' reactions are mixed, in part due to concerns about a loss of creativity. Kasneci et al. (2023) contend that excessive dependence on ChatGPT might detrimentally affect students' abilities to think critically and solve problems.

Using its ability to produce human-like writing on a broad range of subjects, ChatGPT has become a potent conversational AI agent (George et al., 2023). However, some worry that relying on it too much can result in problems like plagiarism, a lack of critical thinking skills, and the dissemination of false information (Sallam, 2023). To give students feedback on their work and encourage them to think more carefully about the course material, Javaid et al. (2023) suggested employing ChatGPT as a teaching assistant. They discovered that posing challenging queries and highlighting errors in students' logic could assist them in developing their critical analysis abilities. ChatGPT was conceived by Dai et al. (2023) as a student-driven invention with immense potential to empower students and improve their educational resources and experiences. Due to its sophisticated conversational abilities, ChatGPT can offer formative feedback on essays and transform it into a tutoring system, fostering critical thinking and stimulating student debates (Farrokhnia et al., 2023). According to Michel-Villarreal et al. (2023), educators can use simulations or virtual personas driven by ChatGPT, facilitating student involvement in role-playing scenarios, decision-making activities, or historical recreations. These immersive encounters can potentially boost student motivation, critical thinking, and creativity.

Influence of GenAI on Critical Thinking

The study by Thiga (2024) explores the impact of GenAI on developing critical thinking skills, noting that information overload can hinder critical analysis, and the attention economy affects critical thinking by capturing scarce attention resources. The methodology involved a literature review, surveys, and interviews with educators and students to understand their experiences with GenAI and analyse qualitative data to identify patterns and themes. Observations in educational settings assessed the effects of GenAI tools on learning outcomes. Key findings of Thiga (2024) indicate that GenAI can enhance critical thinking by providing personalised learning experiences and promoting creativity. Integrating GenAI tools improves student engagement, motivation, problem-solving, and analytical thinking skills. The study suggests that GenAI in education helps students develop adaptability and resilience.

The study of Jia and Tu (2024) investigates AI's impact on critical thinking awareness in college students, focusing on AI capabilities, general self-efficacy, and learning motivation. The objectives are to explore how AI fosters critical thinking by enhancing self-efficacy and motivation, examine causal relationships between these factors, understand AI's role in education, and provide theoretical and practical insights. The methodology includes a literature review, hypothesis development, data

collection through surveys, questionnaire design and validation, and statistical analysis using structural equation modelling. Key findings indicate that AI indirectly enhances critical thinking awareness by boosting self-efficacy and motivation. General self-efficacy significantly influences learning motivation and critical thinking, while learning motivation strongly correlates with critical thinking skills. However, AI's direct impact on critical thinking is not significant.

The study conducted by Wang (2024) examines how native and non-native English-speaking college students engage with ChatGPT in their writing processes, focusing on their perceptions, experiences, and ethical dilemmas. Employing a phenomenological approach, the research reveals that students use AI tools for convenience and enhancing their critical thinking skills. Students reported both cognitive and emotional benefits from using ChatGPT, showing a critical engagement with AI suggestions and reflecting on their writing practices. The study also underscores the challenges of maintaining an authentic voice while incorporating AI, highlighting the importance of critical AI literacy (Wang, 2024). However, the research's limitations include a small sample size, a brief duration, a specific context, varying proficiency levels, and the constraints of a phenomenological design, which may not fully capture the diversity of student experiences.

GenAI can contribute to education by generating intricate scenarios for students to analyse and assess using Bloom's taxonomy (JISC 2023). Additionally, engaging with GenAI text generators can prompt students to devise innovative solutions, stimulating the highest cognitive skill level (creating) within Bloom's taxonomy (Rudolph et al., 2023). According to the findings of Shanto et al. (2024), students, on average, expressed that AI significantly assisted in idea generation and critical analysis compared to working independently. This study evaluates students' responses using Lee's model (Lee, 2000, as cited in Shanto et al., 2024) of thinking levels. However, the limitations of Shanto et al. (2024) study include the small sample size, the controlled experimental setting, potential AI reliability issues, and the risk of over-reliance on ChatGPT, which could hinder original thought and creativity. On the contrary, the research on the impact of GenAI text generators on critical thinking skills in UK business schools demonstrates that AI-based text generators enhance only the lower levels of Bloom's taxonomy (Essien et al., 2024). Additionally, it tackles concerns regarding reliability, accuracy, and ethical implications associated with the educational use of AI text generators.

GenAI and Critical Thinking in Different Educational Contexts

In a study on fostering critical thinking in solving mathematical problems (Barana et al., 2023), students primarily used ChatGPT to aid in problem-solving by exploring different solutions and testing their validity. ChatGPT facilitated critical thinking, particularly when students evaluated the AI's proposed solutions or used the tool to verify their answers. This has both scientific and practical implications. The results indicate that AI did not replace human involvement but complemented the students, reinforcing their active participation in problem-solving.

The study by Lu et al. (2024) assessed the impact of GenAI-assisted training on 215 Chinese preservice teachers' self-efficacy and higher-order thinking skills. One group received AI-assisted training using a pretest-post-test design, while a control group used traditional methods. The AI group significantly outperformed the control group in self-efficacy and higher-order thinking. Interviews with 25 participants highlighted positive perceptions, demonstrating AI's effectiveness in teacher development.

The study by Yilmaz (2023) investigates the impact of ChatGPT on students' computational thinking skills, programming self-efficacy, and motivation. Conducted in a flipped classroom setting with hands-on coding, the experimental group used ChatGPT for programming homework. Analysis of covariance

(ANCOVA) analysis compared the computational thinking skills of the experimental and control groups. Key findings reveal that the experimental group demonstrated higher computational thinking skills, self-efficacy, and motivation. ChatGPT enhanced students' creativity, algorithmic thinking, cooperativity, and problem-solving abilities. Additionally, the experimental group had significantly higher post-test scores in computer programming self-efficacy. Limitations of the study include the short five-week duration, the small sample size of 45 students affecting generalizability, and the reliance on Unified Modeling diagrams, limiting the variety of programming tasks.

The study of Berg and Plessis (2023) investigates the role of ChatGPT in teacher education, focusing on lesson planning, critical thinking, and openness. It examines how GenAI tools like ChatGPT can assist teachers by providing specific materials and support mechanisms, such as lesson plans, enhancing teachers' critical thinking by encouraging diverse approaches. The qualitative methodology employed an exploratory case study design and phenomenological research with document analysis, ensuring data trustworthiness through credibility, transferability, dependability, and confirmability. Key findings highlight that ChatGPT makes lesson plans accessible to all teachers, promoting equity across geographical, social, and cultural backgrounds. However, the study emphasises the need for caution and critically evaluating AI tools for limitations and biases (Berg & Plessis, 2023).

Taiye et al. (2024) investigated using GenAI chatbots to enhance academic writing and critical thinking, focusing on ethical challenges and stakeholder perspectives. It aims to develop CHAT4ISP-AI, a tool to improve academic writing skills. Utilising Soft Systems Methodology (SSM), the research involved iterative enhancements through stakeholder feedback, incorporating diverse perspectives from developers, IT (Information Technology) support, teachers, and students. SSM employed structured qualitative data and adaptive stakeholder engagement to refine the tool. Key findings reveal varied expectations and concerns among stakeholders, with students engaging more in idea generation, summarising sources, and checking grammar, while teachers have mixed reactions regarding academic integrity (Taiye et al., 2024). The CHAT4ISP-AI tool shows promise but requires further development and ethical considerations. Limitations include a focused scope on first-year Social Sciences students, the initial proof-of-concept stage of the tool, divergent stakeholder objectives, and operational challenges related to time and funding for further development.

Tenakwaha et al. (2023) assess ChatGPT's competence in answering university-level questions across disciplines like Accounting, Social Work, Law, Management, and Education. It highlights ChatGPT's language proficiency, reasoning ability, and response structuring but also identifies its limitations in producing sophisticated, contextually relevant arguments. The study emphasises the importance of human oversight in ensuring the accuracy and feasibility of AI-generated content. A multidisciplinary team from five Australian universities evaluated ChatGPT's responses, noting that while clear and readable, they often lacked depth and engagement. Despite its strengths, ChatGPT's responses were sometimes basic, lacking in critical analysis and specific examples (Tenakwaha et al., 2023). The study suggests using ChatGPT to stimulate deeper thinking rather than as a complete solution for academic writing, underscoring the necessity of human intelligence in reviewing AI output. Limitations included a lack of detailed analysis, correct references, and cohesive idea flow, necessitating user verification of ChatGPT's information.

In the article "Rethinking Plagiarism in the Era of Generative AI," Hutson (2024) explores how GenAI can enhance students' critical thinking skills in English composition courses. He argues that GenAI tools can encourage originality by helping students generate unique ideas and content, fostering creative thinking. Additionally, GenAI provides instant feedback on students' work, aiding in the refinement of

arguments and improving reasoning skills. The article also highlights how GenAI facilitates research by assisting in the gathering and analysing information, which enables students to develop well-informed perspectives.

The research findings from the study on incorporating GenAI tools into introductory programming courses (Styve et al., 2024) indicate an improvement in students' critical thinking practices. After engaging with AI-based programming assignments, students demonstrated a more remarkable ability to critically evaluate AI-generated solutions, reflecting on their appropriateness and reliability.

Strategies of Integration of GenAI in Critical Thinking of Undergraduates

Walter's paper (2024) discusses the importance of AI literacy, prompt engineering, and critical thinking in modern education, employing a two-step methodology. Conceptual discussions and informal conversations with students and lecturers at the Swiss University of Applied Sciences, combined with the author's teaching experience, explored AI's role in education. Real-life case studies identified the need for further clarifications and best practices, while a narrative literature review addressed open questions and offered practical suggestions for higher education. Key findings revealed a lack of comprehensive AI training for students and highlighted AI's potential to support special needs interventions. Practical suggestions emphasise AI literacy and prompt engineering to enhance educational experiences and promote critical thinking. However, the paper's conceptual focus and case study from a single Swiss university may limit its generalizability. Additionally, it relies on informal discussions, which might not fully capture the diverse challenges and opportunities in various educational settings.

Zaphir et al. (2024) introduce the MAGE framework (Mapping, AI vulnerability testing, Grading, Evaluation) to evaluate the quality of critical thinking in GenAI like ChatGPT4. The framework assesses the vulnerability of assessment tasks to AI, emphasising the importance of critical thinking skills that AI can mimic but not fully perform. The methodology involves mapping cognitive skills, testing AI vulnerability with different question versions, grading AI responses, and evaluating results. A case study demonstrates the framework's application, showing how various assessment tasks can be evaluated for AI vulnerability. Key findings of Zaphir et al.'s (2024) paper highlight the limitations of ChatGPT4 in emulating critical thinking, suggesting that educators redesign assessments to focus on more profound comprehension and analytical skills. The study emphasises the importance of authentic learning to deter AI-driven shortcuts.

Integrating AI text generators into education poses distinct challenges, underscoring the intricacy of incorporating them into existing teaching methodologies (Lancaster, 2023). Another challenge pertains to the accuracy of AI-generated content, with nonsensical responses being common, indicating occasional failures in grasping context accurately and raising concerns about its precision. Ensuring the reliability of AI tools necessitates robust fact-checking procedures and continuous review mechanisms (Leiker et al., 2023).

The paper by Ruiz-Rojas et al. (2024) explores the impact of GenAI tools on critical thinking and collaboration among university students, aiming to identify suitable tools, evaluate their effects, and develop effective pedagogical strategies. Using a mixed methods approach, including quantitative surveys and qualitative thematic analysis, the study assessed 121 students selected through purposive sampling. Key findings show high familiarity with AI tools, with 87% of respondents aware of them and 38% using them occasionally. Additionally, 64% believe these tools significantly enhance critical thinking. Despite this, there is a need for continuous training and technical support. Limitations include

limited sample size, a focus on quantitative data, which may not capture the full depth of experiences, a lack of longitudinal data to assess long-term impacts, and ethical concerns related to AI biases and data privacy.

Hsiao-Ping Hsu (2023) generated a short research paper with the support of ChatGPT 4.0 using prompt engineering techniques, and the study found that GenAI can assist in research and education by generating ideas and designs. However, it is crucial for scholars to evaluate its outputs to uphold academic integrity critically. While GenAI offers efficiency and accessibility, it challenges traditional knowledge, scholarship, and teaching concepts. More emphasis should be placed on developing critical thinking skills to responsibly use GenAI, ensuring it complements rather than detracts from the essence of education and scholarly work.

Existing literature highlights the potential integration of GenAI into education while also underscoring the risks associated with excessive reliance on AI. By understanding the constraints of AI models such as ChatGPT and designing questions, educators can encourage active participation in the learning journey, fostering the growth of critical thinking and problem-solving abilities among students (Elsayed,2023).

Nevertheless, it is essential to recognise that merging human intellectual capacity with the potential of GenAI transcends the limits of human capability, accelerating the generation of innovative ideas and fostering a more meaningful and effective educational process (Fiialka. et al.,2023).

Summary of Key Findings

Table 2 summarises significant research works reviewed in this paper, including method, conclusion, key findings, and drawbacks.

Table 2: Summary of key findings

Author	Method	Conclusion	Key Findings	Drawbacks
Thiga (2024)	Literature Review	GenAI can enhance critical thinking	Integrating AI tools improves student engagement, motivation, problem-solving abilities, and analytical thinking skills.	The methodology was not strong enough for a conclusive result. Not focused on a specific GenAI application
Jia et al. (2024).	Structured equation modelling	AI indirectly enhances critical thinking awareness	General self-efficacy significantly influences both learning motivation and critical thinking, while learning motivation strongly correlates with critical thinking skills. However, AI's direct impact on critical thinking is not significant.	Genetic factors were not tested. The proposed path model was only marginally accepted. The reinforcement learning theory was not utilised fully.
Wang (2024)	Phenomenological	Students use AI tools for convenience and	Students reported both cognitive and emotional benefits from using ChatGPT,	Sample size. Short duration of the study.

	research design	to enhance their critical thinking skills.	showing a critical engagement with AI suggestions and reflecting on their writing practices.	
Sadat Shanto et al. (2024)	Quasi-experimental design	AI significantly assisted in idea generation and critical analysis	Framework 'AI-CRITIQUE' enhances critical thinking using ChatGPT in education	Small sample size. The framework was only tested in a controlled and experimental environment and not in real-life situations.
Essien et al. (2024).	Quasi-experimental design	AI-based text generators enhance only the lower levels of Bloom's taxonomy	Significant improvements in lower levels of Bloom's taxonomy	Bloom's Taxonomy may not capture the breadth of skills to evaluate a detailed assessment.
Barana et al. (2023).	Quasi-experimental design	ChatGPT facilitated critical thinking,	AI did not replace human involvement but complemented the students, reinforcing their active participation in the problem-solving process.	It was only tested for a single discipline.
Lu et al. (2024)	Quasi-experimental design	The AI group significantly outperformed the control group in self-efficacy and higher-order thinking.	This study produced a practical teachers' professional development method for preservice teachers with generative AI.	Only teachers of Mathematics, Science and Computer Science were considered.
Yilmaz et al. (2023)	Quasi-experimental design	ChatGPT enhanced students' creativity, algorithmic thinking, cooperativity, and problem-solving abilities.	The experimental group demonstrated higher computational thinking skills, self-efficacy, and motivation.	Small sample size. Short study duration.
Berg et al. (2023).	Exploratory Case Study:	The study emphasises the need for caution, critically evaluating AI tools for limitations and biases	ChatGPT makes lesson plans accessible to all teachers, promoting equity across geographical, social, and cultural backgrounds.	Only one lesson of one module for a specific level was reviewed.

Taiye et al. (2024).	Soft System Methodology	Varied expectations and concerns among stakeholders	Students engaging more in idea generation, summarising sources, and checking grammar, while teachers have mixed reactions regarding academic integrity	Limited scope. only the first-year social science students were considered
Tenakwah et al. (2023)	Competence-based analysis of ChatGPT's task response	ChatGPT's responses were sometimes primary, lacking in critical analysis and specific examples	Instead of viewing ChatGPT as a solution to all academic writing challenges, it should be seen as a tool to generate ideas that spark further, more in-depth thinking. Human intelligence must review the output for accuracy, consistency, and practicality for research-oriented tasks.	Students' perspectives on the motivation of ChatGPT were not considered. The longitudinal approach was not considered. Limited disciplines considered
Hutson (2024)	Desk Research	GenAI tools can encourage originality by helping students generate unique ideas and content, fostering creative thinking.	GenAI provides instant feedback on students' work, aiding in the refinement of arguments and improving reasoning skills. GenAI facilitates research by assisting in gathering and analysing information, enabling students to develop well-informed perspectives.	The methodology was not strong enough.
Ruiz-Rojas et al. (2024)	Mixed method	GenAI tools significantly impact the critical thinking of higher education students.	Incorporating didactic and pedagogical approaches and generative AI tools has enhanced the depth and reflectiveness of critical thinking.	Limited sample size. Lack of longitudinal data.
Styve et al. (2024).	Survey-based, Pre and Post-test	GenAI improves students' critical thinking practices.	Students demonstrated a greater ability to critically evaluate AI-generated solutions, reflecting on their appropriateness and reliability.	Higher-order thinking was not evaluated. The introductory course will not represent all levels of coding. The results are based on students' self-reported opinions and practices. Long-term effects and changes in critical thinking practices were not considered. The focus was on specific AI tools only.

Walter, Y. (2024).	Case study	AI literacy and prompt engineering to enhance educational experiences and promote critical thinking	Challenges in educator training, ethical considerations, and resource accessibility.	A single university was considered. Informal discussion may need to be revised.
Zaphir et al. (2024)	Evaluate the MASE framework using case studies	There are limitations of ChatGPT4 in emulating critical thinking,	Educators redesign assessments to focus on deeper comprehension and analytical skills. The study emphasises the importance of authentic learning to deter AI-driven shortcuts.	Not all aspects of critical thinking were considered in the proposed framework.
Hsiao-Ping Hsu (2023).	Iterative three-stage manuscript generation process with ChatGPT	GenAI offers insights and support in developing research ideas and designs, academic writing, and English composition.	The need to balance the growing capabilities of GenAI with preserving traditional academic and educational values is crucial.	Lack of a guiding map providing the expected major and minor heading required for each chapter.

Conclusions and Recommendations

Although the broader impact of GenAI in education has been thoroughly explored (Lim et al., 2023), there has been a noticeable oversight in examining critical thinking within higher education settings (QAA, 2023). The findings of about fifty percent of the reviewed papers conclude that GenAI positively impacts the critical thinking of undergraduates. This literature study indicates that incorporating GenAI tools like ChatGPT into higher education can significantly enhance students' critical thinking skills when used thoughtfully. Studies show structured engagement with ChatGPT helps students move from basic recall to more advanced reasoning and critical analysis (Shanto et al., 2024). However, these findings cannot be generalised due to the sample size, research design, and study context. A significant number of papers have no conclusive evidence of the impact of GenAI on undergraduates' critical thinking skills. The study of Essien et al. (2024) found that the most notable improvements in critical thinking occurred at the lower levels of Bloom's Taxonomy, such as remembering, understanding and applying, suggesting that AI text generators have a foundational impact on student learning. However, there is a lack of solid evidence from the literature showing the positive effects of GenAI on higher-order thinking skills like analysing, evaluation, and creating.

Additionally, concerns about over-reliance on these tools have been raised, which may inhibit creativity and original thought (Taiye et al., 2024). While students often see GenAI as helpful for personalised learning and writing assistance, they also voice concerns about its accuracy and ethical implications, which could affect the development of their critical thinking skills (Chan & Hu, 2023). Thus, while GenAI has the potential to support critical thinking, its effective use requires thoughtful implementation and continuous evaluation to mitigate potential risks (Berg & Plessis, 2023; Taiye et al., 2024).

The selected studies also emphasise AI literacy and prompt engineering, which are key to developing critical thinking skills in education. Teaching students and teachers techniques like zero-shot and few-shot prompting encourages greater engagement with AI, promoting critical analysis and creative problem-solving (Walter, 2024). Collaborative exercises using prompt engineering challenge students and enhance their understanding of AI interactions, enriching their learning experience. This approach also increases awareness of AI's limitations and capabilities, which are essential for informed decision-making and reflective thinking. Integrating AI literacy and prompt engineering creates a more interactive learning environment that fosters critical thinking (Jia & Tu, 2024).

According to the findings of this Review, further studies are needed to address the literature, theoretical, practical, and contextual gaps to provide a more comprehensive understanding of the topic, particularly considering the significance of critical thinking skills in the ever-changing higher educational landscape.

Recommendations

Educators should prioritise AI literacy and prompt engineering to effectively leverage GenAI in fostering critical thinking within academic activities. It is crucial to evaluate assessment tasks for potential AI vulnerabilities and to redesign them to emphasise the testing of critical and analytical skills. Additionally, ensuring the reliability of AI tools and providing clear guidelines on acceptable GenAI tools are essential. Institutions should also develop robust policies to govern the responsible use of GenAI, thereby upholding academic integrity.

Gaps and Limitations

The common limitations across the numerous studies include small sample sizes, which affect the generalizability of findings, and short study durations that limit the understanding of long-term impacts. Many studies had a geographic or disciplinary focus, reducing the applicability of results to broader contexts. Ethical and social implications, such as biases, data privacy, and academic integrity, were frequently noted but not deeply explored. A reliance on quantitative data might not fully capture the depth of participants' experiences and perceptions. Additionally, several studies were in preliminary or conceptual stages, requiring further development and validation. There was a dependency on specific AI tools, frameworks, or methodologies, which might limit the diversity of findings. Lastly, many studies lacked long-term data to assess the sustained impact of AI tools on educational outcomes.

Future Research

There is a pressing need for additional research on higher education institutions to assess their methods of teaching and fostering critical thinking skills, particularly in relation to students' use of GenAI-based tools. Future studies should examine the application of GenAI across different contexts to gain a deeper understanding of its use and the impact of contextual factors on critical thinking skills. Moreover, studies should focus more on how GenAI can improve higher-order thinking skills.

Prior studies have rarely utilised taxonomies beyond Bloom's to evaluate the critical thinking skills of students using GenAI. Furthermore, research should broaden to include more disciplines, allowing for comparisons across fields to identify factors influencing its use. Additional research is needed to explore the link between prompt engineering and critical thinking skills among higher education students. A longitudinal approach could help track applications like ChatGPT and identify long-term users.

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