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PAPER

How Generative AI Influences Students' Self-Regulated Learning and Critical Thinking Skills? A Systematic Review

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ABSTRACT

Generative artificial intelligence (AI), particularly tools such as ChatGPT, is transforming education by enhancing self-regulated learning (SRL) and critical thinking skills, two essential competencies in the digital era. This study systematically analyzes the impact of generative AI on these skills using the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to identify, evaluate, and synthesize relevant studies. Document searches were conducted in Scopus, Web of Science, and ScienceDirect, focusing on publications from 2022 to 2024, when ChatGPT was first widely adopted. Of the 3,214 documents identified, 557 met the initial screening criteria, and 38 studies were selected for detailed analysis. The findings reveal that 71.4% of studies reported AI's positive role in SRL, mainly through personalized learning, metacognitive support, and adaptive feedback. Likewise, 62.5% of studies reported its significant role in critical thinking, supporting the process of analysis, evaluation, and reflection. However, researchers cautioned against an overreliance on technology, which one said could take away some students' ability to think for themselves. Such findings indicate that educational institutions need to change their ways and include generative AI in a model that focuses on areas that foster learner independence. This approach will assist teachers and decision-makers in harnessing the distinctive kitsch of AI technology by creating new learning spaces that are creative and future-oriented.

KEYWORDS

artificial intelligence (AI), ChatGPT, self-regulated learning (SLR), critical thinking

1 INTRODUCTION

The phenomenon of generative artificial intelligence (AI), as with ChatGPT, is transforming education by quickly making personalized and immersive learning experiences possible. Generative AI leverages large language models (LLMs)

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to generate contextually relevant content, offering instant guidance, feedback, and assistance [1, 2, 3]. Since its public release in November 2022, ChatGPT has become a transformative tool in education, particularly in fostering essential skills such as self-regulated learning (SRL) [4, 5, 6, 7, 8] and critical thinking (CT) [9, 10, 11, 12, 13], both of which are essential in navigating the complexities of the digital era.

Self-regulated learning (SRL) refers to students' ability to set goals and regulate their cognition, motivation, and behavior to achieve them [14, 15]. In today's digital learning environment, students face an overwhelming influx of information, necessitating effective SRL to optimize technology use while maintaining focus on learning outcomes [16, 17]. Studies emphasize the contribution of generative AI to improving SRL by providing tailored feedback, supporting metacognitive processes, and facilitating interactive guidance, which empowers students to take greater control of their learning journeys [18, 19]. For instance, tools such as the Guidance-based ChatGPT-assisted Learning Aid (GCLA) have been instrumental in promoting independence and reflective thinking, allowing students to reach their learning objectives with minimal dependence on external support [20].

Similarly, critical thinking competencies have gained significance in the digital world, where students are presented with information and must analyze and synthesize it [21, 22]. Furthermore, CT growth is facilitated by generative AI because the instrument offers feedback for reflection, urges students to consider different angles, and performs a comprehensive evaluation as a step towards decision-making [23, 24]. Generative AI, such as ChatGPT, provides opportunities for students to develop this skill, mainly by giving reflective feedback that requires students to consider multiple perspectives before concluding [25, 26]. Studies show that when combined with well-designed pedagogical approaches, ChatGPT significantly enhances students' CT abilities, especially in problem-solving and decision-making [27].

Generative AI has many benefits, yet it poses significant challenges and worries. For instance, overdependence is a pertinent concern, whereby the over-reliance on ChatGPT-type tools would lessen the chances of students solving challenges independently, thus affecting their cognitive growth [28, 29, 30]. To address these concerns, researchers emphasize the need for structured integration of AI with a pedagogical framework, such as Hybrid Human-AI Regulation, which combines AI assistance with human oversight to maintain learner autonomy while leveraging technological benefits [31].

This systematic review aims to comprehensively analyze the impact of generative AI on SRL and CT skills. Unlike prior iterations, this evaluation digs deep regarding the behaviors to promote effective AI usage in education, bearing in mind practical evidence for teachers and policymakers. It aims to back the development of efficient and reasonable AI-based learning approaches that meet the requirements of the modern world.

2 MATERIAL AND METHODS

This systematic review adopted the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) framework to ensure a structured, transparent, and replicable approach. PRISMA was chosen for its ability to guide

systematic reviews by facilitating comprehensive identification, evaluation, and synthesis of relevant research. This framework enhances the thoroughness and standardization of the review process, thereby increasing its validity and reliability.

The literature search was conducted in three major academic databases: Scopus, Web of Science, and ScienceDirect. The databases were chosen for their extensive scope and established reputation in educational research. To ensure the relevance of the retrieved documents, targeted keywords, including "generative AI," "ChatGPT," "self-regulated learning," "critical thinking," and "education," were applied. Boolean operators (e.g., AND, OR) were used to refine the search, for instance, "ChatGPT AND critical thinking" or "AI AND self-regulated learning." This strategy ensured that only documents directly addressing the research topic were included. Detailed search terms and keyword combinations for each database are summarized in Table 1.

Table 1. Database and keyword identification

Database	Keyword Identification	Total Documents
Scopus	AI AND Self-Regulated Learning AND Education	128
	AI AND Critical Thinking AND Education	477
Web of Science	AI AND Self-Regulated Learning AND Education	87
	AI AND Critical Thinking AND Education	246
Scient Direct	AI AND Self-Regulated Learning AND Education	767
	AI AND Critical Thinking AND Education	1509
Total		3214

The review targeted publications from 2022 to 2024, deliberately selected to ensure relevance and timeliness as ChatGPT began gaining broad adoption in 2022. To maintain the integrity of the analysis, well-defined inclusion and exclusion criteria were implemented (refer to Table 2). To qualify for inclusion, documents had to be peer-reviewed, written in English, and directly addressed the impact of generative AI on SRL or CT. Studies that failed to meet these criteria, such as those without empirical evidence or those centered on unrelated AI applications, were excluded. This rigorous selection process ensured that the review's conclusions were based on reliable and relevant research.

Table 2. Inclusion and exclusion criteria

Inclusion Criteria	Exclusion Criteria
Documents published between 2022 and 2024	Documents published before 2022
The document was original research.	Conference proceedings, Systematic review documents
Peer-reviewed document written in English	Documents that are not Peer-Reviewed
The document included AI and Self-Regulated Learning or Critical Thinking.	Documents published not in English
The research was conducted in an educational setting	Studies that do not focus on education

The selection process followed four key stages. First, 3,214 documents were retrieved from the databases during the identification stage. After removing duplicates and filtering out publications before 2022, 557 papers remained. In the screening stage, titles and abstracts were examined to determine their relevance, resulting in 119 documents advancing to the eligibility stage. At this stage, full texts were thoroughly evaluated against the inclusion criteria. Ultimately, 38 papers met all requirements and were included in the final analysis (see Figure 1).

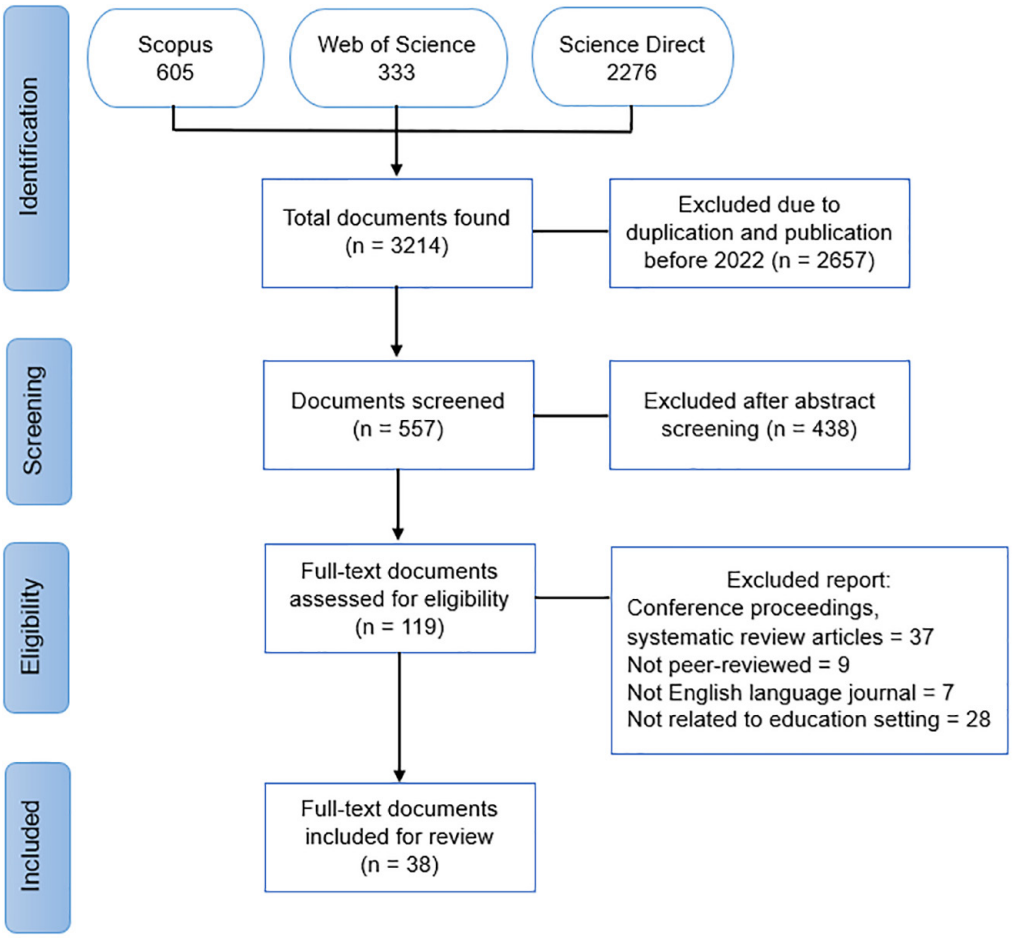

Fig. 1. PRISMA flow diagram

The selected documents were further categorized into two primary themes: SRL and CT. This categorization made it possible to systematically investigate the role of generative AI in these essential educational skills. Document distribution within the decided themes is presented in Table 3. Using the PRISMA framework, this review guarantees an open and consistent approach to selection, providing a robust basis for assessing the impact of generative AI on SRL and CT. This methodological rigor strengthens the reliability of findings and contributes to advancing research in educational technology.

Table 3. Classification of documents

Topic	Documents Reference	Total Document
AI – Self-Regulated Learning (SLR)	[6], [7], [14], [16], [17], [18], [19], [20], [32], [33], [34], [35], [36], [37]	14
AI – Critical Thinking	[1], [2], [9], [12], [13], [20], [23], [24], [25], [26], [27], [28], [29], [35], [38], [39], [40], [41], [42], [43], [44], [45], [46], [47]	24

3 RESULTS

The review of the 38 relevant papers demonstrates an upsurge in research activity concerning generative AI in education. Such a tendency for publication adheres to the exponential increase. According to Figure 2, 2024 was dominated by a precision increase in publications, reaching 78.95% of total studies. It can be noted that this increase comes when ChatGPT and its related technologies are quickly adopted, and therefore, academic evidence about their place in learning is increasing. In contrast, 2022 gave only 2.63% of publications, with one contribution applying to SRL. In 2023, publications grew to 18.42%, dealing with SRL studies (3) and CT studies (4). This pattern accentuates the growing belief in generative AI's ability to solve educational problems.

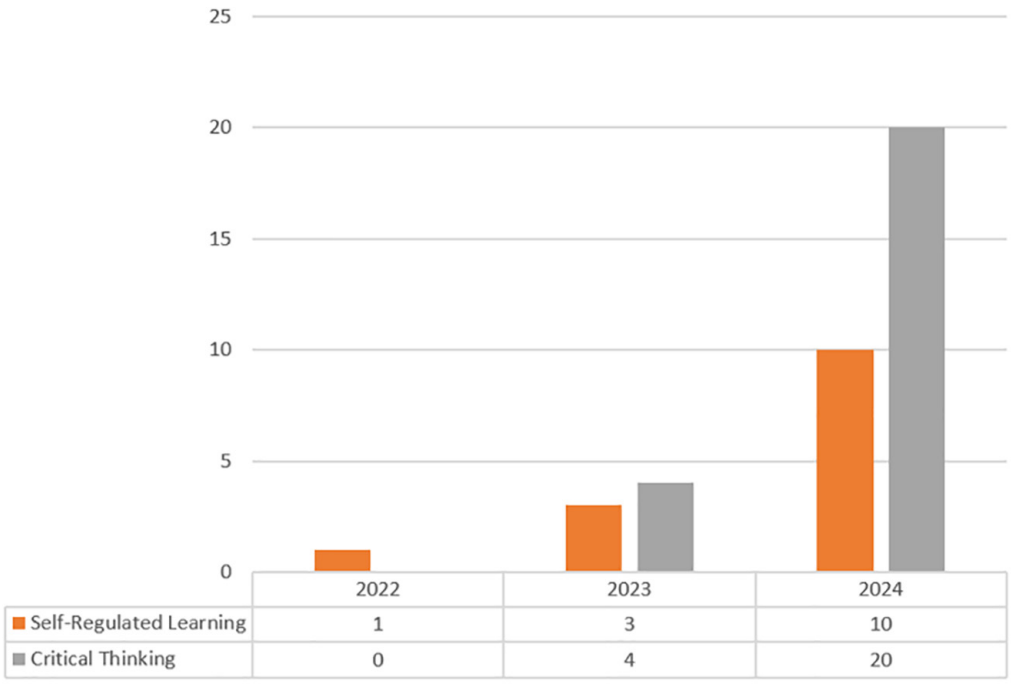

Fig. 2. Number of publications in 2022, 2023, and 2024

The spatial distribution of publications in Figure 3 shows that 25 countries are part of this research work. East Asia dominates with 34.2% of the studies, led by Hong Kong (15.8%), Taiwan, and China (7.9% each). Other significant contributors include Malaysia, Korea, Indonesia, and the USA (5.3% each). Additionally, countries from diverse regions, including Europe, Africa, and the Americas,

contributed 2.6% each. This wide geographical distribution indicates that generative AI research is a global concern, with East Asia emerging as a leading hub, likely due to its emphasis on technological and educational innovation.

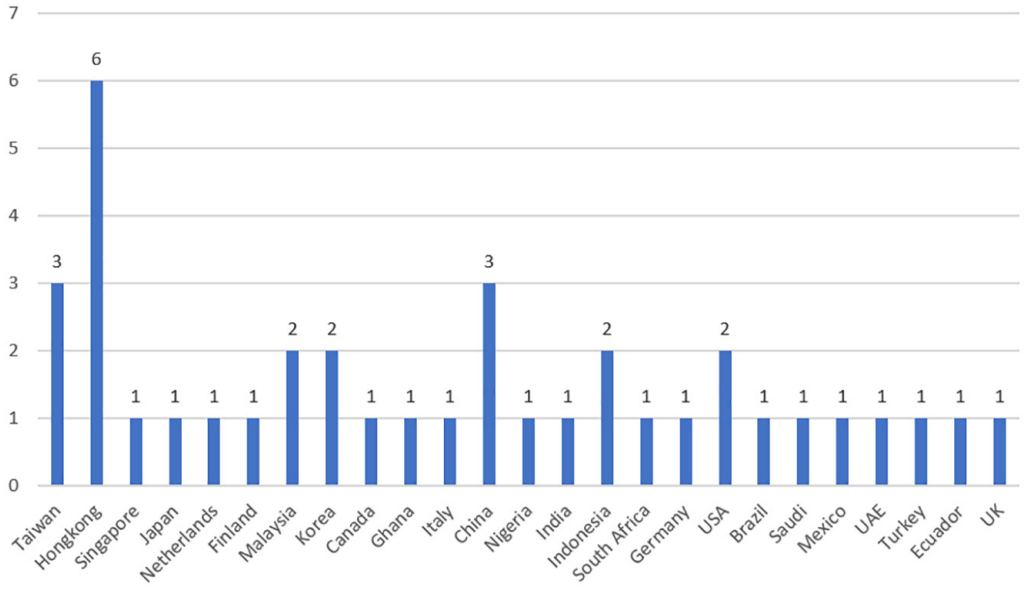

Fig. 3. Number of publications by country

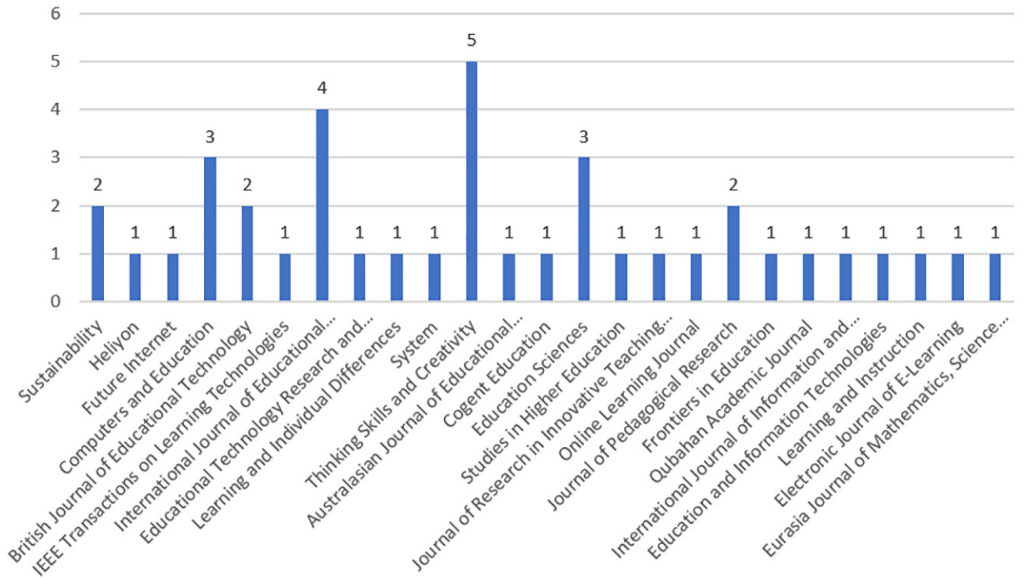

Fig. 4. Number of publications based on journal

Publication platforms also show diversity, as presented in Figure 4. *Thinking Skills and Creativity* leads 13.2% of publications, followed by the *International Journal of Educational Technology* (10.5%), *Computers and Education*, and *Studies in Higher Education* (7.9% each). Journals such as *Sustainability* and the *British Journal of Education* contributed 5.3%, while 17 other journals published one study each (2.6%). This distribution reflects the interdisciplinary nature of generative AI research, spanning education, technology, creativity, and learning innovation.

The research methodologies employed are depicted in Figure 5. Quantitative studies dominate 57.89% of publications, particularly in CT research (14 studies) compared to SRL (8 studies). Qualitative methods account for 15.79%, with slightly more focus on CT (4 studies) than SRL (2 studies). Mixed methods were used in 18.42% of studies, evenly distributed between CT (5) and SRL (2). Additionally, 7.89% of studies employed research and development (R&D) methods, highlighting the practical application of generative AI tools in educational settings.

Figure 6 illustrates the scientific fields of the publications. Language studies and education dominate, contributing 28.95% and 26.32%, respectively, while 26.32% of publications are "unknown," suggesting interdisciplinary research or classification limitations. Science accounts for 13.16% of the studies, with minor contributions from Information Systems and Business (2.63% each). These results indicate that generative AI research strongly emphasizes language and education, reflecting its practical applications in these fields.

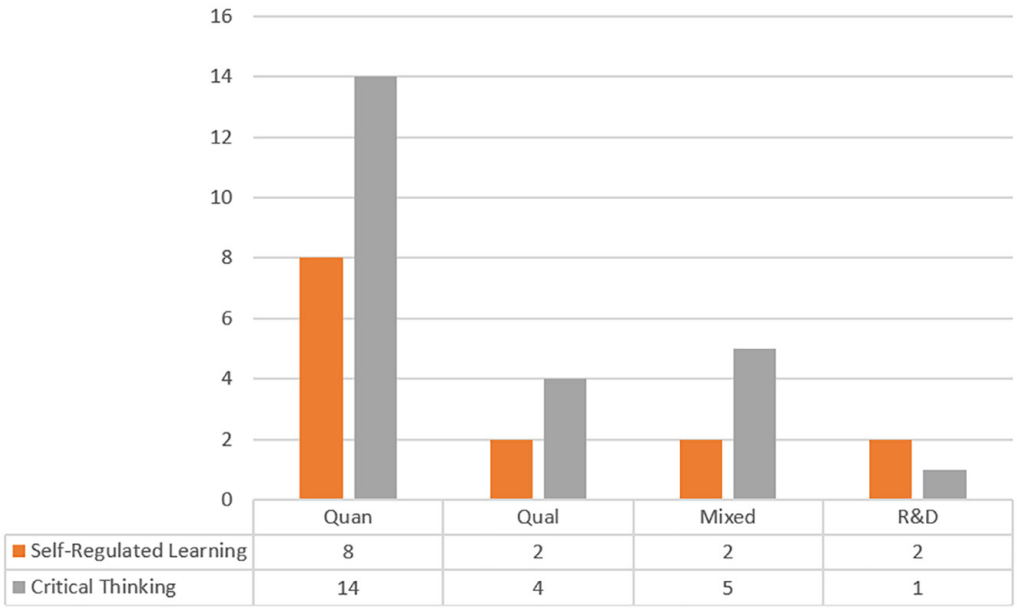

Fig. 5. Number of publications based on method

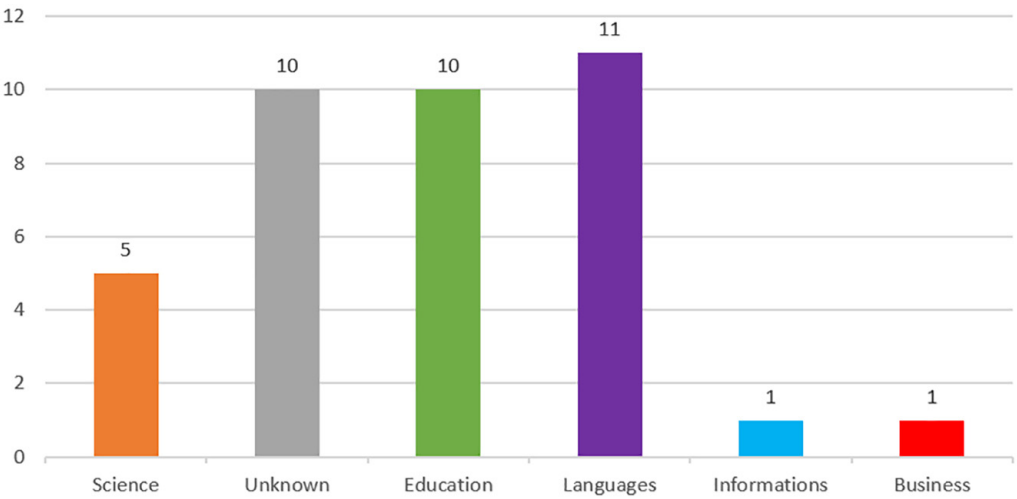

Fig. 6. Number of publications by field of study

The impact of generative AI on SRL and CT is summarized in Tables 4 and 5. Most studies (71.4%) reported a positive effect of AI on SRL, mainly through personalized learning, motivational support, and regulation of learning processes. However, 28.6% of studies noted a neutral influence, often dependent on socio-cognitive factors and the regulatory framework employed. Similarly, 62.5% of studies found a positive effect on CT, particularly in fostering reflective feedback, collaborative learning, and analytical skills. About 33.3% of studies reported a neutral impact influenced by context and methodology, while 4.2% noted a negative impact due to dependency risks.

Table 4. Influence of AI on self-regulated learning

Influence	Documents Reference	Summary of Key Findings	Total
Positive Influence	[5], [6], [16], [18], [32]	Generative AI supports SRL through personalization of learning, metacognitive support, and increased motivation for student self-learning.	71.4%
	[17], [19], [34], [36]	ChatGPT enhances SRL by meeting learning needs, precision support, and high acceptance from users.	
	[14], [20]	Generative AI, guided by the pedagogical framework, showed positive results on SRL and self-regulation of learning.	
Neutral Influence	[7], [33], [35]	The impact of AI on SRL varies and is influenced by socio-cognitive dynamics and the need for guidance in its use.	28.6%

Table 5. Influence of AI on critical thinking

Influence	Documents Reference	Summary of Key Findings	Total
Positive Influence	[2], [13], [27], [44]	Generative AI improves critical thinking skills by providing relevant reflective feedback.	62.5%
	[12], [20], [25], [45]	Generative AI supports critical thinking skills in collaborative learning and through peer feedback assessment.	
	[9], [23], [24], [40]	Generative AI improves complex critical thinking skills, especially in problem-solving and analysis.	
Neutral Influence	[1], [38], [43], [46], [48]	The influence of AI on critical thinking skills is neutral, depending on the context and method of use.	33.3%
	[29], [33], [35]	AI supports independent reflection and competence, but its impact on critical thinking varies depending on the learning dynamic.	
Negative Influence	[28]	It discovered that AI dependency reduces students' initiative to think critically and independently.	4.2%

These findings highlight the global and interdisciplinary interest in generative AI for education. While its potential to enhance SRL and CT is evident, challenges

such as over-reliance and contextual variability underscore the need for thoughtful integration into pedagogical frameworks.

4 DISCUSSION

This systematic review emphasizes that generative AI, especially ChatGPT, already significantly impacts SRL and CT within an educational frame. Generative AI increasingly appears as the tool that could foster main learning competencies through adaptive feedback, metacognitive guidance, and reflective activity [18]. With some conditions, challenges, and opportunities opening up due to this new technology, working out effective strategies for integrating it into education is a complex approach [31, 49, 50, 51].

Generative AI has shown significant promise in supporting SRL by equipping students with resources and strategies to manage their learning processes effectively. SRL involves goal-setting, progress monitoring, and behavior regulation and is vital in navigating modern educational environments with vast and diverse information resources [52]. Tools such as ChatGPT empower students to address specific learning challenges, such as time management or comprehension difficulties, by providing tailored feedback and adaptive learning strategies [18, 32, 34, 37]. The personalization offered by ChatGPT enhances student motivation, a critical component of SRL [53]. Research shows timely and relevant feedback boosts students' confidence and engagement, encouraging sustained effort and fostering autonomy [7, 17, 19, 33]. This immediacy of response addresses immediate learning needs and cultivates long-term self-regulation.

However, generative AI's impact on SRL varies based on cultural and contextual factors. In collaborative cultures, AI tools may need to support teamwork and collective problem-solving rather than individual-focused assistance [35, 36]. Moreover, disparities in digital literacy and access to technology can limit the equitable application of generative AI. Policies promoting digital literacy and equitable access are critical to addressing these disparities and ensuring all students benefit from the technology.

Critical thinking, an essential competency for navigating complex information, is significantly enhanced by AI. ChatGPT contributes to CT development by providing reflective feedback, encouraging students to evaluate their reasoning, consider alternative perspectives, and engage in deeper analytical thinking [12, 23, 45]. For example, its ability to simulate scenarios and pose follow-up questions fosters habits of critical inquiry [2, 27]. Generative AI facilitates higher-order thinking by supporting students in complex cognitive tasks such as argument evaluation and problem-solving [9, 54, 55]. Studies highlight ChatGPT's role as a cognitive partner, enabling students to integrate interdisciplinary knowledge and address practical challenges in project-based learning environments [23, 24, 26, 40]. ChatGPT supports analytical skills by enabling students to dissect multifaceted issues and synthesize solutions.

Despite these advantages, reliance on generative AI without meaningful reflection can limit its impact [56]. Students who use AI passively risk missing opportunities to develop robust CT skills. Additionally, excessive dependence on AI for quick answers can hinder independent problem-solving [28]. These findings emphasize the need for structured guidance to ensure that generative AI complements, rather than replaces, CT development.

Integrating generative AI into education requires structured frameworks that balance technological innovation with human oversight. The *Hybrid Human-AI Regulation* (HHAIR) framework offers a promising approach by combining AI's adaptability with educators' contextual expertise. This model ensures that students retain autonomy while benefiting from AI-driven personalization [14, 16, 57]. For example, AI can facilitate metacognitive development by prompting students to reflect on their learning progress while educators provide the contextual guidance needed to address individual challenges. This synergy enhances immediate learning outcomes and cultivates long-term SRL and CT skills. HHAIR supports immediate learning needs and fosters skills like metacognition and reflection. This framework enables a collaborative dynamic where human and AI interactions complement each other by prompting students to evaluate their progress and adapt strategies accordingly. Such integration minimizes risks such as dependency while maximizing generative AI's transformative potential.

While the potential of generative AI in education is immense, challenges such as dependency, digital inequities, and ethical concerns must be addressed. Policymakers must prioritize training initiatives for educators and students to ensure the effective use of AI tools. Furthermore, collaboration between technology developers and educators is essential to designing AI systems that align with diverse learning needs.

Future research should explore the long-term impact of generative AI on SRL and CT across varied educational settings. Investigating how AI can be adapted for different age groups, cultural contexts, and disciplines will provide valuable insights for scaling its implementation. Furthermore, ethical considerations, including data privacy and bias mitigation, must be prioritized as AI continues to shape the future of education.

5 CONCLUSION

This review aims to demonstrate the radical change that generative AI, especially ChatGPT, can bring to redefine the dimension of education in the digital world. Generative AI introduces two indispensable skills in today's education: improving SRL and CT. Students can take charge of their learning processes independently, enhancing their self-regulation and self-management through generative AI that provides personalized learning, informative feedback, and metacognitive guidance. Furthermore, generative AI shares the merits of promoting reflective, analytic, and evaluative practices, which are fundamental in nurturing critical thinking during this era, which is characterized by high levels of modern, sophisticated, but complex information. Generative AI can have enormous advantages, but this review stresses the need to resolve the issues that come with it. One such concern is the chances of AI being overused, which may inhibit independent or critical thinking among the students. It is a risk highlighting the importance of integrating AI in education with extreme caution. The HHAIR framework supports a robust pedagogical framework and suggests synergies of AI and human interactions to achieve desired learning outcomes. This way helps students control their learning while AI provides faster and more appropriate solutions to set goals, creating efficiency.

Educators and policymakers must develop strategies to promote generative AI's judicious use to maximize its benefits. This includes training educators to effectively integrate AI into teaching practices and ensuring equitable access to AI technologies across diverse cultural and socio-economic contexts. Policies supporting digital literacy and ethical AI implementation will be critical to mitigating potential risks and maximizing the inclusivity and adaptability of AI-driven education systems. This study has also revealed some areas for future work. Research should investigate

the longitudinal effects of generative AI on SRL and CT, as well as across life stages, educational contexts, and cultural contexts. Research on the moral aspects of AI implementation in education (e.g., bias, data privacy, and algorithmic transparency) will be significant as technology advances. Research should also explore how generative AI can be integrated into the broader curriculum to enable collaboration and innovation between fields.

In conclusion, generative AI can change education forever by providing a more inclusive, adaptive, and future-ready learning atmosphere. When implemented thoughtfully, it can enhance the learning experience, support students, and prepare them with the necessary skills to face challenges in the modern world. Thus, generative AI is a tool and a catalyst for the latter global education revolution.

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7 REFERENCES

[1] Y. Dai, S. Lai, C. P. Lim, and A. Liu, "ChatGPT and its impact on research supervision: Insights from Australian postgraduate research students," *Australasian Journal of Educational Technology*, vol. 39, no. 4, pp. 74–88, 2023. https://doi.org/10.14742/ajet.8843

[2] H. B. Essel, D. Vlachopoulos, A. B. Essuman, and J. O. Amankwa, "ChatGPT effects on cognitive skills of undergraduate students: Receiving instant responses from AI-based conversational large language models (LLMs)," *Computers and Education: Artificial Intelligence*, vol. 6, 2024. https://doi.org/10.1016/j.caeai.2023.100198

[3] C. K. Y. Chan and L. H. Y. Tsi, "Will generative AI replace teachers in higher education? A study of teacher and student perceptions," *Studies in Educational Evaluation*, vol. 83, 2024. https://doi.org/10.1016/j.stueduc.2024.101395

[4] L. K. Ng and C. K. Lo, "Enhancing online instructional approaches for sustainable business education in the current and post-pandemic era: An action research study of student engagement," *Educ. Sci. (Basel)*, vol. 13, no. 1, p. 42, 2023. https://doi.org/10.3390/educsci13010042

[5] W. L. Chang and J. C. Y. Sun, "Evaluating AI's impact on self-regulated language learning: A systematic review," *System*, vol. 126, 2024. https://doi.org/10.1016/j.system.2024.103484

[6] S. H. Jin, K. Im, M. Yoo, I. Roll, and K. Seo, "Supporting students' self-regulated learning in online learning using artificial intelligence applications," *International Journal of Educational Technology in Higher Education*, vol. 20, no. 1, 2023. https://doi.org/10.1186/s41239-023-00406-5

[7] J. W. Lai, "Adapting self-regulated learning in an age of generative artificial intelligence chatbots," *Future Internet*, vol. 16, no. 6, p. 218, 2024. https://doi.org/10.3390/fi16060218

[8] K. Lobos, R. Cobo-Rendón, D. Bruna Jofré, and J. Santana, "New challenges for higher education: Self-regulated learning in blended learning contexts," *Front. Educ. (Lausanne)*, vol. 9, 2024. https://doi.org/10.3389/feduc.2024.1457367

[9] R. Suriano, A. Plebe, A. Acciai, and R. A. Fabio, "Student interaction with ChatGPT can promote complex critical thinking skills," *Learn. Instr.*, vol. 95, 2025. https://doi.org/10.1016/j.learninstruc.2024.102011

[10] F. López *et al.*, "Developing critical thinking in technical and vocational education and training," *Educ. Sci. (Basel)*, vol. 13, no. 6, p. 590, 2023. https://doi.org/10.3390/educsci13060590

[11] L. A. Schindler, G. J. Burkholder, O. A. Morad, and C. Marsh, "Computer-based technology and student engagement: A critical review of the literature," *Int. J. Educ. Technol. High. Educ.*, vol. 14, no. 25, 2017. https://doi.org/10.1186/s41239-017-0063-0

[12] L. I. Ruiz-Rojas, L. Salvador-Ullauri, and P. Acosta-Vargas, "Collaborative working and critical thinking: Adoption of generative artificial intelligence tools in higher education," *Sustainability (Switzerland)*, vol. 16, no. 13, p. 5367, 2024. https://doi.org/10.3390/su16135367

[13] A. Essien, O. T. Bukoye, X. O'Dea, and M. Kremantzis, "The influence of AI text generators on critical thinking skills in UK business schools," *Studies in Higher Education*, vol. 49, no. 5, pp. 865–882, 2024. https://doi.org/10.1080/03075079.2024.2316881

[14] I. Molenaar, "The concept of hybrid human-AI regulation: Exemplifying how to support young learners' self-regulated learning," *Computers and Education: Artificial Intelligence*, vol. 3, 2022. https://doi.org/10.1016/j.caeai.2022.100070

[15] R. Guan, M. Raković, G. Chen, and D. Gašević, "How educational chatbots support self-regulated learning? A systematic review of the literature," *Educ. Inf. Technol. (Dordr.)*, 2024. https://doi.org/10.1007/s10639-024-12881-y

[16] S. C. Kong and Y. Yang, "A human-centered learning and teaching framework using generative artificial intelligence for self-regulated learning development through domain knowledge learning in K-12 settings," *IEEE Transactions on Learning Technologies*, vol. 17, pp. 1588–1599, 2024. https://doi.org/10.1109/TLT.2024.3392830

[17] N. A. Dahri *et al.*, "Extended TAM based acceptance of AI-Powered ChatGPT for supporting metacognitive self-regulated learning in education: A mixed-methods study," *Heliyon*, vol. 10, no. 8, 2024. https://doi.org/10.1016/j.heliyon.2024.e29317

[18] T. K. F. Chiu, "A classification tool to foster self-regulated learning with generative artificial intelligence by applying self-determination theory: A case of ChatGPT," *Educational Technology Research and Development*, vol. 72, no. 4, pp. 2401–2416, 2024. https://doi.org/10.1007/s11423-024-10366-w

[19] X. Weng, Q. Xia, Z. Ahmad, and T. K. F. Chiu, "Personality traits for self-regulated learning with generative artificial intelligence: The case of ChatGPT," *Computers and Education: Artificial Intelligence*, vol. 7, 2024. https://doi.org/10.1016/j.caeai.2024.100315

[20] H. Y. Lee, P. H. Chen, W. S. Wang, Y. M. Huang, and T. T. Wu, "Empowering ChatGPT with guidance mechanism in blended learning: Effect of self-regulated learning, higher-order thinking skills, and knowledge construction," *International Journal of Educational Technology in Higher Education*, vol. 21, no. 1, 2024. https://doi.org/10.1186/s41239-024-00447-4

[21] E. Guerra, "The contribution of critical thinking to STEM disciplines at the time of generative intelligence," *STEM Education*, vol. 4, no. 1, pp. 71–81, 2024. https://doi.org/10.3934/steme.2024005

[22] K. Hartley, M. Hayak, and U. H. Ko, "Artificial intelligence supporting independent student learning: An evaluative case study of chatGPT and learning to code," *Educ. Sci. (Basel)*, vol. 14, no. 2, p. 120, 2024. https://doi.org/10.3390/educsci14020120

[23] A. Schenck, "Examining relationships between technology and critical thinking: A study of South Korean EFL learners," *Educ. Sci. (Basel)*, vol. 14, no. 6, p. 652, 2024. https://doi.org/10.3390/educsci14060652

[24] A. Yusuf, S. Bello, N. Pervin, and A. K. Tukur, "Implementing a proposed framework for enhancing critical thinking skills in synthesizing AI-generated texts," *Think Skills Creat.*, vol. 53, 2024. https://doi.org/10.1016/j.tsc.2024.101619

[25] T. Tang, J. Sha, Y. Zhao, S. Wang, Z. Wang, and S. Shen, "Unveiling the efficacy of ChatGPT in evaluating critical thinking skills through peer feedback analysis: Leveraging existing classification criteria," *Think Skills Creat.*, vol. 53, 2024. https://doi.org/10.1016/j.tsc.2024.101607

[26] W. Liang and Y. Wu, "Exploring the use of ChatGPT to foster EFL learners' critical thinking skills from a post-humanist perspective," *Think Skills Creat.*, vol. 54, 2024. https://doi.org/10.1016/j.tsc.2024.101645

[27] Darwin, D. Rusdin, N. Mukminatien, N. Suryati, E. D. Laksmi, and Marzuki, "Critical thinking in the AI era: An exploration of EFL students' perceptions, benefits, and limitations," *Cogent Education*, vol. 11, no. 1, 2024. https://doi.org/10.1080/2331186X.2023.2290342

[28] S. Zhang, X. Zhao, T. Zhou, and J. H. Kim, "Do you have AI dependency? The roles of academic self-efficacy, academic stress, and performance expectations on problematic AI usage behaviour," *International Journal of Educational Technology in Higher Education*, vol. 21, no. 1, 2024. https://doi.org/10.1186/s41239-024-00467-0

[29] M. A. R. Vasconcelos and R. P. dos Santos, "Enhancing STEM learning with ChatGPT and Bing Chat as objects to think with a case study," *Eurasia Journal of Mathematics, Science and Technology Education*, vol. 19, no. 7, 2023. https://doi.org/10.29333/ejmste/13313

[30] I. Molenaar, S. de Mooij, R. Azevedo, M. Bannert, S. Järvelä, and D. Gašević, "Measuring self-regulated learning and the role of AI: Five years of research using multimodal multichannel data," *Comput. Human Behav.*, vol. 139, 2023. https://doi.org/10.1016/j.chb.2022.107540

[31] T. N. Hopfenbeck, Z. Zhang, S. Z. Sun, P. Robertson, and J. A. McGrane, "Challenges and opportunities for classroom-based formative assessment and AI: A perspective article," *Front. Educ. (Lausanne)*, vol. 8, 2023. https://doi.org/10.3389/feduc.2023.1270700

[32] D. T. K. Ng, C. W. Tan, and J. K. L. Leung, "Empowering student self-regulated learning and science education through ChatGPT: A pioneering pilot study," *British Journal of Educational Technology*, vol. 55, no. 4, pp. 1328–1353, 2024. https://doi.org/10.1111/bjet.13454

[33] Y. Wang, "Cognitive and sociocultural dynamics of self-regulated use of machine translation and generative AI tools in academic EFL writing," *System*, vol. 126, 2024. https://doi.org/10.1016/j.system.2024.103505

[34] M. Saqr, R. Cheng, S. López-Pernas, and E. D. Beck, "Idiographic artificial intelligence to explain students' self-regulation: Toward precision education," *Learn Individ Differ*, vol. 114, 2024. https://doi.org/10.1016/j.lindif.2024.102499

[35] S. Xiaolei and M. F. Teng, "Three-wave cross-lagged model on the correlations between critical thinking skills, self-directed learning competency, and AI-assisted writing," *Think Skills Creat*, vol. 52, 2024. https://doi.org/10.1016/j.tsc.2024.101524

[36] Q. Xia, T. K. F. Chiu, C. S. Chai, and K. Xie, "The mediating effects of needs satisfaction on the relationships between prior knowledge and self-regulated learning through artificial intelligence chatbot," *British Journal of Educational Technology*, vol. 54, no. 4, pp. 967–986, 2023. https://doi.org/10.1111/bjet.13305

[37] D. H. Chang, M. P. C. Lin, S. Hajian, and Q. Q. Wang, "Educational design principles of using AI Chatbot that supports self-regulated learning in education: Goal setting, feedback, and personalization," *Sustainability (Switzerland)*, vol. 15, no. 17, p. 12921, 2023. https://doi.org/10.3390/su151712921

[38] Y. C. Tseng and Y. H. Lin, "Enhancing English as a Foreign Language (EFL) learners' writing with ChatGPT: A university-level course design," *Electronic Journal of e-Learning*, vol. 22, no. 2, pp. 78–97, 2024. https://doi.org/10.34190/ejel.21.5.3329

[39] R. Leelavathi and R. C. Surendhranatha, "ChatGPT in the classroom: Navigating the generative AI wave in management education," *Journal of Research in Innovative Teaching and Learning*, 2024. https://doi.org/10.1108/JRIT-01-2024-0017

[40] R. Noni Naatonis, M. Jannah, and E. Ariesto Umbu Malahina, "Evaluation of Problem Based Gamification Learning (PBGL) model on critical thinking ability with artificial intelligence approach integrated with ChatGPT API: An experimental study," *Qubahan Academic Journal*, vol. 4, no. 3, pp. 485–520, 2024. https://doi.org/10.48161/qaj.v4n3a919

[41] G. van den Berg and E. du Plessis, "ChatGPT and generative AI: Possibilities for its contribution to lesson planning, critical thinking and openness in teacher education," *Educ. Sci. (Basel)*, vol. 13, no. 10, p. 998, 2023. https://doi.org/10.3390/educsci13100998

[42] C. Dindorf *et al.*, "Exploring decision-making competence in sugar-substitute choices: A cross-disciplinary investigation among chemistry and sports and health students," *Educ. Sci. (Basel)*, vol. 14, no. 5, p. 531, 2024. https://doi.org/10.3390/educsci14050531

[43] H. S. Mahdi and Y. M. Sahari, "Exploring the relationship between critical thinking, attitude, and anxiety in shaping the adoption of artificial intelligence in translation among Saudi translators," *Journal of Pedagogical Research*, vol. 8, no. 2, pp. 81–94, 2024. https://doi.org/10.33902/JPR.202423345

[44] B. Michalon and C. Camacho-Zuñiga, "ChatGPT, a brand-new tool to strengthen timeless competencies," *Front. Educ. (Lausanne)*, vol. 8, 2023. https://doi.org/10.3389/feduc.2023.1251163

[45] Y. Qawqzeh, "Exploring the influence of student interaction with ChatGPT on critical thinking, problem solving, and creativity," *International Journal of Information and Education Technology*, vol. 14, no. 4, pp. 596–601, 2024. https://doi.org/10.18178/ijiet.2024.14.4.2082

[46] X. Lin, K. Luterbach, K. H. Gregory, and S. E. Sconyers, "A case study investigating the utilization of ChatGPT in online discussions," *Online Learning Journal*, vol. 28, no. 2, 2024. https://doi.org/10.24059/olj.v28i2.4407

[47] M. Saritepeci and H. Yildiz Durak, "Effectiveness of artificial intelligence integration in design-based learning on design thinking mindset, creative and reflective thinking skills: An experimental study," *Educ. Inf. Technol. (Dordr.)*, 2024. https://doi.org/10.1007/s10639-024-12829-2

[48] G. van den Berg, "Generative AI and educators: Partnering in using open digital content for transforming education," *Open Praxis*, vol. 16, no. 2, pp. 130–141, 2024. https://doi.org/10.55982/openpraxis.16.2.640

[49] J. Jose and B. J. Jose, "Educators' academic insights on artificial intelligence: Challenges and opportunities," *Electronic Journal of e-Learning*, vol. 22, no. 2, pp. 59–77, 2024. https://doi.org/10.34190/ejel.21.5.3272

[50] M. F. Teng, "A systematic review of ChatGPT for English as a foreign language writing: Opportunities, challenges, and recommendations," *International Journal of TESOL Studies*, vol. 6, no. 3, pp. 36–57, 2024. https://doi.org/10.58304/ijts.20240304

[51] R. Michel-Villarreal, E. Vilalta-Perdomo, D. E. Salinas-Navarro, R. Thierry-Aguilera, and F. S. Gerardou, "Challenges and opportunities of generative AI for higher education as explained by ChatGPT," *Educ. Sci. (Basel)*, vol. 13, no. 9, p. 856, 2023. https://doi.org/10.3390/educsci13090856

[52] Z. Xu, Y. Zhao, B. Zhang, J. Liew, and A. Kogut, "A meta-analysis of the efficacy of self-regulated learning interventions on academic achievement in online and blended environments in K-12 and higher education," *Behaviour and Information Technology*, vol. 42, no. 16, pp. 2911–2931, 2023. https://doi.org/10.1080/0144929X.2022.2151935

[53] S. Beltozar-Clemente and E. Díaz-Vega, "Physics XP: Integration of ChatGPT and gamification to improve academic performance and motivation in physics 1 course," *International Journal of Engineering Pedagogy*, vol. 14, no. 6, pp. 82–92, 2024. https://doi.org/10.3991/ijep.v14i6.47127

[54] R. E. Wulansari *et al.*, "Computer Assisted Instruction (CAI) integrated case method-flipped classroom: Innovative instructional model to improve problem-solving skill and learning outcome of TVET students," *Journal of Technical Education and Training*, vol. 15, no. 4, pp. 100–113, 2023. https://doi.org/10.30880/jtet.2023.15.04.009

[55] L. T. Ameen, M. R. Yousif, N. A. Jasim Alnoori, and B. H. Majeed, "The impact of artificial intelligence on computational thinking in education at university," *International Journal of Engineering Pedagogy*, vol. 14, no. 5, pp. 192–203, 2024. https://doi.org/10.3991/ijep.v14i5.49995

[56] C. Zhai, S. Wibowo, and L. D. Li, "The effects of over-reliance on AI dialogue systems on students' cognitive abilities: A systematic review," *Smart Learning Environments*, vol. 11, no. 1, 2024. https://doi.org/10.1186/s40561-024-00316-7

[57] S. A. Chauncey and H. P. McKenna, "A framework and exemplars for ethical and responsible use of AI Chatbot technology to support teaching and learning," *Computers and Education: Artificial Intelligence*, vol. 5, 2023. https://doi.org/10.1016/j.caeai.2023.100182

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