



Critical Thinking in the Age of Artificial Intelligence: A Systematic Literature Review of Emerging Concepts and Frameworks

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Abstract. Critical thinking skills is an essential competency in the era of artificial intelligence (AI). However, many traditional frameworks for critical thinking are becoming less relevant when applied to evaluating individuals' skills in the context of AI use. This study aims to identify contemporary conceptualizations of critical thinking within this context. A Systematic Literature Review (SLR) was conducted following the PRISMA protocol. Twelve empirical articles published between 2020 and 2025, indexed in Scopus, were systematically analyzed using defined inclusion and exclusion criteria. The findings reveal a paradigm shift: from frameworks that emphasize the analysis, evaluation, and inference of human arguments to those that require the assessment, evaluation, and critique of AI-generated responses. Thus, critical thinking in the AI era encompasses not only logical and reflective reasoning but also digital literacy, awareness of algorithmic bias, and skills in information validation. These insights carry important implications for developing contextually relevant indicators of critical thinking, encouraging educators and researchers to adapt pedagogical and assessment strategies to meet the emerging challenges of human–AI interaction.

Keywords: Critical Thinking, Critical Thinking Skills, Artificial Intelligence, Conceptual Framework, Systematic Literature Review.

1 Introduction

The 21st century has been marked by rapid technological advancements, particularly with the rise of digital technologies and artificial intelligence (AI). The AI era has significantly influenced various aspects of human life, including education. Recent advancements in AI have introduced numerous tools and applications that provide substantial benefits to society. In recent years, the use of AI across various domains, including education and research, has increased significantly. One of its primary benefits is AI's potential to enhance learning through knowledge transfer, clarification of understanding, and the fostering of critical thinking skills [1]. At the same time, the integra-

tion of AI tools has raised considerable debate and speculation regarding their implications for higher education. Concerns have emerged about the potential adverse effects of AI on students' learning abilities, particularly regarding dependency, academic dishonesty, and weakened academic integrity [2].

This reality underscores the pressing need for individuals to cultivate robust critical thinking skills. In today's digital age, learners are expected to demonstrate awareness and the ability to evaluate AI-generated outputs critically [3]. Critical thinking awareness refers to an individual's ability to deeply analyze and evaluate information when confronted with problems [4]. These skills have been consistently recognized as essential competencies across multiple fields. Education in the current technological era has undergone not only changes in teaching methods but also in broader approaches to learning and knowledge acquisition. The Partnership for 21st Century Learning (2015) identifies critical thinking as part of the 4Cs (Critical Thinking, Creativity, Communication, and Collaboration), competencies that individuals must possess to succeed in the 21st century [5], [6]. These skills are particularly important for adapting to constantly evolving contexts, especially with the integration of new information and communication technologies [7]. Critical thinking has become a central element in contemporary education systems that incorporate digital resources and AI, with a focus on ethical standards, diversity, equity, and inclusivity [8]. Unlike traditional perspectives, critical thinking in the context of AI use is increasingly understood as the reflective, collaborative, and cautious application of generative artificial intelligence [9].

The importance of critical thinking as a form of technological awareness in the AI era has attracted the interest of many researchers to examine and enhance these skills. Since the emergence of ChatGPT in 2022 as one of the generative artificial intelligences (GenAI), research related to GenAI has begun to show progress. While research on GenAI topics has been on the rise, some aspects still require further investigation. Several theoretical studies have been conducted by previous researchers, such as [10], who performed a systematic literature review to examine the positive and negative impacts of using ChatGPT on the development of critical thinking. ChatGPT can support critical thinking by providing access to diverse information sources, expanding various relevant perspectives, enhancing communication and argumentation skills, and facilitating a more profound understanding through the analysis of AI-generated information. However, on the other hand, ChatGPT may lead to excessive dependence, which can hinder the development of critical thinking skills. This dependency can reduce students' motivation to explore information in more depth, potentially leading to misunderstandings of concepts. Therefore, the effectiveness of using generative artificial intelligence, such as ChatGPT, depends mainly on students' ability to use it critically. A more general review was conducted by [11] to reveal the various approaches used by educators to integrate GenAI into teaching and learning. These approaches include strategies such as task-based learning, self-directed learning, self-regulated learning, scaffolded instruction, and reflective teaching. The scoping review conducted by [11] demonstrates that, with appropriate pedagogical design, GenAI can effectively enhance critical thinking skills. Student engagement becomes a key factor in increasing metacognitive awareness, argumentation abilities, and reasoning skills that support the achievement of critical thinking.

Despite several literature reviews have suggested that critical thinking skills can be enhanced through the use of AI in learning, empirical studies have yet to yield promising results. Research by [12] indicates that the use of ChatGPT by students primarily enables them to develop low-level critical thinking skills, such as remembering, understanding, and application. A similar finding was shown in the study by [13], which indicated that despite students' use of ChatGPT, their critical thinking skills remain weak. Several factors contribute to this, including students' dependency on ChatGPT, the lack of proper guidance on its use, and the application of critical thinking frameworks that are not relevant to the context of artificial intelligence. Therefore, further investigation is needed to examine what concepts and frameworks of critical thinking are relevant for enhancing critical thinking skills in the context of AI usage. Understanding these concepts and frameworks will guide educators and other researchers in using artificial intelligence appropriately within a suitable conceptual framework, thereby improving critical thinking skills in a more contextually relevant manner. Given these challenges, researchers have increasingly focused on exploring how critical thinking is conceptualized and measured in the era of AI. This study aims to review recent literature to address two research questions systematically:

1. What concepts and frameworks of critical thinking have been applied in studies related to AI over the past five years?
2. To what extent are these concepts and frameworks relevant for measuring critical thinking in the context of AI usage?

2 Method

2.1 Protocol and Tools

This study employed a Systematic Literature Review (SLR) methodology, adhering to the PRISMA protocol. The Watase Uake Research Collaboration Tools (<https://www.watase.web.id/home/index.php>) were used to manage the process, retrieving data exclusively from the Scopus database. Only peer-reviewed journal articles published between 2020 and 2025 were considered. The inclusion criteria required studies to explicitly examine critical thinking in the context of AI use, while exclusion criteria eliminated non-empirical studies and those outside the educational domain. The identification process initially retrieved 119 articles. After screening and eligibility checks, 12 articles met the criteria and were included for analysis.

2.2 Identification

The identification phase involved determining keywords as search sources for retrieving scientific articles from the Scopus database. The keywords used were "Critical Thinking and AI." The search was limited to a five-year period, from 2020 to 2025. Using these keywords, the tool identified 119 relevant scientific articles in journals, proceedings, and research repositories. Because this study limited its literature sources to journals, 24 Scopus-based articles were filtered. Nevertheless, one of these 24 articles was not included in the Scopus journal rankings Q1, Q2, Q3, or Q4, resulting in 23 articles remaining for abstract review.

2.3 Screened

In the screening stage, abstracts were read from 23 scientific articles to determine whether the content met the specified criteria: empirical research, not a literature review, and a focus on critical thinking skills in the context of artificial intelligence applications. Only 20 articles met the criteria and were selected for the next stage.

2.4 Retrieval

In the retrieval stage, the process of downloading the articles that passed the screening stage was carried out. Out of the 20 articles, 8 could not be downloaded due to closed access; therefore, 12 articles proceeded to the next stage.

2.5 Extraction

In the extraction stage, a review of the entire content of the 12 articles was conducted. This review aimed to extract information to answer the research questions.

2.6 Report

In the reporting stage, a PRISMA diagram and other necessary visuals were generated (see Fig. 1).

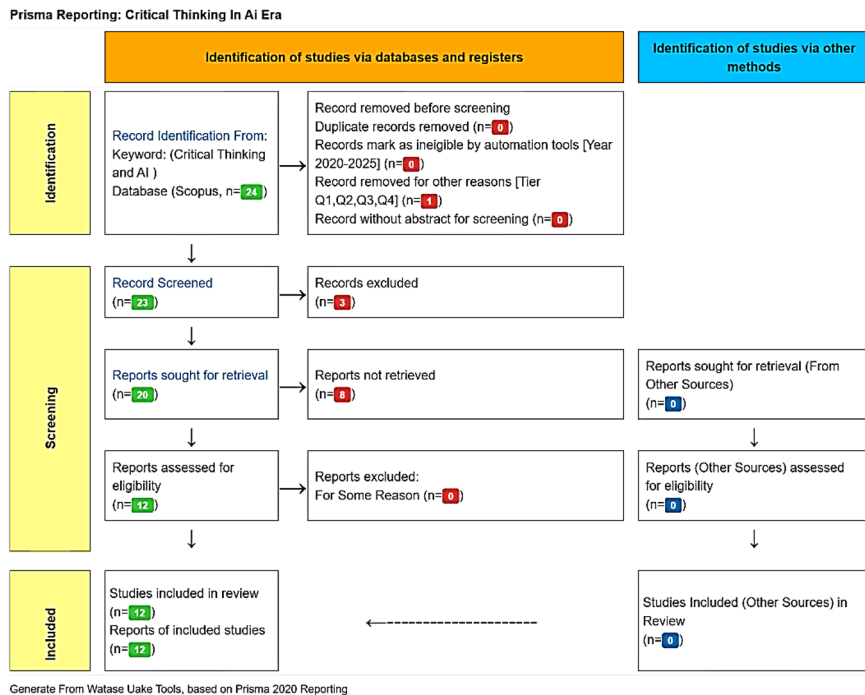


Fig. 1. PRISMA diagram generated from Watase Uake Research Tools.

3 Results

3.1 Overview of SLR Data

In this section, we present a general overview of the SLR conducted using Watase Uake Research Tools. After passing the PRISMA protocol, 12 Scopus-based studies were identified for further review to answer the research questions. Furthermore, a word cloud is presented to identify the most frequently occurring words/terms in studies related to critical thinking in the context of artificial intelligence applications.

List of the Studies. In this SLR study, we identified 12 scientific articles from the Scopus database. These articles present empirical research examining critical thinking within the context of artificial intelligence. The findings were published in reputable international journals, with eight articles appearing in Q1 journals and four in Q2 journals. Most of these studies have also been cited extensively by other researchers. Table 1 presents detailed data on the 12 studies included in the SLR.

Table 1. Studies included in the systematic literature review.

Authors	Title	Journal	Tier	Citation
[13]	The influence of AI text generators on critical thinking skills in UK business schools	Studies in Higher Education	Q1	144
[14]	Three-wave cross-lagged model on the correlations between critical thinking skills, self-directed learning competency and AI-assisted writing	Thinking Skills and Creativity	Q1	53
[15]	Generative AI's impact on critical thinking: Revisiting Bloom's taxonomy	Journal of Marketing Education	Q1	48
[16]	Exploring the use of ChatGPT to foster EFL learners' critical thinking skills from a post-humanist perspective	Thinking Skills and Creativity	Q1	30
[17]	Impact of AI literacy and adaptability on financial analyst skills among prospective Thai accountants: The role of critical thinking	Technological Forecasting and Social Change	Q1	13
[18]	Investigating the use of ChatGPT as a tool for enhancing critical thinking and argumentation skills in international relations debates among undergraduate students	Smart Learning Environments	Q1	12
[19]	An assessment of human-AI interaction capability in the generative AI era: The influence of critical thinking	Journal of Intelligence	Q1	1

[20]	Effect of AI Chatbots on EFL students' critical thinking skills and intrinsic motivation in argumentative writing	Innovation in Language Learning and Teaching	Q1	0
[21]	Leveraging ChatGPT for enhancing critical thinking skills	Journal of Chemical Education	Q2	228
[22]	Playing with AI to Investigate Human-Computer Interaction Technology and Improving Critical Thinking Skills to Pursue 21st Century Age	Education Research International	Q2	174
[23]	Critical thinking in the AI era: An exploration of EFL students' perceptions, benefits, and limitations	Cogent Education	Q2	121
[24]	Socratic wisdom in the age of AI: A comparative study of ChatGPT and human tutors in enhancing critical thinking skills	Frontiers in Education	Q2	16

Word Cloud. The word cloud generated using Watase Uake Tools reveals that three main words emerge: artificial intelligence, critical thinking, and ChatGPT (see Fig. 2).

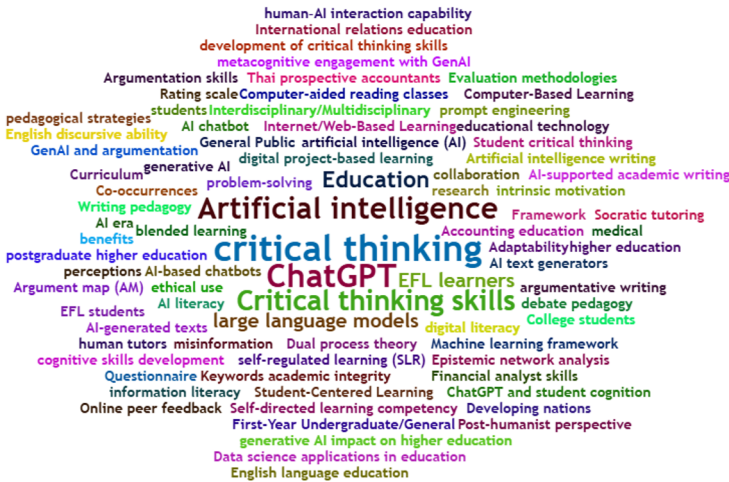


Fig. 2. Word cloud generated from Watase Uake Research Tools.

The prominent emergence of the term artificial intelligence (AI) reflects a paradigm shift in education toward the utilization of generative technologies. Recent research underscores that AI—particularly generative AI such as ChatGPT—has transformed learning processes by enabling personalized instruction, providing rapid access to

knowledge, and creating complex scenarios that challenge students to analyze and evaluate information [14], [21]. AI not only facilitates the comprehension of intricate concepts but also raises ethical issues and highlights the need for digital literacy, enabling students to assess information bias and accuracy. The term critical thinking ranks second because it represents a key competency targeted when AI is integrated into learning. Studies by [18] demonstrate that the use of ChatGPT in academic debates enhances students' abilities to analyze complex concepts and construct logical arguments. Similarly, [15] found that structured interaction with ChatGPT cultivates skills such as identifying assumptions, evaluating evidence, and drawing rational conclusions. Findings from [12] affirm that AI text generators reinforce higher-order thinking skills within Bloom's taxonomy, although they are most robust at the initial levels of understanding and application. The term ChatGPT itself appears prominently as the concrete representation of an AI application in the classroom. ChatGPT is regarded as a medium that facilitates reflective dialogue and argumentative inquiry. Research by [16] and [21] confirms that ChatGPT helps students develop critical thinking skills through problem-based discussions and argumentative writing. Furthermore, [25] even proposes revising Bloom's taxonomy to incorporate AI-specific competencies such as melioration and ethical reasoning, which are crucial for guiding students' reflective engagement with ChatGPT.

The three terms that emerge in the word cloud—artificial intelligence, critical thinking, and ChatGPT—do not stand alone but form a mutually reinforcing conceptual ecosystem; (1) AI as the Enabler – AI provides the infrastructure and generative algorithms that enable natural language processing and intelligent dialogue, (2) ChatGPT as the Concrete Implementation – ChatGPT represents the practical embodiment of AI in educational contexts, serving as a platform that facilitates analysis, evaluation, and synthesis tasks, and (3) Critical Thinking as the Primary Goal – The integration of AI and ChatGPT is directed toward cultivating critical thinking skills, namely the capacity to assess evidence, challenge assumptions, and make reasoned decisions. Interdisciplinary research supports this interconnectedness. [15] highlights that interactive dialogue with ChatGPT stimulates the analysis and synthesis of information. [12] emphasizes that AI text generators guide students through Bloom's cognitive stages—from remembering to creating—thus fostering deep learning. Meanwhile, [25] underscores the importance of reorganizing Bloom's taxonomy to accommodate emerging competencies that arise in interaction with AI. The word cloud emphasizing artificial intelligence, critical thinking, and ChatGPT illustrates the landscape of cutting-edge educational research: AI (through ChatGPT) is not merely a technology but a pedagogical catalyst that leads students through more profound critical thinking processes, while presenting ongoing ethical and methodological challenges that must be continually anticipated.

3.2 The Concept and Framework of Critical Thinking

The 21st century has emerged as the digital era, during which humanity has experienced an unprecedented rate of change through the advent of new and innovative technologies. The digital era has had a profound impact on various aspects of human life, including education.

Table 2. Critical thinking concepts and frameworks from the 12 Studies included in the SLR.

Authors	Critical Thinking Concept	Critical Thinking Framework
[13]	Cognitive capacity to conceptualize, apply, analyze, synthesize, and evaluate information, and to make well-founded decisions, supported by dialogic interaction between humans and AI technologies.	<p>The researchers adopt Bloom's Taxonomy (Bloom et al., [13]; Krathwohl, 2002) as its theoretical framework for assessing critical thinking skills.</p> <ul style="list-style-type: none"> • Basic level (Lower-Order Cognitive Skills): Remembering, Understanding, Applying. • Advanced level (Higher-Order Cognitive Skills): Analyzing, Evaluating, Creating.
[14]	Cognitive skills that enable individuals to engage in rational and logical problem-solving, decision-making, and reflective reasoning	<p>The researchers adopt Ennis's (1985, 2011) framework of critical thinking;</p> <ul style="list-style-type: none"> • Cognitive skills, such as analyzing, evaluating, making inferences, and applying logical reasoning. • Dispositional attributes, including open-mindedness, intellectual curiosity, and healthy skepticism
[15]	Reflective analytical capacity to evaluate, synthesize, and generate ideas autonomously, while taking ethical dimensions into account and leveraging iterative learning cycles in conjunction with AI technologies	<p>The researchers expanded the revised Bloom's Taxonomy for AI-enhanced learning and critical thinking.</p> <p>Cognitive Domain</p> <ul style="list-style-type: none"> • Discovering: using AI for rapid exploration and information gathering. • Understanding: simplifying complex concepts with AI assistance. • Applying: connecting theoretical knowledge with practical scenarios through AI. • Analyzing: critically assessing the accuracy and bias of AI-generated outputs. • Creating: synthesizing and generating novel ideas with AI support <p>Affective Domain</p> <ul style="list-style-type: none"> • Collaborating; engaging with AI as a cognitive partner (e.g., tutor, assistant). • Ethical reasoning; navigating issues of academic integrity, originality, and ethical use of AI <p>Metacognitive Domain:</p> <ul style="list-style-type: none"> • Interrogating and refining; engaging in critical questioning and refining AI-generated responses. • Articulating; formulating clear and specific queries.

[16]

Critical thinking is understood not merely as an individual cognitive skill of analyzing or evaluating, but as a dialogic process and a social practice shaped through human–technology interaction. Within a post-humanist framework, critical thinking is conceived as the outcome of human–AI collaboration, where learners engage in questioning, challenging assumptions, and reflecting on diverse perspectives in their interactions with ChatGPT.

- Iterative learning; participating in cyclical learning processes through feedback and revision.
- Melioration; integrating AI outputs with traditional sources or complementary tools.
- Reflective thinking; evaluating the limitations of AI and adapting strategies accordingly.

The researcher extends Facione's (1990) framework of critical thinking through a post-humanist perspective.

Cognitive Skills

- **Analysis:** breaking down arguments into key components.
- **Evaluation:** judging the strength and relevance of evidence.
- **Inference:** drawing logical conclusions from information.
- **Explanation:** clearly stating reasons or decisions.
- **Self-regulation:** reflecting on and adjusting one's own thinking.

Critical Dispositions

- **Intellectual curiosity:** desire to question and explore deeply.
- **Open-mindedness:** readiness to consider different views.
- **Reflective skepticism:** caution in accepting claims.
- **Considering alternatives:** openness to new perspectives.

[17]

Cognitive ability to critically assess information, consider multiple perspectives, and make decisions based on accurate and logical data analysis, whether generated by humans or AI-based systems

The researchers adopted the critical thinking framework proposed by Facione (1990);

- **Interpretation;** understanding the meaning of information and arguments.
- **Analysis;** identifying relationships among ideas and evidence.
- **Evaluation;** assessing credibility and strength of arguments.
- **Inference;** drawing logical conclusions from information
- **Explanation;** presenting reasons and arguments clearly.
- **Self-Regulation;** reflecting on and correcting one's thinking.

- [18] High-order cognitive and reflective capacity to analyze complex issues, evaluate and synthesize diverse information, and construct well-reasoned, evidence-based arguments through dialogic and metacognitive processes, including the critical appraisal of AI-generated content
- A synthesis of the concepts proposed by Guo [21], Kasneci et al. (2023), and the cognitive load theory Liang et al., [16]
- **Exploration:** employ ChatGPT to elicit and examine multiple perspectives on the issue.
 - **Evaluation:** fact-check information, identify potential biases, and assess the logical coherence of AI-generated arguments.
 - **Dialogue:** engage in debate with ChatGPT, challenging and responding to arguments.
 - **Argument construction:** formulate one's own arguments by integrating evidence and additional insights.
 - **Anticipation of counter-arguments:** use ChatGPT to generate potential objections and reinforce one's position accordingly.
 - **Reflection & peer review:** exchange arguments with peers and provide constructive critical feedback
- [19] Combination of skills (analysis, evaluation, inference, etc.) and dispositions (the internal motivation to engage in critical thinking)
- The researchers constructed a three-dimensional framework of Human–AI Interaction Capability
- **Information retrieval and analysis;** formulating valid, multi-perspective, and logically structured prompts, while refining them to obtain relevant information
 - **Information evaluation;** critically assessing the relevance, credibility, logic, and possible biases in AI responses.
 - **Information integration;** selecting key evidence, synthesizing ideas, and constructing logically consistent conclusions by combining AI output with one's own reasoning
- [20] Cognitive skills encompass the ability to analyze, evaluate, and synthesize information logically and reflectively, in order to construct coherent and rational arguments.
- The researchers adopted the critical thinking framework proposed by Facione (1990)
- **Interpretation:** understanding and categorizing information
 - **Analysis:** identifying logical relationships within arguments
 - **Evaluation:** assessing the credibility of sources and the strength of reasoning
 - **Inference:** drawing conclusions from data or evidence
 - **Explanation:** formulating arguments in a clear and coherent manner

- [21] A multifaceted construct that encompasses various skills, including reflection, reasoning, communication, evaluation of arguments, assessment of assumptions, conceptualization, and synthesis of information.
- **Self-regulation:** reflecting upon and correcting one's own thinking
- A synthesis of Facione (2011) theory, information literacy frameworks (ACRL, ACS), and the research findings of Danczak et al. (2017) and Kogut (1996)
- **Critique;** identification of underlying assumptions, assessment of reasoning and arguments, and examination of information credibility.
 - **Evaluate:** assignment of value and meaning to information, along with assessment of its quality and relevance.
 - **Analyze:** deconstruction of information, breakdown of problems into constituent parts, and identification of logical relationships.
 - **Draw logical conclusions with limited knowledge:** formulation of reasonable conclusions based on partial or incomplete information.
- [22] Multidimensional skill involving the evaluation, interpretation, analysis, and synthesis of information.
- The researchers adopted the critical thinking framework proposed by Miri et al. (2007)
- **Trust seeking;** encouraging open-ended classroom discussions.
 - **CT self-confidence:** enabling students to ask questions and seek their own solutions.
 - **Open-mindedness:** fostering inquiry-based experimentation, cooperative learning, and knowledge sharing.
 - **Maturity:** connecting learning activities with real-world, everyday situations.
- [23] Structured reflective analytical capability to interpret, analyze, evaluate, and draw evidence-based logical conclusions, and to make responsible decisions, enriched through critical interaction with artificial intelligence technologies.
- The researchers adopted the critical thinking framework proposed by Facione (1990)
- **Interpretation:** the ability to comprehend and ascribe meaning to information.
 - **Analysis:** the capacity to deconstruct information, ideas, or arguments into constituent parts in order to examine their relationships.
 - **Evaluation:** the skill of assessing the credibility of sources and the strength of arguments.
 - **Inference:** the ability to draw logical conclusions from data or evidence.

- [24] Cognitive skills encompass the capacity to analyze arguments, evaluate evidence, identify biases and underlying assumptions, and formulate well-reasoned conclusions grounded in logical justification.
- The researchers adopt the Socratic questioning framework;
- **Explanation:** the capacity to communicate the outcomes of reasoning clearly and to substantiate them with justifications.
 - **Self-regulation:** the ability to monitor, reflect upon, and adjust one's own thinking processes.
 - **Probing inquiry,** requires learners to move beyond superficial answers and critically explore the rationale underlying their responses
 - **Reflective dialogue,** understood as a reciprocal exchange between interlocutors (human tutors or AI systems) that stimulates students to defend, refine, or reconstruct their reasoning
 - **Dialectical engagement,** through which multiple perspectives are juxtaposed and the coherence of arguments is systematically examined
 - **Metacognitive awareness,** enabling learners to monitor, reflect upon, and enhance the quality of their own thought processes
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4 Discussion

4.1 Addressing RQ1: Critical Thinking Concepts and Frameworks in the Age of Artificial Intelligence

The systematic review reveals that the twelve studies examined between 2020 and 2025 operationalize critical thinking through diverse conceptualizations and frameworks. Despite the variation, two dominant traditions emerge. First, cognitive-oriented definitions remain central, emphasizing analytical reasoning, evaluation, inference, and decision-making [13], [14]. These studies often adopt classical models such as Bloom's Taxonomy and Ennis's framework. Their adoption reflects continuity with pre-AI understandings of critical thinking, yet demonstrates adaptability as these models are applied to assess how students engage with AI-generated texts or AI-assisted writing.

Second, several works extend critical thinking beyond cognition into ecological, affective, and metacognitive dimensions, aligning with the complexities of human–AI interaction. expands the revised Bloom's taxonomy by incorporating affective and ethical reasoning skills necessary for evaluating AI outputs. [16] apply Facione's framework through a post-humanist lens, viewing critical thinking as an emergent process shaped by human–technology assemblages. Similarly, [18] and [20] conceptualize crit-

ical thinking as a dialogical, iterative, and collaborative process, emphasizing reflection, skepticism, and ethical responsibility when learners interact with AI. The literature demonstrates that traditional critical thinking frameworks still dominate as reference points; however, scholars are increasingly recognizing the need to integrate ethical reasoning, metacognition, and socio-technical awareness into critical thinking constructs to remain aligned with AI-mediated learning environments. Subsequent paragraphs, however, are indented

4.2 Addressing RQ2: Relevance of Critical Thinking Concepts and Frameworks for AI Contexts

The review reveals that critical thinking frameworks differ in their relevance to AI-mediated contexts, ranging from classical models, such as Bloom's Taxonomy and Ennis's framework, which provide important cognitive foundations, to recent adaptations that offer more comprehensive approaches by integrating metacognitive, ethical, and relational dimensions (Table 3). While the reviewed frameworks provide a strong foundation, their adequacy in AI contexts requires critical evaluation. Classical frameworks, such as Bloom's taxonomy and Ennis's model, remain relevant because they capture fundamental cognitive processes (remembering, analyzing, and evaluating) that learners must apply when engaging with AI out-puts. However, several limitations are apparent.

First, traditional models were not initially designed for human–AI collaboration. As noted by [15] and [16] learners today must not only analyze information but also interrogate algorithmic bias, ethical implications, and iterative co-construction of knowledge with AI. Thus, relevance is con-tingent on extending these frameworks to account for the technological mediation of thought. Second, affective and dispositional dimensions such as skepticism, open-mindedness, and intellectual curiosity [14], [16] gain heightened importance in AI contexts where the credibility and originality of information are constantly in question. Frameworks that omit these dispositions risk overlooking essential competencies for critical engagement with AI-generated content.

Third, emerging models explicitly adapted for AI-enhanced learning [15], [20] demonstrate the most direct relevance, as they incorporate ethical reasoning, collaborative learning, and metacognitive regulation. These frameworks better capture the ecological and dynamic character of critical thinking in AI-mediated environments compared to static taxonomies. The findings suggest that while classical critical thinking frameworks remain partially relevant, they require reinterpretation and expansion to address the challenges posed by AI technologies fully. Future research should aim to develop integrated models that blend cognitive, affective, ethical, and ecological dimensions, ensuring that critical thinking assessment remains valid and reliable in AI-supported educational settings.

Table 3. The order of relevance of the critical thinking conceptual framework among the reviewed articles.

Framework	Relevance	Reasoning/Justification
Expanded Revised Bloom's Taxonomy by [15]	Directly relevant	The most comprehensive framework, integrating cognitive, affective, metacognitive, and ethical dimensions. Its structure aligns with iterative and collaborative learning processes characteristic of AI use, making it highly adaptable to contemporary educational contexts
Facione's CT Framework + Post-humanist Adaptation by [16]	Directly relevant	Reconceptualizes critical thinking as an ecological process—a systemic and relational phenomenon emerging from the interaction of humans, AI systems, and social-cultural contexts. Highly relevant in addressing issues of algorithmic bias, authorship, and ethical AI use.
Hybrid Dialogic-Reflective Framework by [20]	Strongly relevant	Emphasizes dialogue, reflection, and iterative reasoning, closely mirroring the prompt–feedback–revision cycles in AI engagement. Its limitation lies in the comparatively limited treatment of ethical reasoning and broader socio-technical integration.
Ennis's CT Framework by [14]	High relevant	Valuable for its focus on critical dispositions such as curiosity, open-mindedness, and skepticism, which are essential in AI-mediated learning. However, its predominantly cognitive orientation limits its ability to address the relational and ecological dimensions of human–AI interaction
Bloom's Taxonomy by [13]	Relevant	While it remains a foundational framework for cultivating analysis and evaluation skills, its applicability is significantly constrained in AI contexts, as it does not adequately address AI collaboration, algorithmic bias, or ethical considerations.
Other Variations/Integrative Models (2020–2023)	Depend on the context	Their relevance depends on the extent of adaptation. Many represent only incremental modifications of traditional frameworks, offering partial responses to the new challenges posed by AI in education

The comparative analysis of the twelve selected studies reveals that critical thinking frameworks exhibit considerable variation in their applicability to AI-mediated contexts. The ranking highlights not only the foundational value of classical models but

also the increasing relevance of frameworks that explicitly integrate ethical, relational, and socio-technical dimensions.

At the top of the hierarchy, [15] expanded revised Bloom's taxonomy emerges as the most comprehensive and adaptable framework. By extending the original taxonomy to include cognitive, affective, metacognitive, and ethical dimensions, it reflects the iterative and collaborative processes central to human–AI interaction, particularly in educational settings. Closely aligned with this is [16] adaptation of Facione's framework through a post-humanist lens, which reconceptualizes critical thinking as an ecological process—not ecological in the environmental sense, but as a systemic and relational phenomenon shaped by the interplay of humans, AI systems, and broader socio-cultural contexts. This framing directly addresses contemporary challenges, including algorithmic bias, authorship concerns, and the ethical use of AI.

In the middle tier, [20] hybrid dialogic-reflective framework captures the iterative cycle of prompting, feedback, and revision that typifies AI engagement. Its strong emphasis on dialogue and reflective reasoning makes it particularly useful for fostering student–AI interaction, though it pays less attention to ethical reasoning and systemic integration. Similarly, [14] application of Ennis's framework underscores the importance of dispositions such as curiosity, open-mindedness, and skepticism—traits that are indispensable when engaging with AI tools. However, its predominantly cognitive orientation limits its ability to address the relational and ecological dynamics inherent in human–AI collaboration.

At the lower end of the spectrum, Bloom's taxonomy [13] and other incremental variations from 2020 to 2023 remain valuable as scaffolds for fostering analytical and evaluative skills. However, their applicability is significantly constrained in AI-mediated contexts, as they lack attention to dimensions such as algorithmic bias, collaboration with AI systems, and ethical reasoning. These models, therefore, require substantial reinterpretation and adaptation to remain relevant in contemporary learning environments.

5 Conclusion

This research reveals a clear progression in critical thinking frameworks, from classical models such as Bloom's Taxonomy, Ennis's framework, and Facione's framework which provide essential cognitive foundations but are limited in addressing AI-mediated challenges, to transitional models that introduce reflective and dialogical practices, and finally to AI-integrated frameworks like the expanded revised Bloom's taxonomy and the post-humanist adaptation of Facione's framework, which reconceptualize critical thinking as a multidimensional, relational, and ethically grounded process. These findings highlight the need for educators and researchers to move beyond traditional cognitive orientations and adopt frameworks that prepare learners to critically and responsibly engage with the socio-technical complexities of AI.

6 Implication

The findings of this review have several important implications for theory, practice, and policy in the field of education in the age of artificial intelligence.

Theoretical implication. The review demonstrates that critical thinking frameworks are undergoing a paradigm shift from classical, cognitively oriented models toward multidimensional, ecological, and AI-integrated approaches. This suggests the need to reconceptualize critical thinking as not merely an individual cognitive skill but as a relational process shaped through continuous human–AI interactions.

Practical implications. For educators and curriculum designers, the adoption of AI-integrated frameworks provides a basis for designing learning experiences that foster critical engagement with AI tools rather than passive consumption. This includes activities that promote iterative questioning, critical dialogue, and ethical reflection on AI-generated outputs. Such pedagogical practices will help learners cultivate dispositions such as open-mindedness and ethical responsibility, which are crucial in AI-mediated environments.

Policy implications. Policymakers and educational leaders should support the integration of updated critical thinking frameworks into curricula and assessment systems. This entails not only updating learning standards to reflect AI literacy but also providing professional development opportunities for teachers to implement AI-responsive pedagogies. Institutional policies should also consider issues of academic integrity, originality, and the responsible use of AI in assessment and evaluation practices.

7 Limitation

The limitation of this study lies in the reliance on data exclusively retrieved from the Scopus database, which may not comprehensively capture the entirety of relevant literature. Consequently, important studies indexed in other databases such as Web of Science, PubMed, or Google Scholar might not have been included, potentially leading to selection bias. This reliance on a single source may limit the generalizability of the findings, as the dataset's scope may not fully represent the breadth and diversity of existing research. Future studies are therefore encouraged to incorporate multiple databases to provide a more holistic and representative overview of the field.

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