Integration of Generative Artificial Intelligence in Information Technology Education: A Systematic Literature Review on Its Impact on Critical Thinking Skills and Digital Literacy

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ABSTRACT

The development of generative Artificial Intelligence (AI) has significantly transformed learning dynamics in Information Technology Education (ITE), particularly in programming activities and computational problem-solving. Although numerous studies highlight the efficiency and convenience offered by this technology, analyses concerning the transformation of students' cognitive processes especially in relation to critical thinking remain relatively fragmented. This study aims to systematically synthesize scholarly findings on the impact of integrating generative AI into the cognitive structure of learning in ITE through a systematic literature review approach. Data sources were obtained from international and national databases covering the period 2018–2026 using structured selection criteria. The synthesis results indicate that generative AI functions as an accelerator at lower cognitive levels by reducing technical load; however, transformation at higher-order levels analysis, evaluation, and creation appears conditional. When employed as a reflective tool, AI can enhance self-regulation and critical thinking skills. Conversely, substitutive use may shift learning from a constructive process toward a merely verificative one, thereby diminishing the depth of cognitive engagement. The novelty of this study lies in integrating perspectives from cognitive taxonomy, cognitive load theory, and metacognition to comprehensively explain patterns of cognitive transformation within the context of Information Technology Education in Indonesia. These findings offer important implications for the design of AI-supported learning environments that are adaptive while remaining oriented toward strengthening higher-order thinking competencies.

INTRODUCTION

The development of digital technology over the past decade has fundamentally transformed learning practices across disciplines, including Information Technology Education (ITE). Digital transformation in Indonesia's education sector has intensified alongside the implementation of the *Merdeka Belajar* policy and the accelerated integration of technology into instructional practices (Kemendikbudristek, 2022; Nadiem, 2020). Similar trends have also been observed in other sectors where integrated information systems

improve efficiency, accuracy, and decision-making processes (Hartinah et al., 2025) . The emergence of generative Artificial Intelligence (AI) has further accelerated this shift, as it is capable of automatically producing text, program code, and analytical outputs within a short time frame (Dwivedi et al., 2023). In the context of ITE in Indonesia, this technology has begun to be utilized by students to support programming tasks, debugging processes, and the understanding of algorithmic concepts (Sari & Prasetyo, 2023; Hidayat et al., 2024). The integration of generative AI offers opportunities for personalized learning and instant feedback; however, it simultaneously raises concerns regarding its impact on the quality of students' cognitive processes.

Learning in the field of information technology inherently demands higher-order cognitive skills. Students are not only required to memorize syntax or comprehend foundational concepts, but also to analyze problems, generate alternative solutions, and creatively design new systems. This cognitive structure aligns with the revised Bloom's Taxonomy, which positions analysis, evaluation, and creation as the highest cognitive levels (Anderson & Krathwohl, 2001). In Indonesia, strengthening critical thinking skills is also embedded within the *Profil Pelajar Pancasila* emphasized in the national curriculum (Kemendikbudristek, 2022). Critical thinking enables students to evaluate the validity of information, identify logical fallacies, and make decisions grounded in rational argumentation (Facione, 1990; Ennis, 2011). Several studies conducted in Indonesian higher education institutions indicate that ITE students' critical thinking skills require further enhancement through well-designed instructional strategies (Rahmawati & Anwar, 2021; Putra et al., 2022).

The emergence of generative AI has the potential to significantly influence these dynamics. From the perspective of Cognitive Load Theory, technological tools can help reduce extraneous cognitive load, thereby allowing students to focus more effectively on core conceptual understanding (Sweller, 1988; Sweller et al., 2011). Studies conducted in several Indonesian universities suggest that AI-based learning systems can improve task completion efficiency and enhance learning motivation (Wibowo & Nugroho, 2023). Moreover, AI may function as a reflective tool when used to compare solutions or test hypotheses in programming contexts.

Nevertheless, the literature also highlights concerns that AI utilization without structured pedagogical design may diminish deep cognitive engagement. When solutions are obtained instantly, students may bypass the processes of exploration, alternative analysis, and critical evaluation that are central to the development of higher-order thinking competencies (Kirschner et al., 2006). Research in Indonesian higher education contexts indicates that excessive dependence on technology may weaken reflective capacity and self-regulation if not accompanied by appropriate instructional strategies (Yuliana & Firmansyah, 2022). The perspective of metacognition underscores the importance of students' awareness of their own thinking processes in constructing deep understanding (Flavell, 1979; Schraw & Dennison, 1994).

Research on AI in education in Indonesia continues to expand, particularly in areas related to learning effectiveness and digital literacy (Sari & Prasetyo, 2023; Hidayat et al., 2024). However, most existing studies focus primarily on learning outcomes or user perceptions, while analyses concerning the transformation of cognitive processes—

especially within the context of ITE—remain relatively limited. Discussions of critical thinking, cognitive load, and metacognition are often treated separately and have not yet been systematically synthesized within an integrated conceptual framework.

This gap highlights the need for a systematic literature review that integrates multiple theoretical perspectives to understand how generative AI influences the cognitive structure of ITE students in Indonesia. Without comprehensive analysis, technological integration risks merely enhancing surface-level efficiency without strengthening the higher-order cognitive competencies that constitute the primary objective of national information technology education. Therefore, this study aims to synthesize empirical findings and conceptual insights regarding the relationship between generative AI usage and the transformation of cognitive processes, particularly in the domain of critical thinking.

The principal contribution of this research lies not only in synthesizing previous studies but also in proposing an integrated analytical framework that connects cognitive taxonomy, Cognitive Load Theory, and metacognition to explain how generative AI reshapes cognitive engagement in Information Technology Education. Accordingly, this study not only consolidates previous findings but also provides a conceptual foundation for the development of adaptive AI-based instructional designs that preserve and enhance the depth of students' cognitive engagement.

Therefore, this study aims to systematically review and synthesize previous research on the integration of generative Artificial Intelligence in Information Technology Education and its impact on students' critical thinking skills and digital literacy. Specifically, this study seeks to (1) identify patterns of cognitive transformation associated with the use of generative AI, (2) analyze its implications from the perspectives of cognitive taxonomy, cognitive load theory, and metacognition, and (3) provide conceptual recommendations for AI-supported instructional design in Information Technology Education.

METHOD

This study employs a Systematic Literature Review (SLR) approach to identify, evaluate, and systematically synthesize relevant research concerning the use of generative Artificial Intelligence (AI) in Information Technology Education (ITE) and its implications for the transformation of cognitive processes and critical thinking skills. This approach was selected because it enables a structured, transparent, and replicable review process, thereby producing findings with stronger conceptual validity compared to conventional narrative reviews (Tranfield, Denyer, & Smart, 2003; Snyder, 2019). Furthermore, SLR provides a clear methodological framework for the selection and analysis of scholarly sources (Kitchenham & Charters, 2007).

The literature search was conducted using several international and national academic databases, including Scopus, Web of Science, Google Scholar, as well as Indonesia's nationally indexed journal portals SINTA and Garuda. The selection of these databases aimed to ensure representation of both global studies and context-specific Indonesian research in the fields of education and information technology. The search strategy employed combinations of keywords in English and Indonesian, such as "Artificial Intelligence in education," "generative AI," "Pendidikan Teknologi Informasi," "critical

thinking," "cognitive load," "metacognition," and "cognitive transformation." These keywords were combined using Boolean operators (AND, OR) to obtain comprehensive and relevant search results (Moher et al., 2009).

The inclusion criteria comprised peer-reviewed scholarly articles published between 2018 and 2026, considering the relatively recent emergence of generative AI in educational contexts. Selected articles were required to address the implementation of AI or AI-based systems within learning environments, particularly in technology education, informatics, or computational disciplines. Additionally, eligible studies needed to include empirical or conceptual analyses related to cognitive processes, critical thinking, cognitive load, or metacognition. Sources that were not peer-reviewed, unavailable in full text, or limited to non-academic opinion pieces were excluded from the selection process.

The selection procedure was conducted in stages, beginning with initial identification based on titles and abstracts, followed by topic relevance screening, and concluding with full-text review of articles meeting preliminary criteria. This process adhered to the transparency principles recommended in the PRISMA guidelines (Moher et al., 2009). Articles that met the final inclusion criteria were subsequently analyzed using a thematic analysis approach to identify recurring patterns and research trends.

The thematic analysis categorized findings into three principal dimensions forming the conceptual framework of this study: (1) the cognitive taxonomy dimension (based on the revised Bloom's Taxonomy), (2) the Cognitive Load Theory dimension, and (3) the metacognition and critical thinking dimension. Each article was critically examined with attention to research design, implementation context, and measured cognitive indicators. This analytical process enabled identification of whether generative AI functions as a facilitator of higher cognitive levels or, conversely, poses risks of diminishing deep cognitive engagement.

The synthesis was conducted narratively to construct an integrative conceptual understanding of cognitive transformation in ITE learning resulting from the use of generative AI. This study does not perform a quantitative meta-analysis; rather, it emphasizes the integration of theoretical perspectives and empirical findings to develop a comprehensive analytical framework. Through this approach, the study aims to provide a systematic overview of research developments related to generative AI in information technology education, while also identifying research gaps and future directions for instructional design development.

RESULT AND DISCUSSION

The results of the literature synthesis indicate that the integration of generative Artificial Intelligence (AI) in Information Technology Education (ITE) leads to cognitive process transformations that are conditional and contextual in nature. These transformations are not linear—that is, they do not consistently enhance or diminish the quality of thinking—but rather depend on how the technology is positioned within pedagogical design.

Transformation from the Perspective of Bloom's Taxonomy

Within the framework of the revised Bloom's Taxonomy, the use of generative AI

tends to accelerate cognitive activities at lower to intermediate levels, such as *remember*, *understand*, and *apply*. Students can quickly obtain conceptual explanations, code examples, or initial solutions, thereby increasing efficiency in foundational comprehension. At this stage, AI functions as a learning accelerator.

However, at higher cognitive levels—*analyze*, *evaluate*, and *create*—the transformation demonstrates a more complex pattern. The literature identifies two primary tendencies. First, when AI is employed as a reflective tool (for example, to compare solutions or evaluate program logic), students remain engaged in analytical and evaluative activities. Second, when AI is used in a substitutive manner—replacing exploration and design processes—engagement at higher cognitive levels tends to decline.

Accordingly, the transformation can be conceptualized as a shift from constructive processes to verificative processes in the absence of pedagogical intervention. Students increasingly verify system outputs rather than independently constructing solutions.

Transformation from the Perspective of Cognitive Load Theory

From the standpoint of Cognitive Load Theory, generative AI consistently demonstrates the capacity to reduce extraneous cognitive load, particularly in technically complex programming tasks. The reduction of syntactical errors and the provision of instant feedback enable students to allocate cognitive resources more effectively toward understanding core concepts.

Nevertheless, the literature also indicates the potential for a decrease in germane cognitive load—the mental effort required to construct long-term knowledge schemas. When students no longer engage deeply in debugging, trial-and-error experimentation, or alternative exploration, the construction of conceptual schemas may become less optimal. In this context, AI may inadvertently diminish the intensity of meaningful learning if cognitive challenges are not deliberately redesigned by instructors.

Thus, the transformation is not merely a reduction of cognitive load but rather a redistribution of it. While technical load decreases, reflective load may also decline without adaptive instructional design.

Transformation in the Dimensions of Metacognition and Critical Thinking

In the metacognitive domain, generative AI exhibits two distinct transformation patterns. When used as an interactive dialogic partner that encourages students to question, revise, and evaluate solutions, AI can strengthen self-regulation and reflective processes. Students are prompted to test assumptions and assess the quality of arguments, thereby maintaining critical thinking components such as analysis, evaluation, and inference.

Conversely, when AI functions primarily as a provider of final answers, metacognitive engagement tends to diminish. Students become more outcome-oriented than process-oriented, weakening self-monitoring and self-evaluation. This condition suggests that cognitive transformation does not involve the direct loss of critical thinking ability, but rather a shift in patterns of cognitive engagement—from active-constructive to passive-verificative modes.

Conceptual Synthesis of Cognitive Transformation

Across these three dimensions, it can be concluded that the cognitive transformation resulting from the integration of generative AI in ITE is inherently dualistic. AI serves as an

accelerator at foundational cognitive stages and as a potential facilitator at higher cognitive stages; however, it may also function as a reductive factor when it replaces knowledge construction processes.

The transformation may therefore be articulated as follows:

Generative AI transforms cognitive processes from an exploratory, construction-based model toward a collaborative, verification-based model, wherein the quality of critical thinking is largely determined by accompanying pedagogical strategies.

The primary implication of this finding is that technology itself is not the sole determinant of improvements or declines in critical thinking quality. Rather, the observed transformation emerges from the interaction among technology, instructional design, and students' self-regulatory capacities. Consequently, the integration of AI in ITE must be intentionally designed to preserve explicit demands for analysis, evaluation, and creation, ensuring that higher-order thinking competencies continue to develop.

CONCLUSION

This literature review demonstrates that the integration of generative Artificial Intelligence in Information Technology Education transforms students' cognitive processes in a conditional and contextual manner. AI functions as an accelerator at lower cognitive levels by reducing technical load and enhancing efficiency in initial comprehension. However, at higher cognitive levels—analysis, evaluation, and creation—the nature of the transformation is highly dependent on the pedagogical design employed.

When AI is utilized as a reflective and collaborative tool, critical thinking skills can be strengthened through processes of verification, evaluation, and self-regulation. Conversely, when AI serves as a substitute for exploratory processes, learning shifts from a constructive model toward a verificative one, potentially diminishing the depth of cognitive engagement.

Accordingly, the cognitive transformation induced by generative AI is neither a linear improvement nor a decline, but rather a redistribution of thinking activities shaped by instructional strategies. The integration of AI in Information Technology Education must therefore be designed adaptively to ensure that technological efficiency remains aligned with the strengthening of critical thinking competencies as a central objective of technology education.

Practically, these findings suggest that curriculum development in Information Technology Education should integrate generative AI through structured learning activities that emphasize analysis, evaluation, and creation. Educators need to position AI as a reflective learning partner rather than merely a tool for generating answers. Future research is recommended to conduct empirical studies examining how different AI-supported instructional models influence students' critical thinking and digital literacy in diverse educational contexts.

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