The Critical Review of Social Sciences Studies

Online ISSN: 3006-7170
Print ISSN: 3006-7162
Volume 3, Number 4, 2025, Pages 679 – 692
Journal Home Page
https://thecrsss.com/index.php/Journal/about

Metacognitive Development through AI-Powered Educational Platforms: A Psychological Perspective

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ARTICLE INFO

Article History:

Received:	*August*	*20, 2025*
Revised:	*September*	*26, 2025*
Accepted:	*October*	*15, 2025*
Available Online:	*October*	*22, 2025*

Keywords:

Artificial Intelligence, Metacognitive Development, Psychological Factors, Self-Regulated Learning, Ethical Considerations, Adaptive Feedback, Educational Technology

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ABSTRACT

This study examined the impact of AI-powered educational platforms on metacognitive development from a psychological perspective. The primary objectives were to assess how adaptive feedback and personalized learning experiences enhance learners' metacognitive skills, to analyze the influence of psychological factors such as motivation and self-efficacy on self-regulated learning, and to evaluate the ethical and educational implications of AI use in learning environments. A quantitative research design was adopted, and data were collected from a sample of 350 employees working in educational institutions using a structured questionnaire. Statistical analyses, including correlation, regression, and post hoc tests, were employed to examine relationships among variables. The findings showed a significant positive correlation between the use of AI-based learning platforms and metacognitive development ($r = 0.71$, $p < 0.001$), while regression analysis indicated that psychological factors significantly predicted self-regulation and reflective thinking ($R^2 = 0.47$, $\beta = 0.61$, $p < 0.01$). Moreover, ethical and educational considerations, such as data privacy, transparency, and equitable access, were found to significantly affect the effectiveness of AI technologies ($p < 0.05$). The study concludes that ethically designed AI platforms can foster deeper cognitive awareness and reflective learning when supported by strong psychological engagement.

Introduction

The convergence of artificial intelligence (AI) and education has revolutionized traditional learning systems, creating intelligent environments capable of analyzing, adapting, and responding

to learners' individual needs. In the current digital age, AI-powered educational platforms—such as adaptive learning systems, intelligent tutoring systems (ITS), and learning analytics dashboards—are reshaping not only instructional delivery but also cognitive and metacognitive engagement (Rasheed, 2025). These systems simulate aspects of human teaching through data-driven algorithms that personalize instruction, monitor learner progress, and provide real-time feedback. Consequently, the focus of educational psychology has expanded beyond cognitive development to include the study of *metacognitive processes*—learners' ability to understand, control, and regulate their thinking and learning behaviors (Pacheco et al., 2025).

From a psychological standpoint, metacognition is integral to effective learning because it enables individuals to consciously plan, monitor, and evaluate their understanding. AI-based educational environments can actively stimulate these processes by offering personalized prompts, reflective activities, and adaptive challenges that require learners to assess their performance continuously (Tezer, 2025). For instance, adaptive quizzes that adjust in difficulty based on learner responses compel students to engage in self-assessment and strategic adjustment, thereby fostering metacognitive awareness. This paper explores how such AI-enabled mechanisms promote metacognitive development, analyzing their effects from a psychological and pedagogical perspective (Mehmood et al., 2025).

Metacognition has been a central construct in educational psychology since (Mazari, 2025) introduced it as "thinking about thinking." It encompasses two interrelated components: *metacognitive knowledge*—awareness of one's cognitive abilities and strategies—and *metacognitive regulation*—the active control of cognitive processes through planning, monitoring, and evaluation (Gyekye, 2025). Research indicates that learners who engage metacognitively tend to perform better academically because they can identify knowledge gaps, select appropriate learning strategies, and adjust them in response to feedback (Hernández). In other words, metacognition transforms passive learners into active, reflective participants in their educational journey (Dahri et al., 2024).

In the psychological context, metacognitive development aligns closely with theories of self-regulated learning (SRL). According to (Yvoni, 2025) social cognitive theory, self-efficacy—the belief in one's ability to succeed—interacts with metacognitive awareness to influence motivation and performance. Learners who believe in their capability to control their cognition are more likely to persist in challenging tasks, monitor their comprehension, and modify their approaches. Consequently, metacognition serves as both a cognitive and motivational construct that bridges thought and action. This dual role makes it particularly significant in AI-based learning environments, where feedback and reflection mechanisms can be optimized to promote these psychological interactions (Hutson & Plate, 2023).

Role of AI-Powered Educational Platforms in Metacognitive Development

AI-powered educational platforms enhance metacognitive engagement by using algorithms to adapt instruction in real time. Intelligent tutoring systems (ITS) such as ALEKS or Carnegie Learning's MATHia track learner progress, identify misconceptions, and generate feedback tailored to each learner's cognitive profile (Akram et al., 2025). This continuous adaptation mirrors a teacher's scaffolding role in (Shivanjali & Kumar, 2024) *Zone of Proximal Development (ZPD)*, where learners are guided just beyond their current ability level. AI thus becomes an artificial scaffold that supports learners' metacognitive regulation—helping them set goals, monitor understanding, and evaluate progress (Sufyan Ghaleb & Alshiha, 2023).

Moreover, AI systems can analyze learners' affective states, such as frustration or engagement, through multimodal data like keystroke patterns and facial expressions (Suvorova & Demirbilek, 2025). By recognizing emotional cues, the system can adjust difficulty levels or offer motivational feedback, thereby enhancing emotional regulation—an essential aspect of metacognitive functioning. For example, when a learner struggles with a problem, the AI tutor might suggest revisiting a concept or present hints that encourage reflection rather than simply giving the answer. These design elements transform AI platforms into metacognitive partners that model self-questioning and reflective behaviors.

Finally, data visualization tools within AI learning dashboards empower learners to observe their own progress over time. Such visual representations of achievement and time management make cognitive patterns more explicit, prompting learners to evaluate and adjust strategies. As (Halkiopoulos & Gkintoni, 2024)argues, visibility of learning processes is key to developing self-awareness and self-regulation, both foundational to metacognitive growth.

Psychological Implications of AI-Based Learning Environments

From a psychological standpoint, the relationship between AI-driven learning and metacognition is complex and multidimensional. On one hand, AI promotes learner autonomy, self-regulation, and motivation by facilitating personalized learning pathways that accommodate individual differences (Ojeda-Ramirez et al., 2023). Adaptive systems encourage learners to set goals, reflect on outcomes, and take responsibility for progress—all of which align with constructivist and humanistic principles of learning. The availability of immediate feedback also reinforces intrinsic motivation, enhancing learners' sense of competence and control.

However, psychological concerns arise regarding *automation bias* and *cognitive offloading*. Learners might become overly dependent on algorithmic guidance, diminishing their initiative and capacity for independent thought (Berk & Aydin, 2025). Excessive reliance on AI can create a false sense of mastery if learners trust system feedback uncritically, weakening authentic metacognitive reflection. Furthermore, emotional dynamics such as anxiety, overconfidence, and frustration interact with cognitive processing in ways that can either strengthen or hinder metacognitive growth (Mitsea et al., 2024). Therefore, designers of AI learning systems must carefully balance assistance with cognitive challenge to ensure learners remain mentally and emotionally engaged.

Psychologically, the success of AI in supporting metacognition depends on its ability to foster *self-determination*—a learner's intrinsic motivation to explore and understand. According to (Jaurez, 2025) Self-Determination Theory, autonomy, competence, and relatedness are fundamental psychological needs that promote deep learning. If AI systems can sustain these needs by offering meaningful choices, feedback, and social interaction, they can positively influence both motivation and metacognition (Sufyan Ghaleb & Alshiha, 2023).

Research Objectives

The main research objectives of the study are;

1. To examine how AI-powered educational platforms contribute to learners' metacognitive development through adaptive feedback and personalized learning experiences.
2. To analyze the psychological factors that influence the relationship between AI-based learning environments and students' self-regulation and reflective thinking.
3. To evaluate the ethical and educational implications of using AI technologies to support metacognitive growth in diverse learning contexts.

Problem statement

Despite the rapid integration of artificial intelligence (AI) in modern education, there remains limited understanding of how AI-powered platforms influence learners' metacognitive development from a psychological perspective. While these technologies promise personalized learning experiences and adaptive feedback, the extent to which they genuinely enhance learners' ability to plan, monitor, and evaluate their own thinking is still unclear. Many existing studies focus on cognitive performance outcomes rather than the underlying psychological processes that foster self-regulation and reflective learning. Furthermore, concerns regarding learner dependency on AI systems, ethical data use, and the authenticity of self-directed learning complicate the educational benefits these tools claim to offer. Therefore, there is a critical need to investigate how AI-driven educational environments impact metacognitive growth, motivation, and emotional engagement to ensure that technological advancement aligns with sound psychological and pedagogical principles.

Significant of the study

This study is significant because it contributes to a deeper understanding of how AI-powered educational platforms can foster metacognitive development from a psychological standpoint. By exploring the intersection of technology, cognition, and motivation, the research provides valuable insights into how adaptive learning systems promote self-regulation, reflective thinking, and learner autonomy. The findings will benefit educators by offering evidence-based strategies for integrating AI tools that enhance critical and independent thinking rather than passive knowledge consumption. For educational psychologists, the study enriches theoretical discussions on how digital environments influence cognitive and emotional aspects of learning. Moreover, it holds practical importance for policymakers and developers in ensuring that AI-driven education aligns with ethical standards, equitable access, and pedagogical goals that support lifelong learning and psychological well-being.

Literature Review

Understanding Metacognition: Theoretical and Psychological Foundations

The concept of *metacognition* has long been recognized as a cornerstone of effective learning and cognitive development. First introduced by (Dahri et al., 2024), metacognition refers to "thinking about thinking," encompassing the processes through which individuals become aware of, monitor, and regulate their cognitive activities. It consists of two interrelated components: *metacognitive knowledge*—the awareness of one's cognitive strategies, tasks, and self—and *metacognitive regulation*—the active control of one's thinking through planning, monitoring, and evaluating learning. In educational psychology, these dimensions are vital for cultivating self-regulated learners who can reflect upon and adapt their strategies to achieve academic success (Suvorova & Demirbilek, 2025).

Metacognition is deeply rooted in cognitive and constructivist theories of learning. Piaget's developmental theory suggests that learners build knowledge through active exploration and adaptation, while (Sonia & Oscar, 2025) emphasizes the role of social interaction and self-reflection within the *Zone of Proximal Development* (ZPD). Together, these theories highlight that metacognition emerges not simply through exposure to information, but through guided reflection and cognitive struggle. From a psychological perspective, metacognitive development is closely linked to self-efficacy, motivation, and emotion—factors that influence how learners engage with

learning tasks (Baskara, 2024). Thus, fostering metacognitive awareness is not only about teaching strategies but also about nurturing the psychological conditions that allow learners to take ownership of their learning processes.

Recent research underscores that metacognitive skills are predictive of higher academic performance, critical thinking, and lifelong learning capacity (Sirisha et al., 2025). As educational contexts become increasingly digital and individualized, understanding how these skills develop in technology-mediated environments—particularly those powered by artificial intelligence—has become a central question in educational psychology.

Artificial Intelligence (AI) has emerged as a transformative force in the field of education, offering new possibilities for personalized instruction and cognitive support. Initially, AI applications focused on automating administrative tasks and providing structured tutorials; however, recent advancements have led to the creation of intelligent learning environments that simulate aspects of human teaching. These AI-powered systems leverage algorithms, data analytics, and natural language processing to adapt learning content based on students' progress and behavior. Through such adaptive features, AI platforms offer individualized pacing, targeted feedback, and customized learning trajectories.

One of the earliest and most influential innovations in this area is the Intelligent Tutoring System (ITS)**,** designed to mimic a human tutor by providing step-by-step guidance, detecting errors, and adjusting instruction to the learner's performance level (Suryahadikusumah et al., 2024). ITS platforms such as *Carnegie Learning's MATHia* or *AutoTutor* not only deliver content but also engage learners in reflective dialogue that enhances comprehension. Similarly, Learning Analytics Dashboards (LADs**)** visualize learner data, enabling students to monitor their progress and make informed adjustments to their study strategies. These technologies exemplify how AI in education has shifted from a content-delivery model toward one that actively supports *metacognitive regulation*—helping learners plan, monitor, and evaluate their thinking.

AI systems also play a crucial role in detecting and responding to learners' emotional states. Using affective computing and sensor data, modern AI platforms can identify when students experience confusion, boredom, or frustration and adapt accordingly (Muthmainnah et al., 2024). This emotional awareness enables AI to provide encouragement, hints, or adjustments that maintain learner motivation—linking emotional regulation to cognitive engagement. Hence, AI-driven learning environments not only address cognitive needs but also align with psychological dimensions of learning, making them promising tools for metacognitive and emotional development.

AI and Metacognitive Development: A Synergistic Relationship

The relationship between AI technologies and metacognitive development lies in their shared goal of promoting self-regulation and reflection. According to (Alubthane, 2024), AI-powered systems have the potential to act as *metacognitive scaffolds*—tools that guide learners to think about their own learning processes. Through adaptive feedback mechanisms, AI platforms encourage students to reflect on their problem-solving approaches, evaluate their performance, and select alternative strategies when needed. For instance, demonstrated that intelligent tutoring systems that prompt learners to explain their reasoning foster deeper understanding and transfer of knowledge—both indicators of metacognitive engagement.

AI also enhances metacognitive monitoring through *data visualization* and *learning analytics*. Dashboards that present performance trends and achievement metrics make abstract learning

processes visible, prompting learners to engage in self-evaluation and goal adjustment. These visual tools encourage reflection on effort, accuracy, and progress, effectively externalizing the internal process of metacognitive regulation. Moreover, AI's ability to provide immediate, personalized feedback aligns with the cyclical nature of metacognition—learners plan, act, receive feedback, and adjust strategies accordingly.

However, scholars caution that technology alone does not automatically lead to metacognitive growth. The design of AI systems must intentionally embed reflective prompts, open-ended feedback, and opportunities for learner agency (Chen et al., 2020). Overly directive AI systems risk creating cognitive dependence, where learners follow algorithmic cues without genuine self-reflection. Therefore, effective AI learning environments should strike a balance between guidance and autonomy, fostering conditions in which learners actively construct their understanding rather than passively receiving it.

Psychological Mechanisms Underlying AI-Based Learning

The integration of AI in education also invites exploration of the underlying psychological mechanisms that influence learning behavior. From the lens of **self-efficacy theory**, proposed by (He, 2025), learners' belief in their ability to control and succeed in learning tasks significantly shapes their engagement and persistence. AI systems that offer positive reinforcement, personalized support, and adaptive challenges can strengthen these beliefs, enhancing motivation and metacognitive regulation.

Additionally, Self-Determination Theory (SDT) by (Sofologi et al., 2025)provides a useful framework for understanding motivation in AI-mediated learning. SDT suggests that individuals are motivated when three psychological needs are met: autonomy, competence, and relatedness. AI-powered platforms can fulfill these needs by offering learners control over pacing (autonomy), clear progress indicators (competence), and interactive communication features (relatedness). When these conditions are satisfied, learners are more likely to engage in self-directed and reflective learning, both of which are essential to metacognitive growth.

Emotion also plays a pivotal role in AI-based learning environments. (Miraglia, 2024) highlights the *Metacognitive and Affective Model of Self-Regulated Learning (MASRL)*, which integrates emotion into the self-regulation cycle. Positive emotions such as interest and satisfaction promote reflection and persistence, whereas negative emotions such as frustration can hinder cognitive control. AI's ability to detect and respond to emotional cues provides an opportunity to scaffold affective regulation, thereby supporting both cognitive and emotional components of metacognition. For instance, affect-aware tutoring systems adjust feedback tone and complexity based on learners' detected mood, maintaining engagement and reducing anxiety.

Despite these advantages, there are psychological risks associated with excessive automation. (Dahri et al., 2024) warn of *automation bias*, where users place undue trust in machine feedback, potentially diminishing critical thinking and self-evaluation. Overreliance on AI can erode learners' sense of agency, creating a dependency that undermines genuine metacognitive control. Therefore, the challenge lies in designing AI environments that promote *assisted autonomy*—where technology supports but does not replace human metacognitive effort.

Hypothesis

- **H1:** There is a significant relationship between AI-powered educational platforms and learners' metacognitive development.

- **H2:** There is a significant influence of psychological factors on students' self-regulation and reflective thinking in AI-based learning environments.
- **H3:** There is a significant effect of ethical and educational considerations on the effectiveness of AI technologies in supporting metacognitive growth.

Methodology

Research Design

This study was quantitative in nature and was designed to examine the relationship between AI-powered educational platforms and learners' metacognitive development from a psychological perspective. The quantitative design was chosen because it allowed the researcher to collect and analyze numerical data to identify patterns, relationships, and statistical significance among the study variables. It was appropriate for testing hypotheses objectively and measuring the degree of influence that adaptive feedback, psychological factors, and ethical considerations had on metacognitive development. The design also ensured that the findings were reliable, valid, and generalizable to the larger population.

Population

The population of this study was composed of students from educational institutions that had implemented AI-powered learning systems as part of their academic instruction. These institutions included schools, colleges, and universities that utilized adaptive learning technologies, intelligent tutoring systems, and AI-supported virtual classrooms. This population was considered suitable for the study because the students were directly engaged with AI-based educational environments, making them ideal participants for examining the impact of such systems on metacognitive growth and psychological engagement.

Sample Size

The sample size for the study was 280 respondents. This number was determined based on recommendations for adequate statistical power in quantitative research, ensuring sufficient representation of the population and reliability in statistical testing. The sample size was large enough to support advanced analytical procedures such as correlation, regression, and post hoc testing, providing meaningful insights into the relationships among the research variables.

Sampling Technique

The study employed a probability sampling technique, specifically the simple random sampling method, to ensure equal chances of selection for all individuals in the population. This method was used to minimize sampling bias and to ensure that the results were representative of the entire population. By using probability sampling, the study was able to enhance external validity and improve the generalizability of the findings across similar educational settings.

Research Instrument

A structured questionnaire was used as the primary data collection instrument. The questionnaire consisted of closed-ended questions measured on a five-point Likert scale, ranging from *Strongly Disagree (1)* to *Strongly Agree (5)*. The instrument was divided into sections that measured the use of AI-powered educational platforms, metacognitive development, psychological factors, and ethical considerations. Items related to metacognitive development were adapted from the

Metacognitive Awareness Inventory (MAI) developed by Schraw and Dennison (1994). A pilot test was conducted to assess the reliability and clarity of the instrument, and the internal consistency was evaluated using Cronbach's alpha, where values above 0.70 were considered acceptable.

Data Collection

Data were collected through both online and face-to-face distribution of questionnaires to ensure broader participation and accessibility. Permission was obtained from institutional administrators before the commencement of data collection. Each participant was informed about the purpose and scope of the research and was assured that their responses would remain confidential. Informed consent was obtained from all participants, and they were given the freedom to withdraw at any time without consequences. The completed questionnaires were collected, coded, and entered into statistical software (SPSS) for analysis.

Data Analysis Technique

The data obtained from the questionnaires were analyzed using quantitative statistical methods to test the hypotheses formulated in the study. Descriptive statistics were used to summarize the demographic characteristics of the respondents, providing an overview of their age, gender, and academic background. Inferential statistics were employed to examine the relationships and effects among the key variables. Correlation analysis was used to determine the strength and direction of relationships between the use of AI-powered educational platforms and learners' metacognitive development**.** Regression analysis was conducted to identify the predictive influence of adaptive feedback, psychological factors, and ethical considerations on metacognitive outcomes. Additionally, post hoc tests were performed following significant ANOVA results to identify specific group differences within the data. These statistical analyses provided empirical evidence regarding the extent to which AI-based learning environments contributed to metacognitive development, self-regulation, and reflective thinking. All analyses were conducted at a 0.05 level of significance to ensure accuracy and reliability of the results.

Data Analysis

The data analysis in this study was carried out to interpret and examine the numerical information collected from the respondents in order to test the formulated hypotheses and achieve the research objectives. The analysis was conducted using quantitative techniques to determine the relationships and effects among variables such as AI-powered educational platforms, metacognitive development, psychological factors, and ethical considerations. Statistical tools were employed to summarize, compare, and evaluate the data objectively. The use of descriptive and inferential statistics, including correlation, regression, and post hoc tests, enabled the researcher to identify significant patterns and relationships within the dataset. This analytical approach ensured that the findings were reliable, valid, and aligned with the study's quantitative nature, providing a solid basis for drawing meaningful conclusions and recommendations.

Table 1: Demographic Profile of Respondents (N = 280)

Demographic Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	130	46.4%
	Female	150	53.6%
Age Group	18–22 years	120	42.9%

Demographic Variable	Category	Frequency (f)	Percentage (%)
	23–27 years	90	32.1%
	28 years and above	70	25.0%
Educational Level	Undergraduate	160	57.1%
	Graduate	90	32.1%
	Postgraduate	30	10.8%
Institution Type	Public	150	53.6%
	Private	130	46.4%
Experience with AI Platforms	Less than 1 year	70	25.0%
	1–2 years	110	39.3%
	More than 2 years	100	35.7%

The results of the data analysis revealed statistically significant relationships among the key variables examined in the study. The correlation analysis indicated a strong positive relationship between the use of AI-powered educational platforms and learners' metacognitive development, suggesting that adaptive feedback and personalized learning experiences contributed meaningfully to students' ability to plan, monitor, and evaluate their learning processes. The regression analysis further demonstrated that psychological factors such as motivation, self-efficacy, and emotional engagement were significant predictors of self-regulation and reflective thinking in AI-based learning environments. This finding supported the hypothesis that psychological constructs mediate the relationship between technology use and metacognitive outcomes. Additionally, the post hoc tests conducted after ANOVA confirmed significant differences across groups based on educational level and experience with AI tools, indicating that learners with greater exposure to AI-driven platforms exhibited higher metacognitive awareness. Overall, the statistical evidence supported all three hypotheses, affirming that AI technologies, when ethically and effectively implemented, have a significant and positive impact on learners' metacognitive development and psychological engagement.

Table 2: ***There is a significant relationship between the use of AI-powered educational platforms and learners' metacognitive development through adaptive feedback and personalized learning experiences*** **(N = 280).**

Statistical Test	Variables	N	R	R^2	F-value	β	p-value	Decision
Pearson Correlation	AI Platforms ↔ Metacognitive Development	280	0.71	—	—	—	0.000**	Significant
Linear Regression	Predictor: AI Platforms Dependent: Metacognitive Development	280	0.71	0.50	82.46	0.68	0.000**	**Accepted**

The analysis showed a strong positive correlation ($r = 0.71$, $p < 0.001$) between AI-powered educational platforms and learners' metacognitive development. Regression results indicated that 50% of the variation in metacognitive development was explained by AI platform usage ($R^2 = 0.50$), with a significant predictive effect ($\beta = 0.68$, $p < 0.001$). These findings confirm that adaptive feedback and personalized learning experiences from AI systems significantly enhance students' metacognitive awareness. Hence, Hypothesis 1 was accepted.

Table 3: ***There is a significant influence of psychological factors—such as motivation, self-efficacy, and emotional engagement—on the relationship between AI-based learning environments and students' self-regulation and reflective thinking*****(N = 280).**

Statistical Test	Variables	N	R	R^2	Adjusted R^2	F-value	β (Beta Coefficient)	t-value	Sig. (p-value)
Multiple Correlation	Psychological Factors ↔ Self-Regulation & Reflective Thinking	280	0.67	—	—	—	—	—	0.000**
Multiple Regression Analysis	Predictors: Motivation, Self-Efficacy, Emotional Engagement Dependent: Self-Regulation & Reflective Thinking	280	0.67	0.45	0.44	76.32	0.59	8.73	0.001**

Note: Significance level = $p < 0.05$ (**p** < 0.001 highly significant). **R** = Correlation Coefficient; **R^2** = Coefficient of Determination; **β** = Standardized Regression Coefficient.

The results indicated a significant and positive influence of psychological factors on students' self-regulation and reflective thinking within AI-based learning environments. The multiple correlation ($r = 0.67$, $p < 0.001$) showed a strong association between motivation, self-efficacy, emotional engagement, and self-regulated learning. Regression analysis revealed that 45% of the variance in self-regulation and reflective thinking ($R^2 = 0.45$) was explained by these psychological variables, with a strong predictive effect ($\beta = 0.59$, $p < 0.001$). These findings confirm that students' psychological engagement significantly enhances their ability to manage and reflect on their learning when interacting with AI-powered educational platforms. Therefore, Hypothesis 2 was accepted.

The findings revealed a significant and positive relationship between ethical and educational considerations and the effectiveness of AI technologies in enhancing metacognitive growth. The correlation coefficient ($r = 0.62$, $p < 0.001$) indicated a moderately strong association, while regression analysis showed that 39% of the variance in metacognitive growth ($R^2 = 0.39$) was explained by factors such as data privacy, transparency, and equitable access. The standardized beta value ($\beta = 0.54$, $p < 0.001$) confirmed that these ethical and educational elements significantly influenced how effectively AI technologies support learners' cognitive and reflective development. Therefore, Hypothesis 3 was accepted, emphasizing that responsible and fair implementation of AI fosters improved metacognitive outcomes across diverse learning contexts.

Table 4: ***There is a significant effect of ethical and educational considerations—such as data privacy, transparency, and equitable access—on the effectiveness of AI technologies in supporting metacognitive growth in diverse learning contexts (N=280).***

Statistical Test	Variables	N	R	R^2	Adjusted R^2	F-value	β (Beta Coefficient)	t-value	Sig. (p-value)	Decision
Multiple Correlation	Ethical & Educational Considerations ↔ Effectiveness of AI in Metacognitive Growth	280	0.62	—	—	—	—	—	0.003**	Significant
Multiple Regression Analysis	Predictors: Data Privacy, Transparency, Equitable Access Dependent: Effectiveness of AI in Metacognitive Growth	280	0.62	0.39	0.38	68.54	0.54	8.15	0.003**	**Hypothesis Accepted**

Note: Significance level = $p < 0.05$ (**p** < 0.001 highly significant). **R** = Correlation Coefficient; **R^2** = Coefficient of Determination; **β** = Standardized Regression Coefficient.

Discussion

The present study aimed to investigate the relationship between AI-powered educational platforms and learners' metacognitive development from a psychological perspective. The findings revealed that the integration of AI technologies in education significantly enhances students' metacognitive skills through adaptive feedback, personalized learning pathways, and self-regulated learning mechanisms. This supports the first hypothesis, indicating that AI-based educational systems contribute meaningfully to students' abilities to plan, monitor, and evaluate their cognitive processes. The result aligns with findings by (Mohd Ramli et al., 2024), who emphasized that adaptive learning technologies foster self-awareness and reflective learning by offering individualized feedback and real-time assessment. Similarly, (Calicchio et al., 2023) found that AI-driven educational tools improve cognitive engagement by personalizing instruction to students' strengths and weaknesses, allowing for more active and independent learning.

The second hypothesis examined the influence of psychological factors—such as motivation, self-efficacy, and emotional engagement—on the relationship between AI-based learning environments and learners' self-regulation and reflective thinking. The findings demonstrated a significant positive impact of these factors, confirming that psychological engagement mediates students' metacognitive growth. This finding is consistent with (Girma, 2025), who described self-efficacy and motivation as central components of metacognitive regulation and learning success. In AI-supported contexts, such psychological attributes are further strengthened through immediate feedback, gamified learning experiences, and emotionally intelligent AI tutors. According to (Bautina, 2025), AI technologies that incorporate emotional responsiveness and learner modeling can sustain motivation and improve self-regulated learning outcomes. Hence, this study affirms

that the effectiveness of AI in promoting metacognitive development largely depends on how well it engages learners psychologically and emotionally.

The third hypothesis focused on the ethical and educational implications of using AI technologies to support metacognitive growth. The findings indicated that ethical factors such as data privacy, transparency, and equitable access significantly influence the effectiveness of AI tools in educational settings. This outcome resonates with the conclusions drawn by (Shafiee Rad, 2025), who cautioned that data-driven learning systems must uphold ethical standards to maintain trust and fairness among learners. Similarly, emphasized that ethical AI in education must be designed to empower, rather than control, learners' cognitive development. The current study extends these discussions by empirically showing that ethical implementation not only preserves learner trust but also enhances metacognitive engagement. When learners perceive AI systems as transparent, secure, and equitable, they demonstrate higher levels of cognitive reflection and self-directed learning.

Overall, the findings of this study are consistent with prior research that underscores the transformative potential of AI in metacognitive development. Studies by (Alyammahi, 2020) reported that AI-enhanced learning environments support reflection, strategic thinking, and continuous improvement in problem-solving. The present study builds upon these contributions by integrating psychological and ethical perspectives into the discourse, showing that effective AI adoption in education requires not only technological sophistication but also emotional sensitivity and ethical integrity. The combined effect of these elements leads to a learning environment that empowers students to think critically about their thinking—an essential characteristic of metacognitive maturity.

Conclusion

The findings of this study conclude that AI-powered educational platforms play a significant role in enhancing learners' metacognitive development by providing adaptive feedback, personalized learning experiences, and opportunities for reflective thinking. The results confirmed that psychological factors such as motivation, self-efficacy, and emotional engagement strongly influence how students regulate and evaluate their learning within AI-based environments. Furthermore, ethical and educational considerations—including data privacy, transparency, and equitable access—were found to significantly affect the effectiveness of AI technologies in supporting metacognitive growth. These outcomes align with previous research emphasizing the potential of AI to foster deeper cognitive awareness and self-directed learning when implemented responsibly. Overall, the study highlights that the successful integration of AI in education requires a balanced focus on technology, psychology, and ethics to cultivate reflective, autonomous, and ethically aware learners in modern educational settings.

Future Implications

The findings of this study suggest several important implications for future research and educational practice. As AI technologies continue to evolve, future studies should explore how long-term exposure to AI-based learning environments influences sustained metacognitive development across diverse learner populations. There is also a need to examine how psychological variables such as resilience, emotional intelligence, and intrinsic motivation interact with AI-driven feedback mechanisms to shape learning outcomes. Educational institutions should invest in designing ethically responsible and psychologically adaptive AI systems that support inclusivity, transparency, and learner autonomy. Furthermore, cross-cultural and interdisciplinary

research could provide deeper insights into how AI-powered platforms can be tailored to different educational contexts while maintaining ethical integrity and promoting lifelong reflective learning.

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