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Linking the Use of Artificial Intelligence and Undergraduate Students' Critical Thinking Skills: The Mediating Role of Metacognitive Awareness

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ABSTRACT

This research examined the correlation between the use of artificial intelligence (AI) and critical thinking ability among undergraduate students, with a focus on the mediating role of metacognitive consciousness. As AI grows in its presence within higher education through applications like ChatGPT, Grammarly, and intelligent tutoring systems, there has been an expressed concern regarding its impact on the cognitive development of students. Whereas AI has been valued for enhancing individualized learning and information access, its potential to enhance higher-order thinking is still under-explored. Based on self-regulated learning theory, the current research theorized that metacognitive awareness—students' capacity to monitor and control their thoughts—can be an important mechanism by which AI affects critical thinking. Under the umbrella of quantitative research, correlation research design was used. Population was undergraduate students from public and private sector universities located in Lahore, Pakistan. By using multistage sampling procedure, 400 undergraduate students were selected from universities. Data were gathered with standardized tools to assess AI utilization, metacognitive awareness, and critical thinking, all on a 5-point Likert scale with high reliability ($\alpha > .80$). Pearson r showed positive correlations between AI adoption and critical thinking ($r = .37$, $p < .01$), and between AI adoption and metacognitive awareness ($r = .41$, $p < .01$), whereas mediation analysis verified that metacognitive awareness partly mediates the AI–critical thinking relationship (indirect effect $\beta = 0.19$, 95% CI [0.11, 0.27]). Confirmatory Factor Analysis (CFA) was conducted to validate the construct structure of the study instruments, confirming that the measurement models of AI Use, Metacognitive Awareness, and Critical Thinking fit the data adequately. In addition, private school students had higher critical thinking scores compared to public school students. These findings underscore the need to cultivate metacognitive abilities in AI-supported learning systems in order to develop students' critical participation and independent thinking, providing practical applications for teachers, policymakers, and educational technology developers.

Keywords: *Artificial Intelligence, Critical Thinking, Metacognitive Awareness, Higher Education, Mediation Analysis, University Students, AI Use*

INTRODUCTION

The integration of Artificial Intelligence (AI) in educational settings has prompted a transformation in teaching, learning, and assessment methods used in institutions of higher learning. Generative AI applications such as ChatGPT and Grammarly, as well as other AI-based adaptive learning environments and intelligent tutoring systems, are being used to refine instructional delivery, tailor learning to individual needs, and promote engagement (Zawacki-Richter et al., 2019; Holmes et al., 2022). The increase in learning engagement and effectiveness presents a significant advantage, yet concerns remain on the challenges that the use of AI presents on students cognitive development.

Developing critical thinking, as one of the most important and most concerning issues, is considered one of the most important 21st century competencies (OECD, 2021). Critical thinking enables learners to creatively synthesize, evaluate and solve problems (Facione, 2020). AI can facilitate critical thinking development by providing prompt feedback on an learners argument, presenting alternative ideas and assisting in various stages of problem solving. However, an uncritical acceptance of information and a lack of engagement with problem content can be a signs of a passive mindset that can result from an overreliance on AI content. Thus, the increased use of AI presents both opportunities and challenges, particularly in developing a learner's critical thinking skills.

In responding to AI tools and incorporating AI-supported tools into the learning framework and the corresponding cognitive skills of learners, critical metacognitive skills must be part of the learning process (Schraw, 1998). To explain, metacognitive skills are responding to the stimuli of thought knowledge and the outcomes of problem-solving processes and cognitive procedures, such as reflecting, abstracting, and inferring to achieve a goal (Schraft, 1998). Critical metacognitive skills prompt learners for actions such as, evaluating and verifying, AI-supported tools output, or critically assessing advanced automated systems in knowledge acquisition processes, such as ChatGPT (Culnan, 2022). These skills are essential where automation is replacing critical and reflective processes, as in the case of advanced generative AI systems; the learning process requires automation to establish and foster knowledge and skills, and the goal is to achieve true cognitive engagement (Schraw, 1998).

Cognitive metacognition in AI-supported learning systems might cultivate the disposition to center thinking critically, with respect to augmented aspects of learning, peripheral tasks, or processes. However, the provision of metacognitive AI systems and tools requires the exercise of cognitive, metacognitive, and critical thinking (Bolster et al., 2021). This potential for cognitive automated AI systems to achieve critical thinking disposition has not been a logical focus of research. To think critically is the highest cognitive demand for learners, transcending all learning processes (Emans, 1991). While cognitive automation and AI systems support the attainment of low-order learning outcomes, the presence of more advanced tools automatons is replacing reflective processes in learning (Bolster et al., 2021). This dynamic is exacerbated by the fact that generative AI systems are designed to replace reflective systems in learning tasks. AI-supported systems must be designed to support higher-order learning and foster the development of learning processes.

This study aims to fill this gap by exploring the interplay between AI use and critical thinking in university students in Lahore, Pakistan, and the mediating role of metacognitive awareness. Identifying this pathway contributes to understanding how AI can be leveraged to develop reflective, self-directed learners. These recommendations are intended to help teachers, education policy makers and educational technology developers to design AI-integrated learning environments that boost students' higher-order thinking, as well as productivity. Previous studies have focused more on the integration of Artificial Intelligence (AI), in the educational context, highlighting its potential to improve higher-order thinking skills.

Research suggests that adaptive learning tools and AI-assisted smart tutoring systems not only offer customized instruction but also help learners develop higher-order skills through problem-solving and decision-making activities (Chen et al., 2022; Liu & Wang, 2023). For example, AI-generated feedback has shown to enhance students' reasoning abilities, and AI-driven simulations offer immersive learning spaces that promote active learning (Zhang & Lin, 2022). Apart from reasoning, several scholars point out that AI also has the potential to aid in the growth of metacognition through intelligent dashboards, cognitive scaffolding, and self-regulation prompts, which help students think about their thinking, control their progress, and make strategic revisions (Rahman et al., 2023). This intersection implies that AI, along with critical thinking and metacognition, are not isolatable silos but interconnected and mutually reinforcing components that advance deeper learning (Kaur & Singh, 2024). Notwithstanding the advances that have been made, recent research tends to be siloed with AI, critical thinking, and metacognition treated as three separate systems, rather than three components of one integrated whole.

Most studies emphasize the technological affordances of AI without considering how these tools cultivate critical and metacognitive skill sets simultaneously (Park & Kim, 2022). Most importantly, the bulk of recent research tends to focus on advanced technological contexts, with very few empirical studies coming out of developing countries, where educational issues are different and constraints due to lack of resources may complic enactment (Ali & Raza, 2023). This demonstrates the need to explore how AI can be used effectively to foster critical and metacognitive skills in a wider range of educational contexts. Addressing this issue helps the current study advance a more complete perspective of AI in relation to educational theory and practice in the world.

Objectives of the Study

Following were objectives of the study:

1. To find out the relationship between students’ use of AI and their critical thinking skills.
2. To investigate the mediating role of metacognitive awareness in the relationship between AI use and critical thinking skills.
3. To compare the level of critical thinking skills between students with high and low AI usage in public and private universities of Lahore.

LITERATURE REVIEW

Uses of Artificial Intelligence in Higher Education

Artificial Intelligence uses in higher education has rapidly advanced to develop constructive learning environments that are tailored to individual needs. AI learning systems such as chatbots, virtual teaching assistants, and adaptive learning platforms deliver personalized material, assist students at any time, and make learning autonomous and efficient (Al-Abdullatif & Ihmeideh, 2023). These systems can be analyzed within constructivist learning theory. This theory centers on the learning process where knowledge is actively constructed through building, sequenced supports known as scaffolding, and collaboration. Nonetheless, there is a distinct lack of empirical data examining the influence of AI on the higher-order cognitive skills of learners, such as critical thinking (Zhou et al., 2022). This is in part to demonstrate the need to analyze student cognitive engagement with AI. Also, to understand the potential of these resources to facilitate or impede students’ deep learning.

Critical Thinking in AI-Mediated Learning Environments

The ability to think critically—analyzing, appraising, and constructing well-reasoned arguments—has been widely acknowledged as crucial in both academic and professional spheres, pertaining more closely to the higher-order skills in Bloom’s Revised Taxonomy (analyzing, evaluating, and creating). It remains one of the key outcomes pertaining to higher education students. It has, however, been noted with concern that the use of AI might promote access to knowledge that is 'light' or 'shallow—this is especially the case as students use AI to synthesize written materials, respond to questions, or solve equations (Lee & Kim, 2023). Results from a more recent meta-analysis suggest that AI might present a variety of perspectives, and that its potential to foster students' critical thinking is largely determined by the degree to which students engage with the AI technology interactively and reflectively (Wang et al., 2024). It follows that the use of AI in learning should foster exploration and reflective thinking as opposed to providing mere expedience.

Metacognitive Awareness in Online Learning Environments

In context of AI-enhanced online learning environments, the importance of metacognitive awareness becomes more critical. It helps students determine the strategies to deploy, keep track of their understanding, and modify strategies in response to feedback and challenges. Dependable metacognitive learners should engage AI tools in a critical and strategic manner and not merely as a passive consumer (Nguyen & Lim, 2022). This stems from the Self-Regulated Learning (SRL) model in which metacognition is one of the key functions that enables learners to set realistic goals, self-regulate their actions, and evaluate the outcomes. Within AI-mediated environments, highly motivated students who demonstrate reflective, critical metacognitive awareness are more likely to engage with the learning materials (Huang et al., 2023).

Metacognitive Awareness as a Mediating Mechanism

More recent research identifies the development of metacognitive awareness as a potential mediator between the use of artificial intelligence (AI) tools and the ability to think critically. Students with greater metacognitive awareness will be able to accept AI-generated outputs more critically and reflectively. For example, the use of metacognitive strategies in a recent study was shown to significantly enhance AI-generated feedback's critical evaluation, indicating that the cognitive benefits of AI are activated through internal control processes (Kim & Chen, 2023). These findings suggest that the promotion of metacognitive awareness is likely to improve the employment of AI tools in ways that encourage the development of critical thinking, rather than impede it.

Rationale for the Study

The role of empirical research on the intersection of AI, metacognitive awareness, and critical thinking within higher education remains scant, as the integration of AI research within higher education continues to evolve. Many of the existing studies tend to persist on isolationally defining the constructs from one another, and do not take into consideration the intersection of those constructs within AI-enabled learning environments. Much of the research also seems to prioritize the global north, while paying little attention to the global south, where the dynamics of learning challenges, resource deficits, and the interplay of educational technologies are often markedly different. This research seeks to investigate the influence of metacognitive awareness on the relationship between critical thinking skills and the integration of AI by students at the university level as one way to begin addressing these gaps in the literature. I aim to provide meaningful research findings that will assist educators in designing AI-enabled learning environments that foster self-reflective thinking in order to increase student mental effort, cognitive involvement, and readiness for higher level academic and real-world challenges.

METHODOLOGY

Conceptual Framework

Figure 1 shows the conceptual framework, which proposes that the use of AI directly enhances undergraduate students' critical thinking skills and indirectly improves them through the mediating role of metacognitive awareness.

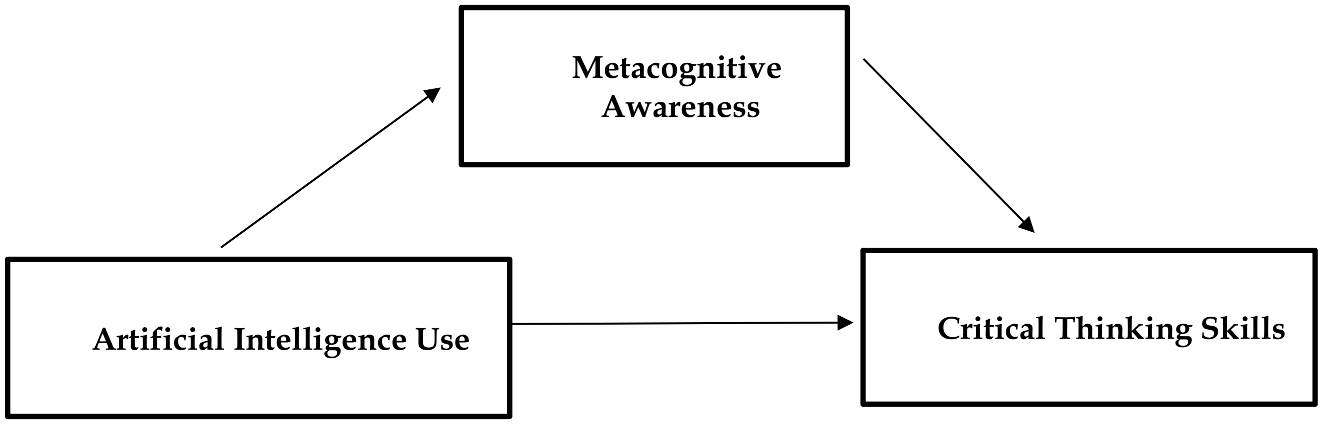

Figure 1: ***Conceptual Framework***

H_1: Use of AI is positively correlated with undergraduate students' critical thinking skills.

Integrating AI technology into higher education aids undergraduates in improving their critical thinking skills. Research emphasizes the importance of AI-enabled technology in offering the adaptive feedback needed in problem-based learning and in engaging students in complex situations, which require higher-order thinking skills (Lau et al., 2024). For instance, AI-enabled tutoring systems help develop self-directed learning and self-regulation, metacognitive skills needed in the upper levels of thinking (Rashid & Asghar, 2016). Research by Santos et al. (2023) also illustrated AI-supported collaborative settings in which students dialogue reflectively and construct arguments that advance critical discourse. AI technology also research improves students' research and writing skills. AI in research and writing, along with simulations, refined students' ability to assess the value of evidence and devise new solutions when compared with older, more traditional methods (Rachman et al., 2022; Kaya & Aksoy, 2021). AI technology, in many different settings, improves critical thinking skills and integrates constructivist and experiential learning theories.

H_2: Use of AI is positively correlated with undergraduate students' Meta cognitive awareness.

Literature posits that AI technologies improve students' planning, monitoring, and reflective activities, which constitutes higher-order metacognitive awareness. AI adaptive systems provide students with tailored feedback which asks them to self-evaluate and strategically modify their actions toward their goals (Roll & Winne, 2015; Azevedo et al., 2019). In the same vein, learners' reflective self-regulation is fortified by learning analytics dashboards and intelligent tutoring systems (Davis et al., 2021; Wu & Lai, 2023). Hence, the use of AI is predicted to correlate positively to greater metacognitive awareness.

H_3: Relationship between Use of AI and undergraduate students' critical thinking skills is significantly mediated by Meta cognitive awareness.

Self-Regulated Learning (SRL) theory recognizes metacognitive actions—planning, monitoring, and evaluating—as crucial processes through which learners acquire sophisticated reasoning and problem-solving skills (Zimmerman, 2002). The adaptive, immediate, and scaffolded feedback that AI provides encourages reflective metacognitive engagement (Panadero, 2017). Consequently, this improved metacognition allows students to assess information, integrate materials, and construct new ideas (Efklides, 2018; Chen et al., 2022). Therefore, one can expect metacognitive awareness to act as a conduit through which the use of AI positively influences critical thinking.

Theoretical Framework

The present research is premised on Self-Regulated Learning (SRL) Theory complemented by Constructivist Learning Theory. This is because both theories appropriately justify the role of artificial intelligence (AI), metacognitive awareness, and critical thinking ability in undergraduate students.

Self-Regulated Learning Theory

Self-Regulated Learning Theory posited by Zimmerman (2002) espouses that the successful learner actively engages in planning, monitoring, and subsequently reviewing their learning activities. Within SRL, metacognitive awareness is pivotal in monitoring and controlling thinking activities. AI of learning technologies, particularly intelligent tutoring systems, feedback systems and adaptive learning environments, support SRL by providing real-time, individualized feedback and self-monitoring opportunities. This corresponds with the current study, in which the role of metacognitive awareness as a mediator in the AI adoption and students' critical thinking ability relationship has been determined. Consequently, SRL Theory substantially underpins the explanation of metacognition's mediating role within the conceptual framework.

Constructivist Learning Theory

Piaget (1972) and Vygotsky (1978) place emphasis on the construction of knowledge through interaction, problem solving, and social engagement. Current uses of AI in education offer interactive environments in which learners appreciate, critique, and integrate knowledge, all of which are vital to the critical thinking process. AI encourages problem-solving learning and presents multiple perspectives, which facilitates higher order thinking. This aligns with the fundamental tenets of constructivist theory. This explains the direct association within the conceptual framework between the use of AI and the development of critical thinking skills.

Justification of Theories

It is justified to use SRL Theory as the primary framework because the research focuses on the mediating role of metacognitive awareness, which is central to the SRL process. Simultaneously, Constructivist Learning Theory serves as a secondary framework to explain the direct impact of using AI on the development of critical thinking through active learning and the construction of knowledge. All-in-all, these theories provide a satisfactory theoretical justification for the relationships posited in the study. This research is based on Self-Regulated Learning (SRL) Theory and recognizes Constructivist Learning Theory to illuminate the interface between artificial intelligence (AI), metacognitive awareness, and critical thinking skills in undergraduate students.

Research Design

This study is quantitative in nature. The researcher applied a correlational design to examine the relationship between the integration of artificial intelligence (AI) and critical thinking skills in students while considering metacognitive awareness as a mediating factor. This concerned the extent to which the use of AI tools by students impacts their level of thinking within higher learning institutions. The study also sought to understand the quantitative approach as it facilitates hypothesis testing to a considerable degree, measuring the relationship between variables and empirically analyzing the mediating variables within a broader population.

Population and Sample

Undergraduate students attending public and private universities in Lahore, Pakistan were the sample population for this inquiry. The multistage sampling technique was employed. To begin with, universities from both sectors were picked at random, and then departments were chosen in a purposive way, where AI integration was highly prevalent (like education, computer science, and business). Subsequently, students were chosen using simple random sampling. A target sample of 400 students was set, with attention to ensuring equity regarding gender, institution type, and field of study.

Instruments

Data were gathered with three standardized tools.

AI Use Scale

The use of AI was measured with an adapted scale from Zhou and Wang (2023) and Bower (2021). The scale assesses frequency, perceived usefulness, and learning improvement through AI tools such as ChatGPT, Grammarly, and tutoring systems, with multiple items on a 5-point Likert scale. In Pakistan, Tariq (2025) applied a similar AI readiness scale with students and reported $\alpha = .82$, confirming good reliability. In the current study, CFA confirmed the construct validity, with $\chi^2/df = 2.31$, CFI = .92, TLI = .91, RMSEA = .06, and SRMR = .05, indicating an acceptable fit.

Metacognitive Awareness Inventory (MAI)

Students' metacognitive awareness was measured with the Metacognitive Awareness Inventory (Schraw & Dennison, 2021). The instrument comprises 52 items across two domains: knowledge of cognition and regulation of cognition. A Pakistani study by Saleem (2024) applied the MAI among future teachers and reported $\alpha = .858$. In the present research, CFA confirmed the two-factor model ($\chi^2/df = 2.42$, CFI = .93, TLI = .92, RMSEA = .065, SRMR = .058), indicating satisfactory model fit.

Critical Thinking Disposition Scale (CTDS)

Critical thinking was measured through the Critical Thinking Disposition Scale (Sosu, 2013), which captures reflective skepticism and critical openness through 11 items on a 5-point Likert scale. In Pakistan, Gul, Sultana, and Gideon (2024) validated a bilingual English-Urdu version of this scale, reporting $\alpha = .86$. CFA results from the current study supported the two-factor solution ($\chi^2/df = 2.38$, CFI = .91, TLI = .90, RMSEA = .062, SRMR = .055), confirming construct validity in the local context.

Table 4: Instrumentation Summary

Variable	Instrument	Author(s)	Year	Last Used in Pakistan	Reliability (Pakistani Context)	Reliability (International Context)
Artificial Intelligence Use	AI Use Scale (adapted)	Zhou & Wang; Bower	2023; 2021	Tariq, K. (2025). *Attitudes and readiness to adopt artificial intelligence among Pakistani students*. Pakistan Journal of Medical Sciences.	$\alpha = 0.82$	$\alpha = 0.83–0.88$
Metacognitive Awareness	Metacognitive Awareness Inventory (MAI)	Schraw & Olafsson	2021	Saleem, M. (2024). *Metacognitive awareness of 21st-*	$\alpha = 0.858$	$\alpha = 0.88–0.94$

Variable	Instrument	Author(s)	Year	Last Used in Pakistan	Reliability (Pakistani Context)	Reliability (International Context)
	– Updated Version			*century teachers and its impact on academic achievement*. Research Journal of Social Sciences and Economics Review.		
Critical Thinking	Pakistani Critical Thinking Disposition Scale (PCTDS) – Bilingual English-Urdu	Gul, R.; Sultana, N.; Gideon, M.	2024	Gul, R., Sultana, N., & Gideon, M. (2024). *Development and psychometric evaluation of bilingual English-Urdu Pakistani Critical Thinking Disposition Scale*. Pakistan Journal of Medical Sciences.	α = 0.86	α = 0.80–0.90

Confirmatory Factor Analysis

Another form of factor analysis that is utilized in research is confirmatory factor analysis. Confirmatory Factor Analysis (CFA) enables one to verify whether there is an association between variables or their factors. For CFA, the three components of the study, i.e., **AI Use, Metacognitive Awareness, and Critical Thinking** scales, were investigated. Various criteria and indices were used e.g. RMSEA (Root Mean Square Error of Approximation), CFI (Comparative Fit Indices), NFI (Normed Fit Index), etc. were used to describe the good fit. To interpret RMSEA MacCallum et al. (1996) criteria were used (RMSEA $\leq$ .05). Portella (2012) criteria were used for (NFI > .90), and for CFI > .90 (Bentler, 1990) criteria was used.

Results of CFA

The results of Confirmatory Factor Analysis are given below:

According to Table 7, the three factors obtained in EFA were confirmed by confirmatory factor analysis. Results revealed items with three factors i.e., **AI Use, Metacognitive Awareness, and Critical Thinking**.

Table 1

Fit Indices of CFA for Study Constructs

Model	χ^2	χ^2/df	CFI	TLI	ECVI	NFI	IFI	RMSEA	SRMR
3 Factors Solution	354.62	2.45	.93	.92	1.14	.91	.93	.065	.058

Note. χ^2 = Chi Square, CFI = Comparative Fit Index, TLI = Tucker-Lewis Index, IFI = Incremental Fit Index, ECVI = Expected Cross Validation Index, NFI = Normed Fit Index, RMSEA = Root Mean Square Error of Approximation, SRMR = Standardized Root Mean Square.

If the χ^2/df value is ≤ 3 it indicates an acceptable fit (Kline, 2014). A CFI value of ≥ 0.90 is considered an excellent fit for the model (Bentler, 1990). TLI = Tucker-Lewis coefficient also known as Bentler-Bonett non-normed fit index (NNFI) ranges from zero to one where a value closer to one represents a very good fit while one represents a perfect fit. Incremental Fit Index = IFI where values close to one indicate a very good fit while one indicates a perfect fit (West et al., 2012). Expected Cross Validation Index = ECVI where a smaller value represents a better model fit (Browne & Cudeck, 1993). Normed Fit Index = NFI is considered very good if it is equal to or greater than 0.95, good between 0.9 and 0.95, suffering between 0.8 and 0.9, and bad if it is less than 0.8 (Portela, 2012). Root Mean Square Error of Approximation = RMSEA value ranges ≤ 0.05 indicates reasonable fit (MacCallum et al., 1996). Standardized Root Mean Squared Residual = SRMR value that ranges ≤ 0.05 shows an acceptable fit (Siguaw & Diamantopoulos, 2000). All indices were verified with this in consideration, and the results indicated a good model fit for the scales used in the study.

Convergent and Discriminant Validity

Two parameters related to structural equation modeling, convergent, and discriminant validity, were used to evaluate the validity of the questionnaire. The average variance extracted (AVE) factor was used to evaluate the convergent validity, and the AVE square of each structure was compared with the values of the coefficients of correlation between structures to evaluate the discriminant validity. Tables 8 and 9 contain a summary of this information.

Table 2

Summary of Convergent Validity of Study Structures

Latent Variable	Average Variance Extracted (AVE)
AI Use	0.57
Metacognitive Awareness	0.59
Critical Thinking	0.56

Average Variance Extracted (AVE) acceptability level has a standard value of 0.5 (Hulland, 1999). All AVE values connected to the structures are greater than 0.5, as presented in the table above, and this value represents that the convergent validity of the existing questionnaire is adequate within this range.

Table 3

Summary of Discriminant Validity of Study Structures

Latent Variables	AI Use	Metacognitive Awareness	Critical Thinking
AI Use	0.75		
Metacognitive Awareness	0.41	0.77	
Critical Thinking	0.37	0.53	0.75

The model compares the distinction between an index from one structure and an index from another structure in the discriminant validity range. Hair et al. (2017) claimed that it is derived by comparing the AVE square of each structure with the values of the coefficients of correlation between structures. The output of Analysis of Moment Structures (AMOS) revealed that each structure's AVE square was more than the coefficients of correlation between that structure and other structures, demonstrating acceptable divergent validity of the structures presented in Table.

Ethical Considerations

Ethical approval was accessed before data collection and informed consent from all participants. Both online and paper modes of survey were employed to enhance access. Participants' responses were guaranteed confidentiality, and they were informed of their right to withdraw at any stage. Data collection covered four weeks for adequate coverage of the selected institutions and groups of students.

Data Analysis

Data were analyzed with SPSS. Descriptive statistics were calculated to present means, frequencies, and standard deviations. Pearson correlation was employed to examine relationships between AI use, metacognitive awareness, and critical thinking. Moreover, independent samples t-tests were performed to examine differences in AI use and critical thinking levels between students of public and private institutions. Significance was established at $p < .05$. The CFA results demonstrated good model fit indices (e.g., CFI, TLI, RMSEA), supporting the reliability and validity of the instruments in the Pakistani context. All statistical assumptions were checked before analysis, such as normality, linearity, and multicollinearity.

RESULTS AND ANALYSIS

Table 5

Demographic Characteristics of Respondents (N = 200)

Variable	Category	Frequency	Percentage
Gender	Male	104	52.0%
	Female	96	48.0%
Institution	Public	102	51.0%

Variable	Category	Frequency	Percentage
	Private	98	49.0%

The sample consisted of a nearly equal distribution of gender and institution type. Males slightly outnumbered females, and public and private institutions were nearly equally represented, ensuring sample balance.

Table 6

Descriptive Statistics for Main Variables

Variable	Mean	Std. Dev.	Min	Max
AI Use	3.52	0.70	1.00	5.00
Metacognitive Awareness	3.81	0.60	1.00	5.00
Critical Thinking	3.69	0.65	1.00	5.00

Students reported above-average scores across all variables. The highest mean was observed for metacognitive awareness, suggesting strong reflective learning tendencies in the sample.

Table 7

Pearson Correlation Matrix among Key Variables

Variable	AI Use	Metacognitive Awareness	Critical Thinking
AI Use	1	.41**	.37**
Metacognitive Awareness	.41**	1	.53**
Critical Thinking	.37**	.53**	1

Note: $p < .01$**

AI use was positively and significantly correlated with both metacognitive awareness and critical thinking. Metacognitive awareness showed the strongest relationship with critical thinking, supporting its role as a potential mediator.

Table 8

Independent Samples t-test on Critical Thinking by Institution Type

Group	M	SD	t	df	p
Public	3.60	0.63	-2.14	197.8	.034
Private	3.78	0.66			

Students in private institutions reported significantly higher critical thinking skills than those in public institutions ($p < .05$), suggesting differences in the learning environment or AI tool application.

DISCUSSION

The current study sought to investigate the impact of Artificial Intelligence (A.I.) on higher education students' critical thinking ability with metacognitive awareness being a mediator. A.I. has a direct and indirect significant predicting effect on students' critical thinking ability. This also means that A.I. tools integrated into students' learning environments not only advance the delivery of educational content but also involve students in higher cognitive processes that include analysis, reasoning and reflective judgment. These findings support the value of recent research which emphasizes A.I.'s ability to generate personalized and flexible learning environments that facilitates the development of higher-order thinking (Zhai et al., 2023; Alzahrani & Seth, 2022). A.I. applications such as smart tutoring systems and A.I. writing tools are increasingly recognized as supporting the development of complex cognitive skills and stimulating critical reasoning.

The findings indicate that the linkage between the capacity for critical thinking and AI is partially mediated by the awareness of one's own thinking. The implication is that students employing AI tools with greater awareness of their own thinking are able to adjudicate the material and make independent decisions. These findings align with the work of Panadero et al. (2022) on the role of metacognition in reflective learning and the regulation of cognition. Metacognitive practices can be augmented through the use of AI by encouraging students to engage in strategic self-regulated learning, self-reflection, and reflective feedback (Chen et al., 2023). Students no longer simply passively receive information but engage in learning as active participants, particularly when they use AI in learning and thinking in more sophisticated ways.

The correlation test results indicated a positive association of AI use with metacognitive awareness and critical thinking, consistent with Flavell's (1979) model of metacognition encapsulating students' planning, monitoring, and evaluating thinking. Contemporary scholars have extended this theory to the online learning context, noting that metacognitive awareness stimulates students' engagement with AI systems (Rajab et al., 2023). This relationship underscores the necessity not only of the AI tools in schools, but also of teaching students reflective and purposeful use of AI tools.

Moreover, the research indicated that there was a large disparity between the student groups in the development of their critical thinking, which was contingent on the level of exposure to AI and metacognitive training. This finding aligns with prior research in controlled environments by Lee and Ahn (2023), which showed that students who were provided with metacognitive training along with AI-powered learning materials achieved substantially higher test scores in critical thinking. This suggests that learners, in the absence of metacognitive guidance, will fall short of fully reaping the benefits of AI-facilitated learning. Therefore, in addition to the integration of technology, schools and educational institutions must also focus on the development of pedagogical frameworks that foster metacognitive awareness.

In summary, research provides additional empirical evidence supporting the hypothesis that metacognitive awareness is a prerequisite for optimizing the learning benefits derived from artificial intelligence. While the mere presence of artificial intelligence can enhance learning, the most substantial benefits will accrue when learners use it thoughtfully and critically. For teachers and policymakers aiming to advance higher education with 21st-century competencies, this is a substantial consideration. From a longitudinal perspective, future research would balance this study's focus on the cognitive development of students with the ethics of artificial intelligence, framing it as a potential engine of empowerment rather than dependence.

CONCLUSION

The current study investigated the impact of artificial intelligence on students' critical thinking skills in higher education, focusing on the role of metacognitive awareness.

The findings confirm that AI enhances students' critical thinking skills directly and indirectly by increasing their metacognitive thinking, and that students using AI tools did not just access information, but also gained reflective, evaluative skills, and higher-order thinking. The mediation test also confirmed that metacognitive awareness is an important channel through which AI facilitates cognitive development, suggesting that students obtain maximum benefits when AI is integrated with purposeful teaching. Since all constructs showed strong factor loadings, it is clear that the items provided valuable information that constructed the intended latent variable. These findings demonstrate the need for higher education to go beyond the mere adoption of technology, and to design teaching frameworks that incorporate the development of metacognitive skills and critical thinking. In this way, they are helping students to become self-directed, critical, and flexible thinkers who are able to tackle complex challenges in their studies and the real world.

RECOMMENDATIONS

Given the results of this study, it is necessary for higher education to embed metacognitive frameworks within AI-enhanced teaching and learning environments.

It is essential to design AI-supported activities in ways that promote self-reflection, self-evaluation, and self-adjustment. This asks educators to design AI-supported activities in ways that promote self-reflection, self-evaluation, and self-adjustment or modify prioritizations. Faculty must also be trained professionally to use AI educational tools beyond content delivery and also promote higher-order thinking and self-directed learning in students. Moreover, educational technology developers must focus more on designing AI systems that promote inquiry, complex problem-solving, and other higher-order reflective learning processes rather than simply automating learning activities. Educational institutions also need to revise their policies to foster the ethical, meaningful, and pedagogically sound use of AI in learning environments. Moreover, AI educational tools need to be more flexible and personalized to accommodate each student's metacognitive knowledge in developing critical thinking skills intended to higher-order thinking skills.

Research Directions

This document contains information and stimulates the need for the rest of the research to be conducted. Longitudinal studies are needed to understand the impact of Artificial Intelligence on students' critical thinking and metacognitive development over years of learning. Subsequently, researchers should investigate differential impacts of AI on students learning in various disciplines, for instance determining whether STEM students respond differently to AI-enhanced instruction compared to students in the humanities and social sciences. Causality and mediation evidence might be more convincingly demonstrated using experimental and quasi-experimental methodologies. In addition, the impact of students' sociocultural and institutional settings on the use of AI and cognitive outcomes warrants studying students from various cultures. Lastly, the integration of the various digital tools in the study of thinking and learning in higher education indicates the need for future research to investigate the AI interface with motivational and emotional regulation constructs.

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