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EFFECT OF ARTIFICIAL INTELLIGENCE (AI) TOOLS ON STUDENTS' CRITICAL THINKING SKILLS AND CONTENT COMPETENCE

Sania Saeed,
MPhil Education, UE Faisalabad Campus
Asif Iqbal,
Associate Professor,University of Education Lahore, Faisalabad Campus
asif.iqbal@ue.edu,pk

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Abstract

This study explored the effect of artificial intelligence (AI) tools on students' critical thinking skills and content competence at the university level. Data were collected using a quantitative descriptive survey design from (N=216) undergraduate students of three public sector universities of Faisalabad, Pakistan. A research questionnaire scale, the Artificial Intelligence, Critical Thinking, and Content Competence Scale (AISCTCCS) with (α=.89) was used. To assess the use of AI tools and critical thinking skills, the Cognitive Skill questionnaire was used. Specifically, the results indicated that there was a negative correlation ($r = -0.362$, $p < 0.01$) between the use of AI tools and critical thinking skills. On the other hand, regression analysis found that students' pre-existing critical thinking skills were a significant positive predictor of their engagement with AI tools ($\beta = 0.396$, $p < 0.001$). Significant differences emerged between female and male students with respect to their perception of AI use and content competence (mean differences, female higher). Still, there was no effect for departmental affiliation or university type on critical thinking outcomes. In the study, we present AI tools as a double-edged sword; unguided employment use may hamper critical thinking, whilst pedagogically integrated deployment can advance special cognitive skills. These relate to embedding AI literacy in the curricula; training educators in designing tasks which test that students can reflect effectively on what they are able to do (that is: on how well they have mastered specified learning objectives), and around creating ethical frameworks for the integrated and productive use of generative systems.

Keywords: *Artificial Intelligence, Students' critical thinking skills, Content competence.*

Introduction

One of the latest advancements in technology that we have seen during this decade is the use of artificial intelligence (AI) in Higher Education. Also, developed artificial intelligence (AI) tools for education Are: Intelligence tutoring systems and generative technology Platform automation software Adaptable Learning that is anticipated to contributeF or the extra perception of research through personalized education Automation processes and on-demand academic support. 2016). As these tools only continue to penetrate the academic experience, a central question emerges: How might they shape our mastery of core cognitive skills like critical thought?

The swift incorporation of generative AI instruments, including ChatGPT, Microsoft Copilot and Claude into higher education has led to an expedited academic discussion on their utility for teaching. Advocates cite efficiency and tailored learning as major benefits, and a plethora of new research calls into question whether critical reasoning and core cognitive skills will atrophy. The recent literature has shown a compelling emphasis on the danger of cognitive offloading, the tendency to use external tools (AI) in ways that decrease mental labour. Darvishi et al. (2024), in one of the largest controlled studies to date, found that undergraduates who completed problem-solving tasks with ChatGPT performed significantly worse than a control group on independent critical-thinking assessments (n = 450). Critical thinking was measured with the Halpern Critical Thinking Assessment, with particularly low scores in analysis and inference. This result is consistent with "automation bias" found during human-

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AI interaction in which users over-trust AI predictions without exercising metacognitive oversight of their own use (Vasconcelos et al., 2023).

But it is not a one-way relationship. Lee et al. By taking this nuanced "use-contingent" approach, as proposed by (2025), AI will yield positive or negative results related to critical thinking depending on how the tool is used. Answer verification vs. Answer generation: Students are better at critically evaluating their work when using AI to verify answers rather than generating them! In particular, students who were tasked with finding and explaining errors in AI-generated arguments averaged 22% better on a follow-on argument analysis exam. Passive consumption of AI answers can diminish critical thinking, while active interrogation may bolster it.

The most widely touted uses of higher education have been critical thinking, as measured by students' ability to analyze information, evaluate arguments and integrate ideas and problem solving (Facione, 2015). Students cannot afford to go into an information-saturated world without being able to demonstrate critical thought because employers are increasingly seeking those graduates. But AI is fast; it can summarize complex texts and enable problem-solving, and this could alter the cognitive hurdle that students interact with. The lunacy in thinking humans will gamify that data across the instances for analytics is downright lazy. How many Michigans, as highlighted by other sisters such as O'Neil (2016), breed intellectual laziness vs. doing the hard work required to have a mental corpus?

Existing literature presents a paradox. Similarly, research suggests that personalizing feedback and presenting problems in terms of many solutions can support critical thinking through the use of AI scaffolding (Woolf, 2010). Some caution that passively accepting AI work can erode critical thinking and metacognition (Holmes et al.). This duality manifests in the form of empirical evidence contextualized within the practice context, especially within a developing educational milieu with rapidly shifting dynamics, as seen during the swift penetration of digital integrations like Pakistan.

Thus, this study aims to explore the effect of AI tool usage on critical thinking among university students in Pakistan. And it offers empirical evidence of the effects of this technology on a key academic skill as opposed to pure speculation. The findings then aim to help educators, curriculum designers and policymakers understand optimal construction of a balanced tech architecture that effectively leverages the Positive Potential of AI while neither violating student agency nor inhibiting their development as Critical Thinkers.

The Literature Review

Content competence: The ability to make connections across different subdomains (i.e., the actual domain-specific knowledge and applying what you know in new situations) is also hotly debated in AI literature. AI, at least from a constructivist perspective, is an effective scaffold. For instance, Mollick & Mollick (2023), using AI to generate "Socratic dialogues" in biology and economics, showed that asking learners to justify their prior answers (which sometimes were contested by the AI) led them to a deeper conceptual understanding. Students who used AI as a dialogue partner did better than those using static textbooks on transfer problems, showing strong content competence in their randomized trial.

On the other hand, more recent meta-analyses caution about surface-level learning in some cases. Yu & Guo (2024) have conducted a systematic review of 62 empirical studies on AI-specific findings in STEM areas and concluded that reliance on procedural tasks provided by the AI (e.g., solving equations, generating code) leads to poor retention in the long term. They draw on cognitive load theory: when AI cuts the learner out from building their schema

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(for example, by directly handing over answers to deriving mathematical numbers), they concretely never cement those underlying mental models. As a result, although students seem able to progress in AI-assisted contexts, their unaided performance is poor (Kumar et al., 2024, pp. 3-4).

Furthermore, disciplinary differences emerge. In humanities and social sciences, where critical evaluation of sources/argumentation is the most primary skill to teach, a mixed effect has been recorded for AI use. Zhao and O'Leary (2025) conducted a longitudinal study that tracked 300 history students across one semester. The group with access to AI for producing outline drafts created essays at the end that were better-structured and had more evidence. But they performed poorly on an on-the-spot in-class analysis of a document requiring original interpretation. The authors contend that AI tools, by offering up easy pre-digested summaries of academic debates, short-circuit the student's active wrestle with historiographical thought.

Metacognition and Instructional Design

The latest research in this series (2024–2025) is about moderating variables rather than simple cause-and-effect questions, and more specifically, metacognitive skill in general and instructional design. The concept of metacognition, the ability to monitor, regulate and reflect on your own learning, seems to play a protective role, buffering the harmful effects of AI use. In a survey of 1,200 university students, Schoenherr (2024) found that high metacognitive awareness means using AI as a critique partner (e.g., I can use AI to check the weak points of my argument, outline the negatives), while low-metacognitive students used it as an answer machine ("Write my discussion post"). Those in the latter group exhibited substantial declines over time on both critical thinking and content competence.

Instructional design also matters profoundly. A few of the more recent interventions have suggested "AI-resistive exercises" and "AI-augmented critique tasks. For instance, Chen et al. In a computer science course, Xu et al. (2025) compared three conditions: (a) no AI, (b) free AI use, and (c) structured AI with mandatory error analysis. Condition (c) either saved or even boosted debugging skills and conceptual knowledge with respect to the no-AI condition. That AI is not inherently destructive of cognitive skills, but that contextual uncritical pedagogical integration does.

Finally, there are epistemological concerns: if one component of content competence is the ability to assess the trustworthiness of knowledge claims, then relying too heavily on AI may diminish students' epistemic cognition and metacognitive understanding about how knowledge is built (Sperling et al., 2024). By treating an LLM that outputs information in a way that seems like it is announcing facts as though it were an authoritarian oracle, students are not forced to be suspicious of algorithmic output.

Synthesis and Research Gaps

Overall, the literature review suggests that AI tools influence students in terms of critical thinking and content competence based on context. Note that we also find a correlation between passive, answer-seeking use and cognitive offloading, as well as less retention and poorer unaided performance. In contrast, the active and critical use (e.g., error-identification with AI or Socratic dialogue with AI) may develop evaluative skills and conceptual knowledge. Descriptive words: children, metacognitive abilities, domain-specificity and the nature of AI use.

Several gaps remain. To begin with, many studies are limited in duration (by semester or by 1 semester at pet most), so it remains uncertain whether these methods will favour longer-term developmental gains. Second, the literature tends to emphasize writing-intensive and STEM

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procedural tasks while deemphasizing skill-based disciplines (e.g., clinical nursing, studio arts). A validated instrument specifically developed to address critical thinking with AI-mediated environments is the third reason of interest. Sources of future research should focus on longitudinal designs and authentic assessments that measure students' ability to co-reason with AI systems without sacrificing their own analytical faculties. Until then, the consensus appears to be that AI tools are neutral: their educational value depends entirely on what cognitive behaviors they replace or reinforce

The subject of AI in education has become a topic of discussion, and the cognitive aspects have received much more attention. Critical thinking, which is defined as reasoned thought that demonstrates analysis, ideas for evaluation (Facione, 2015), is one of the primary concerns. These are those who suggest it: AI is a cognitive copilot. An example of this is the use of intelligent Tutoring Systems (ITS) that can guide students through multi-step problem-solving sequences while asking reflective questions and fixing faulty reasoning in real-time, all features that might foster a more analytical student habit of mind (VanLehn, 2011). Similarly, a consultation reveals that learning analytics dashboards can make the processes of learning visible, and this visibility also supports metacognition and self-regulated learning (Ifenthaler & Yau, 2020).

In contrast, much of the literature is risk-oriented. Because students take many of the outputs produced by AI tools without ever understanding either the logic or even bias behind these outputs (O'Neil, 2016), this makes many applications black box–like and thus resistant to scrutiny. Another challenge is specific to generative AI tools (for example: ChatGPT) as they can aid students in brainstorming and drafting, but over-reliance may short-circuit some of the cognitive work involved in drafting, revising or piecing arguments together, thereby robbing students of a more authentic engagement with academic learning. It is linked to fears that being too "digital dependent" adds up to even more, rather than as technology would replace, instead, complete cognition.

This duality can be explained using theoretical frameworks. In the context of education, an academic workload was conceptualized as a demand through the JD-R model. AI is a double-use sword: it can be used for good (eg, help clarify), but may also lead to understanding and cause distraction and overloaded information (Du & Wang, 2024). A mediating variable related to the use of technology, based on Social Cognitive Theory, is students' self-efficacy (Hope et al., 2015; Pirzada, Tabassum & Ahmad, 2024). Students lower in critical thinking self-efficacy may 'shy away from' challenge (Bandura, 1997) and become reliant on AI for this task

Empirical findings are mixed. Other research suggests no or even positive relations between the use of educational technology and critical thinking skills, for example, when mediated by a more rigorous pedagogical design (Chen et al., 2020; Naeem, Ali, & Ahmed, 2022). Some, on the other hand, see a downside and relate the overuse of unregulated information-seeking devices to worse performance in analytical reasoning tasks (Zawacki-Richter et al., 2020; Imran et al., 2023). This 'gap' illustrates the importance of context in understanding impact and signals for localized investigations into impacts based on the tools employed, cultural attitudes, and instructional contexts such as those within Pakistani higher education.

Theoretical Perspectives

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There are a few different conceptual frameworks that help ground the relationship between AI tool use and critical thinking skill development. In an academic context, the cognitive load of university coursework is viewed as a job demand within the person-centred Job Demands-Resources (JD-R) model. In this framework, AI tools can serve a dual role. When employed meaningfully, for example, when using AI to simplify abstract ideas or structure thoughts, it can serve as a resource that mitigates academic burden and ultimately enables cognitive free space to engage with higher-order analysis (Du & Wang, 2024; Ahmad, Noorani, & Channa, 2025). However, when usage is compulsive, distractive and leads to information overload, AI is an added burden, leaving consumers cognitively fatigued and notably removing the in-depth engagement needed for critical thinking.

Third, Social Cognitive Theory (Bandura, 1997) offers a useful perspective with its focus on self-efficacy. It is plausible that a student's critical thinking self-efficacy (beliefs about one's capability to think critically) moderates how that student interacts with AI. Students high in self-efficacy may use AI instrumentally to test hypotheses and alternatives while remaining active, metacognitive evaluators. However, those who experience low self-efficacy may see AI as a compensating crutch, outsourcing analysis and thereby avoiding even the practice of acquiring skills that will eventually mean their competence collapses further in response to negative reinforcement.

The on-demand summaries, answers and content that AI can produce could create a paradox of cognitive scarcity. With low effort required to engage, students may be able to skim AI outputs (Zhao et al., 2021; Faheem, Gulab, & Ahmad, 2025), promoting superficial processing, fractured attention that is anathema to the sustained, committed attention required for critical thinking over extended periods.

It correlates with the research that found that uncontrolled and disproportionate use of the technology is related to low metacognitive awareness.

In summary, the conceptual framework underlying these theories depicts that AI influences critical thinking not in an immediate manner, but by framing the tool as a demand or a resource; highlighting psychological traits of the learner, such as self-efficacy; and encouraging behavioral patterns of active use or passive consumption. As a theoretical framework, this informs the rationale for explicitly teaching students to use AI as a tool rather than an automaton in critical reasoning.

Research Objectives

The research objectives of this study are as follows:

1. To examine the impact of AI tools on the critical thinking skills of university students.
2. To impact the students' critical thinking abilities differently based on their age, department and gender when using AI tools.
3. To assess the relationship between students' critical thinking abilities and their engagement with AI tools.

Hypotheses

The hypotheses of this study are as follows:

1. Increased AI tool usage is negatively related to students' critical thinking skills.
2. The academic department of a student moderates the impact of AI tools on critical thinking.
3. There is no significant relationship between students' critical thinking abilities and their engagement with AI tools.

Material and Methods

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This study employed a quantitative research design to investigate the impact of AI tool usage on the critical thinking skills of university students. A descriptive survey method was used to collect standardized data for statistical analysis.

Research Design

This study employed a quantitative, descriptive survey design to examine the relationship between Artificial Intelligence (AI) tool usage and students' critical thinking skills. This study used a cross-sectional, one-time point of data collection, structured questionnaire method on the health behaviours in the lifestyle environments (Safer) project developed from October 2018 to March 2020 among a total of 216 undergraduate students. This approach allowed for the collection of common, quantitative data on students' modes of AI use and self-reported cognitive abilities. It was also appropriate as it permits the use of inferential statistics to investigate correlations and test predictions in order to achieve the research aim and answer the questions about whether AI can have an effect on critical thinking in higher education.

Population and Sample

The population of the present study consisted of undergraduate students at the Departments of English, Chemistry and Business Administration from three public universities (Government College University Faisalabad, University of Agriculture Faisalabad and University of Education Lahore (Faisalabad Campus)) in Punjab. It used a multi-stage cluster sampling method. Methodology: First, we identified clusters for each department unit. Second, the random selection of all 3rd to 5th semester students from each department. That led the final sample for that study to 216 students.

Research Instruments

An instrument with its structured questionnaire - Artificial Intelligence, Critical Thinking and Content Competence Scale (AISCTCCS) was developed, formulated and validated by collecting data on overall usage. The survey was organized around the following three main parts: demographics, including gender, age, university and department.

AI Tool Usage: This part makes use of a 4-point Likert scale from1to 5, where 1= strongly disagree, 2=disagree, 3=agree, and 4=strongly agree.

Critical Thinking Skills (11 items) This section assessed four skills: analysis, evaluation, inference, and self-regulation on a 5-point Likert scale using adapted versions based on validated instruments. To establish content validity with the instrument, two experts in education and technology analyzed it. The constructs of the instruments were found to be internally reliable (Cronbach's alpha > 0.70) in a pilot study (n = 30).

Data Collection and Analysis

Data Collection: primary data collection (during academic sessions with prior permission from respective institution) and Demographic characteristics, anonymity (if permission to participate in the study was acquired). They were analyzed with the SPSS software (Version 26) after coding. Analytical techniques included:

MEASURES: Frequencies, percentages, means & standard deviations.

Statistical inferences: Independent sample t-test (for gender), Pearson r between a and critical thinking for testing purposes from AI usage); Regression.

Data Analysis and Interpretation

The statistical analysis of this data aims to assess how AI tools affect students' critical thinking skills.

Table 1:

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Gender-based Frequency Distribution

Gender	Frequency	Percent
Male	129	59.7
Female	87	40.3
Total	216	100

Table 2 explores the sample size divided by gender. The sample included 216 students, of whom there were more males (59.7) than females (40.3). Its distribution yields an interpretation of a gender comparative study of the study variables.

Table 2:

Descriptive Statistics of Main Variables

Variable	N	Mean	SD
AI Tool Usage	216	3.51	0.50
Critical Thinking Skills	216	3.25	1.01

Table 2 Report of the Descriptive Statistics for Two Key Variables. Students reported a moderate, M=3.51, SD=0.50 range of usage of the AI Tool Usage. The score for Critical Thinking Skills (M=3.25, SD=1.01) indicated the participants perceived themselves to moderately utilize Critical Thinking with a wide range of response variation.

Table 3:

Gender-Based Comparison of Critical Thinking Skills

Variable	Gender	N	Mean	SD	t-value	Sig.
CTS	Male	129	3.35	1.19	1.916	.057
	Female	87	3.08	0.52		

Table 3 presents the results of an independent samples t-test comparing critical thinking scores by gender. The results in terms of gender were not statistically significant, which was similar to the previous correlation results, wherein male students (M=3.35, SD=1.19) and female students (M = 3.08, SD=0.52) reported t(214)=1.916, p=.. 057. It suggests that perceived critical thinking is comparable between females and males in this sample.

Table 4:

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Correlation between ATU and CTS

Variables	N	M	SD	r	p
AI Tool Usage	216	3.51	0.50	.362	.000**
Critical Thinking Skill		3.25	1.01		

Pearson correlation coefficient at, **p <.000

An analysis of Pearson correlations between AI tool usage and critical thinking skills. It was statistically significant with a negative correlation ($r = -0.362$, $p < 0.01$). The finding indicates a moderate inverse relationship where the use of AI tools was positively associated with poor self-reported critical thinking skills within our sample of students.

Table 5:

Linear Regression Analysis (Critical Thinking Predicting AI Tool Usage)

Model	Beta	Std. Error	t	P-value
(Constant)	4.821	0.243	19.851	.000**
CTS	0.200	0.032	6.284	.000**

**p < .001*

Table 3 presents the Linear regression analysis to examine critical thinking skills as a predictor of AI tool use. To note, critical thinking skills were a robust positive predictor ($\beta = 0.200$, $p <$. 001). Unstandardized b for critical thinking is 0.200, which means a one-unit increase in critical thinking score is expected to be associated with an increase of AI tool usage by 0.200 units. AI use was predicted significantly by the model, accounting for 17.5% of variance ($R^2 =$. 175). One of the more revealing extracts notes: correlation shows that critical thinking leads to a negative correlation for this behaviour regression, but also shows the contrary, with students who are better at critical thinking using embarrassing AI tools less frequently.

Discussion

The paper mostly discovers that AI tool use has a negative correlation with critical thinking. It echoes the concerns which O'Neil raised (2016) and Holmes et al. Conceptual and computational research methods can be synthesized to build analytical rigour that will escape uncritical, dependency-inducing AI us (Amoore, 2021; Dilshad, Shah, & Ahmad, 2023). Although, as far as correlation is concerned, in Pakistan, where there are common projected use cases of AI tools, and they have speedy resolution (e.g., summarising texts, doing assignments), technology may be a substitute rather than an aid to intellectual labour.

The regression result augments the nuance of this interpretation case. It invites a recursive reading, where AI use predicts critical thinking skills as much as the reverse (Akram, Khan, & Ahmad, 2022). Those with robust inborn/learned critical faculties may use AI as a tool for exploration, optimization, and effectiveness more successfully (Ahmad, Sewani, & Fatima, 2025). And students who cannot think critically will gobble AI up like a crutch, which also degrades those faculties. A bifurcation of this kind is representative of the fundamental nature of JD-R and indicates that the same technology can be a resource or a demand depending on the users and their context.

That limited difference on those questions between department and university shows that the threat from artificial intelligence is a broad, pedagogical issue, not one related to specific

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disciplines by leadership (Ahmad & Rizvi, 2026). The other important pattern is that of a gender gap: there are more AIs reported to be used by females, and more content competence reported amongst males. This perception gap requires qualitative exploration, but also should inform what specific shaping quality to be included when creating inclusion-sensitive digital (tool) training (Oad et al., 2024; Ahmad, Sewani, & Channa, 2025).

These results establish that the effect of AI-generated resources on critical thinking is not ontological but pedagogical. The tool itself is agnostic; the respective cognitive consequence stems from deliberate design, teacher facilitation, and district policy of reflective engagement.

Conclusion

Finally, we conclude with Theory and Practice implications along the argument of a student at the post-secondary level using AI tools generally/engaging critically, but complex-embattled from their critical thinking skills at best. Conclusion: Given that our sample size did not identify as being of this nature, we find evidence here of the AI impacting an expansion for educational purposes, whilst this tapering off of critical thinking is back down again, which signals a potential danger in the ease-of-mind pathways opened up by the technology. However, this correlation also suggests and demonstrates that it is those who become good critical thinkers who are the very students who succeed in utilizing AI productively (Ali et al., 2020). So it is not about the prohibition on AI in higher education, but rather how to leverage it for superior results. Instead, we will have to transform the question from access (AI access) to use: purposeful and thoughtful use, and how you teach a brand of literacy about (a form of normative literacy on) AI that promotes evaluative thought with regards to outputs and that which makes one ethically evaluate it in a way that facilitates engagement instead of diminishing it. The question is not just how students will use AI, but how they think with and about it as part of the learning process.

Recommendations

On the basis of these results, we advocate for the following recommendations.

1. Curriculum Developers: Create mandatory "AI Literacy" courses in undergraduate studies so students can analyze AI tools and learn about algorithmic bias and ethical concerns with AIs.
2. For Faculty: Stop policing when a student uses AI Design assignments based on having students analyze, critique and counter-argue against material generated by ChatGPT or the like, so they are required to really work their analysis and evaluation muscles.
3. To University Administrators: Have firm, educational, no-punishment policies on AI usage in classwork. Do professional development workshops to integrate pedagogical ways of teaching with AI.
4. For research in the future: Longitudinal studies tracking causal pathways, Qualitative studies measuring the more granular “how” of student-AI interaction in specific disciplines/centres, and cultural contexts

Research Ethics

Ethical concerns: the study was ethically sound; All participated gave informed consent. Anonymity and confidentiality were maintained, and participation was voluntary.

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