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Role of Artificial Intelligence in Developing Critical Thinking Skills among University Students in Pakistan

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Abstract

Artificial Intelligence (AI) has rapidly emerged as a defining force in global education, transforming how students learn, interact, and construct knowledge. Although AI offers personalized learning and analytical support, its influence on higher-order thinking—particularly critical thinking—remains debated. Grounded in Socratic philosophy and Constructivist Learning Theory, this quantitative cross-sectional study examines how AI sub-factors such as learning support, motivation, information analysis, personalization, ethical use, and overreliance risk influence critical thinking dimensions, including analysis, evaluation, inference, reflection, questioning, and independence. The study contributes to the philosophical and empirical understanding of AI integration in higher education, offering evidence-based implications for fostering analytical and self-directed learners in Pakistan. Descriptive statistics indicated moderately high levels of both AI engagement and CT. These findings suggest that AI can function as a digital scaffold that enhances analytical and reflective capacities when used critically and ethically, but may undermine intellectual autonomy when over relied upon. The study offers empirical evidence and pedagogical implications for aligning AI-based learning with the cultivation of reflective, independent thinkers in Pakistani higher education

Keywords: Artificial Intelligence, Critical Thinking, Socratic Philosophy, Higher Education, Pakistan

Introduction

The 21st century has witnessed an unprecedented technological transformation that has reshaped all domains of life, with education standing at its epicenter. Artificial Intelligence (AI) — the capacity of machines to simulate human reasoning, learning, and decision-making — is now an integral component of higher education worldwide. Its applications range from intelligent tutoring systems and adaptive learning environments to data-driven analytics that personalize instruction (Chan & Hu, 2023; Kaplan, 2019). In universities, AI-powered platforms can instantly assess student performance, provide customized feedback, and recommend tailored learning materials, thereby redefining pedagogical boundaries.

Globally, AI is celebrated for increasing efficiency, fostering inclusion, and promoting individualized learning pathways (Holmes et al., 2019). Yet, it simultaneously provokes deep philosophical concerns. Educators and philosophers' question whether reliance on AI might erode the very qualities that define human intelligence — reasoning, reflection, and ethical decision-making. Socrates, the classical Greek philosopher, emphasized that genuine knowledge emerges not from passive acceptance but through questioning, reflection, and dialectical engagement. In the modern classroom, these Socratic principles remain central to the cultivation of critical thinking, which is the intellectual foundation of higher education (Paul & Elder, 2006).

Critical thinking (CT) enables students to analyze evidence, question assumptions, evaluate arguments, and form reasoned judgments. Ennis (1996) describes it as "reasonable, reflective thinking focused on deciding what to believe or do." It is not merely a cognitive skill but a philosophical discipline—a way of reasoning about truth, ethics, and understanding. However, with the rise of AI-assisted learning, educators face a new paradox: while AI supports analytical efficiency and access to information, it may also reduce the mental struggle necessary for genuine intellectual growth (Essel et al., 2023).

Universities are now at a critical juncture where AI can either augment students' critical capacities or replace their cognitive agency. As Shahzad et al. (2024) note, the increasing use of AI tools in Pakistani higher education raises important questions about autonomy, creativity, and reflection. Artificial Intelligence, as operationalized in this study, refers to computer-based systems capable of mimicking aspects of human cognition such as reasoning, learning, and decision-making (Kaplan, 2019; Russell & Norvig, 2020). AI in higher education functions as both a pedagogical facilitator and a cognitive partner. To capture its diverse educational roles, AI is examined through six sub-factors, each derived from global empirical literature and validated through prior conceptual frameworks (Szmyd & Mitera, 2024; Chan & Hu, 2023; Pappagallo, 2024):

Support for Learning the extent to which AI tools provide instructional scaffolding, explanations, and assistance to improve understanding of complex academic content. Holmes et al. (2019) highlight that AI-based tutoring systems offer adaptive support that mirrors teacher guidance, especially beneficial in large classes.

Motivation to Learn AI systems can stimulate engagement by providing interactive feedback and progress tracking (Jabbour et al., 2025). When students receive instant reinforcement, their academic motivation and task persistence improve.

Information Analysis and Problem-Solving AI's analytical capabilities enable students to evaluate data, generate hypotheses, and identify relationships among concepts (Szmyd & Mitera, 2024). However, excessive dependence on automated suggestions may limit students' independent analysis.

Personalization and Adaptation AI's adaptive algorithms tailor learning content to the individual's performance and pace (Chan & Hu, 2023). Personalization enhances accessibility but raises ethical concerns about reducing shared critical discourse.

Source Evaluation and Ethical Use AI can assist in verifying source credibility, referencing, and ensuring academic integrity (Pappagallo, 2024). Yet, ethical awareness depends on how students interpret AI-generated outputs within moral and academic norms.

Overreliance Risk the potential cognitive danger of depending excessively on AI for solutions. Overreliance can discourage independent thought and critical judgment, leading to intellectual complacency (Essel et al., 2023).

Critical Thinking (CT) represents the student's ability to reason reflectively and analytically to make informed judgments (Ennis, 1996; Paul & Elder, 2006). Within higher education, it functions as both a learning outcome and a philosophical orientation toward knowledge. This study conceptualizes CT as a multidimensional construct comprising six measurable sub-factors:

Analysis the skill of deconstructing complex ideas into logical components, identifying patterns, and recognizing causal relationships. AI can aid this process by organizing data, though genuine analytical reasoning requires human interpretation (Holmes et al., 2019).

Evaluation assessing the credibility and validity of information. Socratic philosophy aligns with this dimension, as it urges learners to test claims through questioning rather than acceptance (Paul & Elder, 2006).

Inference the ability to draw conclusions from evidence and predict outcomes. AI can enhance inferential thinking by providing data insights, but without reflection, these inferences may remain superficial (Chan & Hu, 2023).

Interpretation and Reflection involves translating abstract information into personal understanding and revisiting one's assumptions. This sub-factor connects directly to Socratic dialogue, which depends on introspective reasoning (Chukhlomin, 2024).

Questioning Assumptions (Socratic Thinking) — an essential philosophical skill where learners challenge underlying premises. Socrates viewed questioning as the foundation of wisdom; hence, this sub-factor evaluates whether AI use encourages or suppresses curiosity and skepticism.

Independent Thinking — refers to the learner's ability to make judgments autonomously rather than relying on authority or algorithms. Excessive AI dependence may weaken this dimension, creating a need for balanced integration (Essel et al., 2023).

Literature Review

Artificial Intelligence (AI) has become an integral part of educational innovation globally, offering transformative potential in how students learn, interact, and reason. Research across developed contexts highlights AI's ability to personalize instruction, provide adaptive feedback, and enhance problem-solving processes (Holmes, Bialik, & Fadel, 2019). For example, adaptive learning systems enable individualized instruction by identifying each student's cognitive strengths and weaknesses, thus fostering deeper engagement (Chan & Hu, 2023). Similarly, intelligent tutoring systems can diagnose misconceptions, scaffold reasoning, and deliver tailored exercises that improve analytical thinking (Jabbour, Teixeira, & Freitas, 2025). These findings suggest that AI can positively influence the analytical and evaluative components of critical thinking (CT) by promoting self-paced and reflective learning.

However, despite these benefits, concerns persist about AI's unintended effects on learners' cognitive independence. Several international scholars have warned that excessive reliance on algorithmic feedback may weaken students' metacognitive regulation and reflective judgment (Szmyd & Mitera, 2024). When learners depend too heavily on AI-generated solutions, their ability to question, interpret, and critique information can diminish. In this sense, while AI enhances performance efficiency, it may inadvertently discourage deeper intellectual engagement. Essel, Boateng, and Mensah (2023) found that AI-based tools improved assignment completion rates but reduced students' willingness to verify information independently—indicating a trade-off between cognitive efficiency and critical reflection.

In Pakistan, the integration of AI into higher education is at an early but accelerating stage. The Higher Education Commission (HEC) has encouraged universities to adopt digital technologies to improve learning quality and institutional efficiency, yet implementation remains uneven across regions and institutions. Studies in the Pakistani context primarily focus on faculty readiness, technological infrastructure, and student attitudes, rather than measurable cognitive outcomes such as CT (Khan, Batool, & Niazi, 2022; Shahzad, Rauf, & Ateeq, 2024).

At the student level, Ahmed and Farooq (2023) explored perceptions of AI-based learning tools and found that while students appreciated AI's convenience and time-saving features, they seldom engaged critically with AI-generated content. The study concluded that although digital literacy is improving, the critical literacy required to evaluate AI outputs remains underdeveloped. Thus, while technology adoption is growing, its alignment with cognitive outcomes—especially critical thinking—remains weak.

In Pakistan, limited empirical research has explored how AI influences critical thinking among university students. Most existing studies focus on infrastructure, digital literacy, or general attitudes toward technology (Khan et al., 2022). There is a lack of studies examining AI's effect on the subfactors of critical thinking within a local higher education context. Furthermore, philosophical approaches—such as the Socratic Method—are rarely integrated into empirical studies on AI in Pakistan. A careful reading of international and national literature reveals a constellation of research deficiencies that motivate the present study. Methodologically, many investigations rely on qualitative case studies or perception surveys without robust quantitative instruments that map AI sub-functions onto discrete CT subdimensions; where quantitative methods exist, measures are often simplistic and nonstandardized (Holmes et al., 2019; Szmyd & Mitera, 2024). Empirically, there is a shortage of statistically powered cross-sectional analyses—especially in developing country contexts—that test whether AI use predicts measurable gains (or decrements) in CT. Conceptually, AI has been treated as a single "tool" when in reality its different affordances may have divergent effects: personalization might promote engagement while simultaneously reducing exposure to argumentative diversity, for example. Theoretically, few studies integrate learning theory with a robust philosophical account of inquiry: constructivist accounts explain how learners build knowledge, but Socratic philosophy explains why the practice of questioning is central to intellectual development (Paul & Elder, 2006; Vygotsky, 1978). 1.Most studies exploring AI and CT rely on qualitative or perception-based methods rather than robust quantitative analysis. Instruments mapping AI sub-functions to specific CT dimensions are rare (Szmyd & Mitera, 2024).

There is limited statistical evidence establishing how distinct AI features affect measurable CT skills, particularly in developing contexts (Essel et al., 2023). The majority of research originates in Western or East Asian contexts; little attention has been given to how AI influences learning in Pakistani universities, where pedagogical norms differ (Khan, Batool, & Niazi, 2022).There is no unified framework that links AI's technological mechanisms with philosophical principles of reasoning such as Socratic questioning and constructivist learning (Vygotsky, 1978; Paul & Elder, 2006).Current studies often focus on STEM or computer science students, overlooking the broader university population and disciplinary diversity (Jabbour et al., 2025).These combined deficiencies form the empirical and philosophical vacuum this study aims to address. By applying a quantitative cross-sectional design rooted in Socratic-Constructivist philosophy, this research offers both measurable evidence and conceptual integration—thereby bridging a crucial divide between technological innovation and human reasoning. The contextual realities of Pakistan's higher education system further complicate AI integration. Large class sizes, resource limitations, and traditional exam-oriented pedagogies constrain opportunities for dialogic and inquiry-based learning (Shahzad et al., 2024). Consequently, while AI adoption is expanding, its capacity to stimulate CT has not been systematically tested through empirical research. This reveals a contextual and empirical gap in understanding how AI can be pedagogically leveraged to cultivate reasoning, reflection, and independent thinking within Pakistani universities. International research has widely explored AI-based learning outcomes (Holmes, Bialik, & Fadel, 2019; Chan & Hu, 2023); however, limited empirical evidence directly links AI's specific features—such as feedback, personalization, and problem-solving algorithms—to measurable critical thinking (CT) performance. Most existing studies rely on students' self-reported perceptions rather than objective assessment outcomes (Essel, Boateng, & Mensah, 2023). In Pakistan, the absence of standardized tools to evaluate how AI use influences CT dimensions like analysis, inference, and independent thinking highlights a significant evidence gap. The present study addresses this by employing quantitative measures to examine AI–CT relationships among university students

Although reputable journals such as Springer, SAGE, Elsevier, and ERIC recognize AI's expanding instructional role (Floridi, 2019; Jabbour, Teixeira, & Freitas, 2025), limited conceptual understanding exists regarding how learners critically and philosophically engage with AI systems during knowledge construction. Within the Pakistani context, no studies have examined how AI promotes critical thinking from a Socratic perspective, resulting in insufficient understanding of AI's influence on higher-order reasoning and reflective inquiry across disciplines. Previous studies predominantly used qualitative case studies or perception-based surveys (Holmes et al., 2019; Szmyd & Mitera, 2024), offering limited statistical precision. There is a lack of quantitative, cross-sectional analyses that connect AI sub-factors (learning support, personalization, information analysis, motivation, and overreliance) with CT subskills (evaluation, inference, and reflection). The present research fills this gap by employing validated instruments for both AI and CT to quantitatively assess these relationships. Few studies have integrated AI–learning research with established philosophical theories such as the Socratic heuristic model or constructivist frameworks (Vygotsky, 1978; Piaget, 1972). Current theoretical approaches rarely link AI-based learning to Socratic questioning, ethical reasoning, or constructivist principles of active knowledge construction. This study aims to bridge that theoretical divide by situating AI's role within these philosophical foundations. Most empirical evidence on AI and CT originates from developed nations such as the United States, China, and the European Union, where digital infrastructure and pedagogical practices differ significantly from Pakistan (Khan, Batool, & Niazi, 2022). Very few studies have explored AI's effect on critical thinking within Pakistani universities, where teaching often remains lecture-driven, resource-limited, and exam-oriented. The current research contextualizes AI's role within Pakistan's higher education system to develop a deeper understanding of its influence on critical thinking. Earlier studies have largely focused on international student populations (Jabbour et al., 2025). This research expands the scope by including diverse participants from both public and private universities in Pakistan, offering a more comprehensive perspective on AI's role in developing critical thinking skills among university students.

Higher education is fundamentally concerned with developing students' capacity for independent reasoning, reflection, and ethical judgment. However, in the current technological age, learning processes are increasingly mediated by Artificial Intelligence (AI), which is reshaping both pedagogical methods and cognitive practices. While AI offers adaptive feedback, efficient assessment, and personalized learning opportunities (Holmes, Bialik, & Fadel, 2019), its uncontrolled or uncritical use may undermine the intellectual autonomy that education seeks to foster (Essel, Boateng, & Mensah, 2023).

Globally, higher education systems are investing in AI-based instructional technologies with the expectation that these tools will enhance learning outcomes and promote cognitive engagement (Chan & Hu, 2023). Yet, many of these initiatives have not been grounded in philosophical reflection or empirical evidence concerning how AI affects deeper cognitive outcomes such as critical thinking (CT). This gap between technological innovation and philosophical purpose provides the principal rationale for this study. AI must not only improve efficiency but also strengthen the intellectual virtues that define educated reasoning — curiosity, skepticism, and reflective inquiry (Paul & Elder, 2006).

The rationale is further strengthened by the educational context of Pakistan, where universities are transitioning from traditional lecture-based models to digitally mediated learning environments. While AI adoption is increasing, the pedagogical designs accompanying these technologies often prioritize administrative functionality over intellectual growth (Khan, Batool, & Niazi, 2022). This raises an urgent need for empirical research that investigates AI's potential to cultivate CT within the Pakistani context, thereby addressing contextual, empirical, and philosophical gaps simultaneously.

Philosophically, the study draws inspiration from Socratic inquiry, which views questioning as the highest form of intellectual engagement. In Socratic pedagogy, knowledge arises from critical dialogue, self-examination, and reasoned justification rather than passive acceptance of authority. This principle is strikingly relevant in an AI-driven era, where learners may substitute machine-generated outputs for reflective reasoning. Integrating Socratic questioning into AI-mediated learning aligns technology with ethical self-awareness and critical judgment — transforming AI from a tool of convenience into a catalyst for reflective thought (Chukhlomin, 2024).

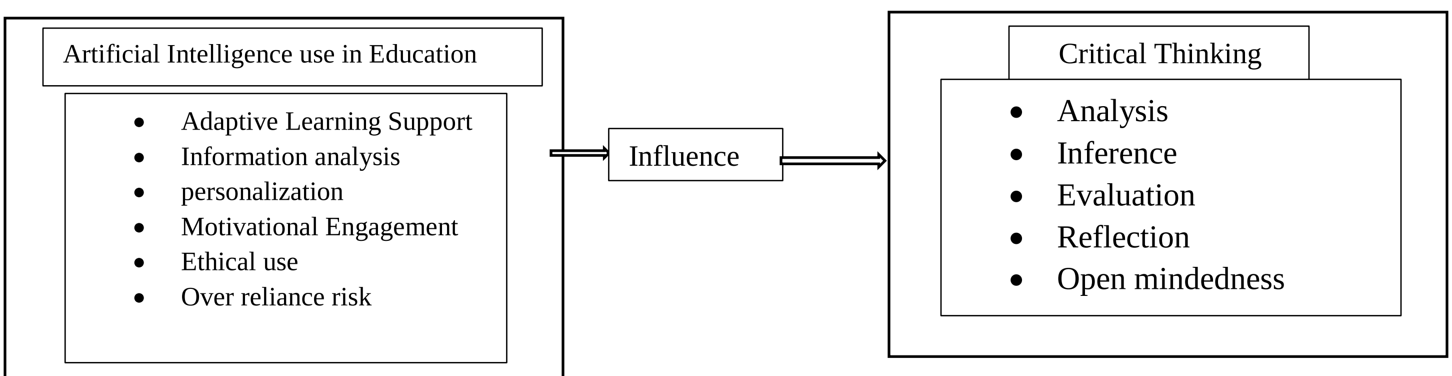
Purpose of the Study

The primary purpose of this study is to investigate the relationship between AI utilization and the development of critical-thinking skills among university students in Pakistan. Specifically, the study aims to:

1. Examine the influence of AI sub-functions — learning support, motivation, personalization, information analysis, ethical use, and overreliance — on distinct CT subdimensions such as analysis, evaluation, inference, reflection, questioning assumptions, and independent thinking.
2. Provide quantitative evidence addressing the empirical and methodological gaps identified in the literature.
3. Interpret findings through a Socratic–Constructivist framework, establishing a conceptual bridge between technological innovation and philosophical reasoning.
4. Generate practical insights for educators and policymakers on aligning AI-based learning with the cultivation of reflective and autonomous thinking.

Conceptual Framework

Figure 1



grates two complementary paradigms — Constructivist Learning Theory and Socratic Philosophy of Inquiry — to explain how AI may influence CT.

Constructivist Learning Theory (Vygotsky, 1978) asserts that learners actively construct knowledge through experience, reflection, and social interaction. Learning occurs when individuals engage in meaningful activities within their *zone of proximal development*, supported by scaffolding mechanisms such as feedback, modeling, and guided discovery. Within this framework, AI functions as a mediating tool that provides individualized scaffolds, enabling students to progress from guided learning to independent mastery (Holmes et al., 2019).

However, constructivism primarily describes *how* learners acquire knowledge, not *why* they should question or evaluate it. This is where Socratic inquiry becomes essential. The Socratic tradition, rooted in philosophical dialogue, maintains that genuine understanding emerges from persistent questioning and the recognition of ignorance as the starting point of wisdom. It values intellectual humility, reflective doubt, and reasoned argument (Paul & Elder, 2006). When applied to AI-mediated learning, this philosophy positions technology as a partner in questioning rather than as an authority providing final answers.

Integrating these two perspectives creates a powerful interpretive model: Constructivism explains the process of learning through AI (interaction, reflection, feedback), while Socratic inquiry provides the purpose (ethical reasoning and self-examination). Together, they form a Socratic–Constructivist Framework that situates AI at the intersection of cognitive scaffolding and moral-intellectual growth.

Socratic Tradition: Inquiry, Reflection, and Ethical Reasoning

The Socratic tradition, originating from the dialogues of *Plato* (trans. 1997), defines education as a moral and intellectual enterprise aimed at self-knowledge. Socrates maintained that true wisdom begins with recognizing one's ignorance — "I know that I know nothing" — a position that fosters intellectual humility and a commitment to questioning assumptions (Vlastos, 1991). Through the *elenchus*, or method of critical questioning, Socrates developed a process in which learners refine their beliefs through dialogue, logical reasoning, and ethical self-examination.

Modern scholars have extended this tradition into pedagogical theory. Paul and Elder (2006) argued that the Socratic method remains the most powerful strategy for cultivating critical thinking (CT), as it trains learners to analyze, evaluate, and reconstruct their thought processes. Similarly, Lipman (2003) emphasized that Socratic dialogue nurtures reflective judgment by compelling learners to justify their reasoning, thereby transforming mere knowledge into wisdom. In educational contexts, this tradition frames CT as a virtue — a disciplined commitment to reason, fairness, and intellectual integrity.

Constructivist Epistemology: Learning Through Active Meaning-Making

Parallel to Socratic inquiry, Constructivist learning theory provides an epistemological explanation of how knowledge is formed. Vygotsky (1978) and Piaget (1972) proposed that learners actively construct meaning through experience, social interaction, and reflection, rather than absorbing information passively. According to Vygotsky, the *Zone of Proximal Development (ZPD)* describes how learners move from dependence to independence with guided assistance — a concept central to modern scaffolding theory.

In this framework, AI can function as a digital scaffold, offering adaptive feedback and customized learning experiences that help students operate within their ZPD (Holmes, Bialik, & Fadel, 2019). Jonassen (1991) further emphasized that technology can support constructivist learning when it promotes active engagement, authentic problem-solving, and collaboration.

However, constructivism alone lacks an explicit moral dimension; it explains *how* learners learn, not *why* they should question or evaluate their beliefs.

Integration with Critical Thinking Philosophy

The philosophical justification of this study is reinforced by contemporary critical-thinking theorists who link cognition, ethics, and self-regulation. Ennis (1996) defined CT as "reasonable, reflective thinking focused on deciding what to believe or do," emphasizing its rational and dispositional dimensions. Facione (1990), in the Delphi Report, conceptualized CT as involving interpretation, analysis, evaluation, inference, and self-regulation — dimensions that align closely with both Socratic and constructivist paradigms. Brookfield (2012) expanded this view by arguing that critical thinkers must question taken-for-granted assumptions and confront power dynamics in knowledge systems.

Contemporary Philosophical Reflections on AI and Human Reasoning

Recent educational philosophers have revisited these traditions in light of AI's rise. Boden (2018) argued that AI expands human cognitive potential but lacks self-reflective consciousness — thus requiring human guidance for ethical use. Floridi (2019) conceptualized AI as an "information partner" that can enhance human reasoning if embedded within ethical frameworks of transparency and accountability. Likewise, Selwyn (2022) cautioned that uncritical technological adoption risks reducing education to mechanical efficiency rather than intellectual emancipation.

These authors collectively stress that the philosophical purpose of education — the cultivation of reflective and ethical agency — must not be surrendered to machine logic. AI, in this view, becomes an extension of Socratic dialogue: a medium for questioning, examining, and refining human thought. This study addresses these gaps through an integrated Socratic–Constructivist approach and quantitative design. Conducted in a Pakistani higher-education context, the study contributes locally relevant evidence and generalizable insights regarding the conditions under which AI fosters rather than undermines critical thought. Practically, the findings will inform curricular design, faculty development, and the responsible deployment of AI tools—advancing an agenda that aligns digital innovation with the core educational mission of cultivating thoughtful, questioning graduates.

Research Objectives

1. To examine the students' perceptions of the AI on Critical thinking among university students in Pakistan.
2. Explore the impact of Artificial Intelligence (AI) use on the development of critical-thinking skills among university students.

Research Questions

The following research questions were developed to address objectives of the study:

1. What are the students' perceptions of the AI on Critical thinking among university students in Pakistan?

2. What is the impact of Artificial Intelligence (AI) on the development of critical-thinking skills among university students in Pakistan?
3. Is there any difference in Leadership behavior on the basis of demographic variable (Age, Gender, Qualification and University)?

Research Methodology

This study is grounded in the **Positivist research paradigm**, which assumes that reality is **objective, stable, and measurable** through empirical observation. This study employs causal comparative research design under **quantitative research approach**, suitable for examining the measurable relationship between variables and for generating findings that can be generalized to a larger population. Quantitative inquiry focuses on **numerical representation of data**, hypothesis testing, and the establishment of cause-and-effect relationships (Cohen, Manion, & Morrison, 2018). The causal comparative research design, quantitative approach is used in this study because the present study seeks to compare the influence of AI-based learning tools on students from public and private universities. A **causal-comparative (ex post facto)** design is appropriate for this research because it allows the researcher to explore possible cause-and-effect relationships between the use of Artificial Intelligence (AI) tools (the presumed cause) and the development of critical thinking skills (the effect) **without manipulating any variables**. It enables the researcher to collect **data from a large sample** drawn from multiple academic disciplines. It allows the testing of **hypotheses derived from theory**—that students' engagement with AI tools significantly predicts their CT performance. It minimizes subjectivity by using standardized instruments and statistical analysis to ensure reliability and validity. A **cross-sectional survey design** is used to gather data at a single point in time from a representative sample of students at the University of Education (Township Campus) and the University of Management and Technology (UMT Lahore).

The participants of this study consist of **undergraduate and postgraduate students** enrolled at two major higher-education institutions in Lahore. The selection of one public and one private institution ensures a **balanced representation** of Pakistan's higher-education landscape, where institutional culture, technological infrastructure, and access to AI tools vary. The participants are **heterogeneous** in nature, drawn from four disciplines common to both universities—**Education, Social Sciences, Natural Sciences.**

A **sample of approximately 350 students** was be selected for this research. The sample size is calculated using **Cochran's (1977)** formula for large populations at a 95 percent confidence level and a 5 percent margin of error. This size is sufficient for conducting correlational and regression analyses with multiple predictors while maintaining adequate statistical power (Hair, Hult, Ringle, & Sarstedt, 2019). The sample of 350 participants provides proportional representation from both universities: approximately 175 students from each. Within each institution, participants will be drawn from the four specified disciplines to ensure balanced coverage. Such distribution permits both **overall analysis** of AI–CT relationships and **discipline-specific comparisons** to explore variations across academic fields.

The study was utilizing a **stratified random sampling technique.** In the first stage, the population will be divided into strata based on **institution (University of Education and UMT)** and **discipline (Education, Social Sciences, Natural Sciences, and Computer Studies).** In the second stage, a **simple random sampling** method will be applied within each stratum to select participants proportionally.

This two-stage process ensures both **representation and randomness.** Stratified random sampling is particularly suitable when the population is heterogeneous and includes identifiable subgroups that may differ in characteristics relevant to the research variables (Cohen et al., 2018).

Instrumentation

Data were collected using a structured, self-administered questionnaire developed from validated instruments on Artificial Intelligence (AI) in education and critical thinking (CT) (Ennis, 1996; Paul & Elder, 2006; Szmyd & Mitera, 2024). The instrument comprised three sections: (a) demographic information (gender, age, academic level, discipline, and institution type), (b) AI sub-factors (support for learning, motivation, information analysis and problem-solving personalization/adaptation, source evaluation and ethical use, and overreliance risk), and (c) CT sub-factors (analysis, evaluation, inference, interpretation and reflection, questioning assumptions, and independent thinking).

After obtaining institutional permission from the University of Education (Township Campus) and the University of Management and Technology (UMT Lahore), the questionnaire was distributed. An information sheet explained the purpose of the study, assured anonymity and confidentiality, and stated that participation was voluntary. Only students who indicated informed consent proceeded to the questionnaire.

Data were analyzed using a statistical software package such as SPSS, following four stages consistent with a positivist, quantitative approach. The data were first screened for missing values, outliers, and normality, with skewness and kurtosis values within ±1 considered acceptable for Likert-scale variables. Descriptive statistics were then generated, including frequencies and percentages for demographic variables, as well as means, standard deviations, skewness, and kurtosis for all AI and CT subscales. Pearson's r correlations were computed to examine bivariate relationships between AI and CT sub-factors. Finally, multiple linear regression was conducted to assess whether AI sub-factors predicted overall CT scores (or a composite CT index), controlling for relevant demographic variables. All analyses used a significance level of $\alpha = .05$, and effect sizes were interpreted according to Cohen's (1988) guidelines.

Findings, Discussion, Implications, and Recommendation

Table 1

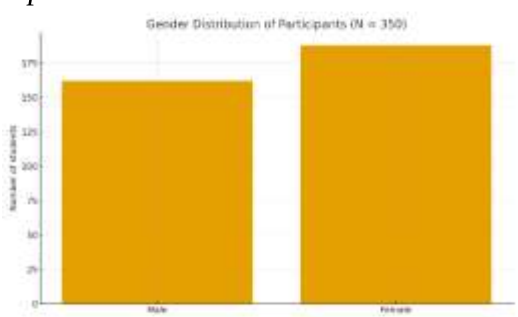
Demographic Characteristics of Participants

Variable	Category	N	%
Gender	Male	162	46.3
	Female	188	53.7
Age group (Years)	18–21	142	40.6
	22–24	78	22.3
	25–30	130	37.1
Academic level	Undergraduate	228	65.1
	Postgraduate	122	34.9
Discipline	Education	96	27.4
	Social Sciences	94	26.9
	Natural Sciences	82	23.4
	Computer Studies	78	22.3
Institution type	Public (UE Township)	180	51.4
	Private (UMT Lahore)	170	48.6

The sample included 350 university students from Lahore. As shown in Table 1, females (53.7%) were slightly more represented than males (46.3%). Most participants were between 18 and 21 years old (40.6%), followed by those aged 25–30 years (37.1%). Approximately two-thirds were undergraduates (65.1%) and one-third postgraduates (34.9%). Participants were fairly balanced across disciplines, with Education (27.4%) and Social Sciences (26.9%) slightly more represented than Natural Sciences (23.4%) and Computer Studies (22.3%). The sample was nearly evenly split between the public (51.4%) and private (48.6%) institution, reflecting the intended stratified design.

Figure 1

Gender Distribution of Participant



As shown in Figure 1, Female students were slightly more represented than male students, indicating a relatively balanced gender distribution in the study.

Table 2

Descriptive Statistics for AI and Critical Thinking Subscale

Variable	M	SD	Skew	Kurtosis
AI Sub-Factors				
Support for Learning	3.78	0.62	-0.21	-0.35
Motivation to Learn	3.65	0.68	-0.18	-0.29
Information Analysis & Problem-Solving	3.72	0.64	-0.25	-0.31
Personalization / Adaptation	3.59	0.70	-0.16	-0.40
Source Evaluation & Ethical Use	3.48	0.71	-0.10	-0.38
Overreliance Risk	3.01	0.76	0.08	-0.27
Critical Thinking Sub-Factors				
Analysis	3.84	0.60	-0.32	-0.19
Evaluation	3.77	0.63	-0.26	-0.23
Inference & Problem-Solving	3.81	0.59	-0.30	-0.15
Interpretation & Reflection	3.69	0.66	-0.22	-0.33
Questioning Assumptions	3.61	0.69	-0.18	-0.29
Independent Thinking	3.73	0.63	-0.20	-0.36

Table 2 Overall, students reported **moderately high AI engagement** and **moderately high critical-thinking levels**. Among the AI sub-factors, support for learning (M = 3.78, SD = 0.62) and information analysis and problem-solving (M = 3.72, SD = 0.64) received the highest ratings, suggesting that students perceive AI as particularly helpful for understanding complex content and solving academic problems. Overreliance risk was moderate (M = 3.01, SD = 0.76), indicating that students are somewhat aware that they sometimes depend too heavily on AI tools. For CT sub-factors, analysis (M = 3.84, SD = 0.60), inference (M = 3.81, SD = 0.59), and evaluation (M = 3.77, SD = 0.63) had the highest mean scores, suggesting that students generally view themselves as capable of breaking down information, drawing conclusions, and judging credibility. Questioning assumptions and interpretation and reflection had slightly lower means but still remained above the scale midpoint, indicating a moderate level of Socratic engagement and reflective thinking.

Skewness and kurtosis coefficients for all variables fell within approximately ±0.5, suggesting no severe departures from normality and supporting the use of parametric analyses (e.g., Pearson correlations and regression).

Table 3

Correlations Between AI Sub-Factors and Critical Thinking

AI Sub-Factor	CT Overall	Analysis	Evaluation	Inference	Questioning	Independent
Support for Learning	.46**	.44**	.41**	.43**	.38**	.35**
Motivation to Learn	.39**	.36**	.34**	.37**	.33**	.32**
Information Analysis & Problem-Solving	.52**	.49**	.46**	.51**	.40**	.37**
Personalization / Adaptation	.31**	.29**	.28**	.30**	.25**	.24**
Source Evaluation & Ethical Use	.43**	.40**	.45**	.38**	.39**	.36**
Overreliance Risk	-.27**	-.25**	-.23**	-.24**	-.29**	-.31**

Note. CT Overall = composite of all critical thinking subscales.
***p** < .01 (two-tailed).*

As shown in Table 3, **all AI sub-factors except overreliance risk were significantly and positively correlated with critical thinking**, with coefficients ranging from r = .31 to .52 (p < .01). The strongest relationship emerged between information analysis and problem-solving and overall CT (r = .52, p < .001), suggesting that students who use AI to analyze information and solve problems tend to report higher critical-thinking skills. Support for learning (r = .46, p < .001) and source evaluation and ethical use (r = .43, p < .001) were also moderately and positively related to CT. In contrast, **overreliance risk showed a significant negative correlation with critical thinking** (r = −.27, p < .001), implying that students who report heavy dependence on AI—such that they often bypass their own judgment—tend to report lower levels of analysis, inference, and independent thinking. These findings support the theoretical assumption that AI can both facilitate and potentially undermine CT, depending on how it is used.