Impact of Artificial Intelligence-Enhanced Learning on Critical Thinking Skills of Pre-Service Teachers: A Study of BEEd Students

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ABSTRACT Artificial intelligence (AI) is increasingly integrated into higher education, creating opportunities for personalized, adaptive, interactive, and collaborative learning while raising questions about its relationship with students' critical thinking. This study examined AI-enhanced learning and perceived critical thinking skills among 146 first-year Bachelor of Elementary Education students at Agusan del Sur State College of Agriculture and Technology. The study employed a descriptive-comparative and correlational design using an adapted and validated questionnaire. Data were analyzed using descriptive statistics, Mann–Whitney U, Kruskal–Wallis H, and Spearman's rho. Results showed high levels of AI-enhanced learning (M = 3.16, SD = 0.35) and perceived critical thinking skills (M = 3.11, SD = 0.40). No significant differences were found according to age or sex. A statistically significant moderate positive association was found between AI-enhanced learning and perceived critical thinking skills ($\rho = .574$, $p < .01$). The findings indicate that students reporting greater AI-enhanced learning also tended to report stronger critical thinking. The study highlights the importance of purposeful, critically guided AI integration in teacher education while recognizing that the correlational, self-reported data do not establish causality.

Keywords: *AI-enhanced learning, artificial intelligence, critical thinking, pre-service teachers, teacher education*

INTRODUCTION

Artificial intelligence (AI) has become increasingly influential in higher education as institutions adopt digital technologies to support teaching, learning, assessment, and student engagement. AI-enabled educational applications can provide automated feedback, intelligent tutoring, learning analytics, and differentiated learning experiences that respond to learners' needs and progress (Holmes et al., 2019; Luckin, 2020). In higher education, AI applications have increasingly supported instruction and student learning, although research has also emphasized the need to examine their pedagogical rather than purely technological value (Zawacki-Richter et al., 2019). More recently, the rapid development of generative AI has further expanded opportunities for students to obtain immediate explanations, generate ideas, explore alternative solutions, and interact with information in ways that may reshape conventional learning practices. Consequently, effective participation in AI-supported learning environments increasingly requires students to develop both AI literacy and the critical-thinking capacity necessary to interpret, question, and evaluate AI-generated information (Walter, 2024).

One important contribution of AI to education is its capacity to facilitate personalized, adaptive, interactive, and collaborative learning experiences. Personalized AI-supported learning can provide resources and activities suited to individual learning needs, while adaptive systems can modify feedback, content, or task difficulty based on learner performance. Interactive applications can offer repeated practice, immediate feedback, simulations, and problem-solving, while collaborative AI environments may facilitate communication, knowledge sharing, and collective inquiry. Jia and Tu (2024) emphasized that AI capabilities can influence students' learning experiences through factors associated with motivation, self-efficacy, and critical-thinking awareness. Similarly, Ng et al. (2023) highlighted the importance of AI-related competencies in supporting learner-centered instructional practices and twenty-first-century skills. These affordances suggest that AI's educational value extends beyond technological convenience when its use is intentionally connected to meaningful learning activities.

AI-supported learning may particularly contribute to the development of critical thinking. Critical thinking enables learners to analyze information, examine assumptions, evaluate evidence and arguments, consider alternative perspectives, and formulate reasoned judgments. It is regarded as an important competence for learners navigating complex information environments and addressing problems that require more than factual recall (Živković, 2016). In this study, critical thinking is examined through the domains of analysis, creating, and evaluating, which represent higher-order cognitive processes involved in examining information, generating possible solutions or ideas, and making judgments based on appropriate criteria. For

pre-service teachers, these competencies matter because future educators are expected not only to acquire knowledge but also to evaluate instructional information, make pedagogical decisions, design meaningful learning experiences, and guide learners in distinguishing credible information from unsupported or inaccurate claims.

AI-supported environments may offer opportunities to develop these higher-order cognitive processes when learners must question, analyze, compare, and evaluate generated information rather than merely receive ready-made answers. Muthmainnah et al. (2022) found that engagement with AI and human-computer interaction technologies can support critical-thinking learning activities. Song and Kong (2021) likewise noted that AI provides educational affordances that may support teaching and learning when educators integrate technologies appropriately into pedagogical processes. AI-generated explanations and feedback may expose learners to alternative perspectives, provide opportunities for iterative problem-solving, and encourage them to reconsider initial responses. For pre-service teachers, these experiences may be particularly valuable because their ability to critically engage with emerging technologies will influence how they select, evaluate, and integrate these tools into their own classroom practices.

Nevertheless, the relationship between AI use and critical thinking should not be viewed as inherently positive. Although AI can support learning, concerns remain regarding excessive dependence on automated systems, academic integrity, misinformation, reduced cognitive effort, and the possibility that students may accept AI-generated responses without adequate evaluation (Aoun, 2020; Selwyn, 2019; Williamson & Piattoeva, 2022). Abbas et al. (2024) further cautioned that extensive reliance on generative AI may produce undesirable educational consequences when students substitute automated assistance for independent reasoning and problem-solving. These concerns matter because AI systems can produce responses that appear convincing despite containing inaccurate, incomplete, or biased information. Thus, the educational contribution of AI may depend less on access or frequency of use alone than on whether learners engage with AI outputs critically, verify information, exercise independent judgment, and use the technology within pedagogically purposeful learning activities. Ethical and human-centered approaches to AI integration are therefore necessary to ensure that technology complements rather than replaces human reasoning (Holmes et al., 2021).

These considerations are particularly significant in teacher education. Pre-service teachers occupy a dual position as current learners and future educators who may eventually determine how AI technologies are introduced and used in elementary classrooms. Their preparation should therefore include not only technical familiarity with AI applications but also the ability to evaluate AI-generated information, recognize limitations and ethical concerns, and make informed pedagogical decisions. Ng et al. (2023) emphasized the relevance of teachers' AI digital competencies to twenty-first-century teaching, while UNESCO's AI competency framework for teachers underscores the importance of a human-centered approach in which educators critically and ethically evaluate AI technologies and determine their appropriate pedagogical use. Developing these competencies during pre-service preparation may consequently help future teachers become more reflective and responsible users of emerging technologies.

Despite the growing body of research on AI in education, important questions remain regarding its relationship with critical thinking among pre-service teachers. Much of the earlier literature on AI in higher education has focused on technological applications, system development, learner support, and general university populations, while comparatively less attention has gone to educators and teacher preparation (Zawacki-Richter et al., 2019). Moreover, the growing availability of generative and adaptive AI technologies has created a need to examine not merely whether students use AI, but how different dimensions of AI-enhanced learning—particularly personalized, adaptive, interactive, and collaborative learning—relate to higher-order cognitive processes. This issue warrants examination in Philippine teacher education, where pre-service teachers must simultaneously develop competence in emerging educational technologies and the critical judgment necessary to use them responsibly. Evidence from specific institutional contexts can help explain how future teachers perceive these learning experiences and provide a basis for informed curriculum and instructional decisions.

Accordingly, this study examined the relationship between AI-enhanced learning and the perceived critical thinking skills of first-year Bachelor of Elementary Education (BEEd) students at Agusan del Sur State College of Agriculture and Technology. Specifically, it sought to determine the perceived level of AI-enhanced learning in terms of personalized, adaptive, interactive, and collaborative learning; determine the perceived level of critical thinking skills in terms of analysis, creating, and evaluating; determine whether AI-enhanced learning and perceived critical thinking skills differ significantly when respondents are grouped

according to age and sex; and determine whether a significant relationship exists between AI-enhanced learning and perceived critical thinking skills. By examining these dimensions, the study seeks to provide empirical evidence that may inform the pedagogically appropriate, critical, and responsible integration of AI technologies into teacher-education programs.

METHODOLOGY

Research Design

This study employed a descriptive-comparative and correlational research design to examine AI-enhanced learning and perceived critical thinking skills among pre-service teachers. The descriptive component was used to determine the respondents' perceived levels of AI-enhanced learning in terms of personalized, adaptive, interactive, and collaborative learning and their perceived critical thinking skills in terms of analysis, creating, and evaluating. The comparative component examined whether these variables differed significantly when respondents were grouped according to age and sex. The correlational component determined the direction and strength of the association between AI-enhanced learning and perceived critical thinking skills.

Sampling Method and Respondents

The participants were 146 first-year Bachelor of Elementary Education (BEEd) students enrolled at Agusan del Sur State College of Agriculture and Technology (ASSCAT). The researchers used universal sampling to include all students in the identified population who met the study criteria. To be included, participants had to be currently enrolled in the BEEd program, have prior exposure to AI-driven learning tools in their academic activities, and voluntarily agree to participate in the study.
Universal sampling covered the eligible first-year BEEd population within the study setting. However, because participants were drawn from a single year level and institution, the findings apply primarily to the population investigated and should be generalized cautiously to other pre-service teacher populations and higher education institutions.

Research Instrument

Data were collected using an adapted and contextualized questionnaire based on the AI-enhanced learning instrument of Jia and Tu (2024). The questionnaire consisted of two major components. The first measured students' perceptions of AI-enhanced learning across four dimensions: personalized learning, adaptive learning, interactive learning, and collaborative learning. The second assessed students' perceptions of their critical thinking skills in the domains of analysis, creating, and evaluating.

The items were rated on a four-point Likert scale, and responses were interpreted according to the corresponding scale intervals. Because the critical thinking component relied on students' self-reports, the scores were treated as measures of perceived critical thinking skills rather than direct performance-based measures of critical thinking.

The adapted questionnaire underwent content validation by subject-matter experts in education and educational technology to assess the relevance and appropriateness of the items to the constructs and study context. Reliability testing was also conducted to determine the internal consistency of the instrument before its administration. The final manuscript should report the number of items under each dimension, the specific validation procedure and results, and the reliability coefficient(s), such as Cronbach's alpha, based on the researchers' actual validation and reliability records.

Data Collection Procedure

Prior to data collection, permission was obtained from the appropriate institutional authorities. Eligible participants were informed of the purpose of the study, the procedures involved, and their rights as research participants. The questionnaire was administered during regular class hours to facilitate orderly data collection and minimize disruption to academic activities.

Completed questionnaires were retrieved after administration and checked for completeness and consistency. The researchers then organized, coded, and prepared responses for statistical analysis.

Appropriate measures were observed throughout data collection and processing to maintain the accuracy, confidentiality, and integrity of the information obtained.

Ethical Considerations

The study strictly adhered to established ethical standards for educational research in accordance with institutional and national guidelines. Prior to participation, respondents were provided with a clear explanation of the study's purpose, procedures, and their rights, after which informed consent was duly obtained. Participation was entirely voluntary, and respondents were informed of their right to withdraw at any time without penalty or disadvantage. To protect data privacy, confidentiality and anonymity were maintained through coded identifiers, ensuring no personally identifiable information was disclosed. All collected data were securely stored in protected files accessible only to the researchers and were utilized exclusively for academic and research purposes. These measures ensured compliance with ethical principles of respect for persons, beneficence, and data integrity, thereby safeguarding the rights and welfare of all participants.

Data Analysis

Descriptive and inferential statistical procedures were used to analyze the data. Frequency counts and percentages were used to describe the respondents' demographic characteristics. Means and standard deviations were computed to summarize the respondents' perceived levels of AI-enhanced learning and critical thinking skills.

For comparative analysis, the Mann–Whitney U test was used to determine whether significant differences existed by sex, while the Kruskal–Wallis H test was used to examine differences across age groups. These non-parametric procedures were used given the characteristics and measurement level of the data.

The Spearman rank-order correlation coefficient (Spearman's rho) was used to determine the direction and strength of the association between AI-enhanced learning and perceived critical thinking skills. Statistical significance was evaluated at the .05 level. A p-value below .05 was interpreted as evidence of a statistically significant relationship or difference, as applicable.

RESULTS AND DISCUSSION

Demographic Profile of Respondents

The demographic profile of the respondents is presented in terms of age and sex. Out of 146 first-year BEEd students, the majority (104 or 71.2%) were aged 18–19, followed by those aged 20–21 (39 or 26.7%), while only a small proportion belonged to the 22–23 age group (3 or 2.1%). In terms of sex, the sample was predominantly female, comprising 117 respondents (80.1%), whereas males accounted for 29 respondents (19.9%).

This distribution indicates that the respondents largely fall within the typical age range of first-year college students, suggesting a relatively homogeneous cohort in terms of developmental stage and academic exposure. The predominance of female students reflects the common gender trend in teacher education programs in the Philippines, where female enrollment is significantly higher than male participation. Such demographic characteristics may influence learning preferences, engagement with digital tools, and collaborative tendencies in academic settings.

The implications of this profile suggest that AI-driven learning interventions can be designed to cater to a digitally inclined and relatively young population, who are generally more adaptable to emerging educational technologies. Moreover, the gender distribution highlights the need for inclusive and gender-responsive instructional strategies, ensuring that both male and female students benefit equitably from AI integration. For teacher education institutions, these findings provide a basis for tailoring curriculum design, instructional delivery, and capacity-building initiatives that are responsive to the demographic realities of BEEd students in Philippine state colleges and universities.

As reported by Muralidharan et al. (2023), designing age-appropriate AI learning tools requires collaboration among educators, clinicians (where relevant), families, and researchers to address developmental

appropriateness, safety, and engagement across age groups. Furthermore, gender-responsive and culturally sustaining approaches should be embedded within AI education platforms to promote equity, inclusion, and positive outcomes for all learners, regardless of sex or gender identity (Holmes et al., 2023; Knox, 2023; UNESCO, 2023).

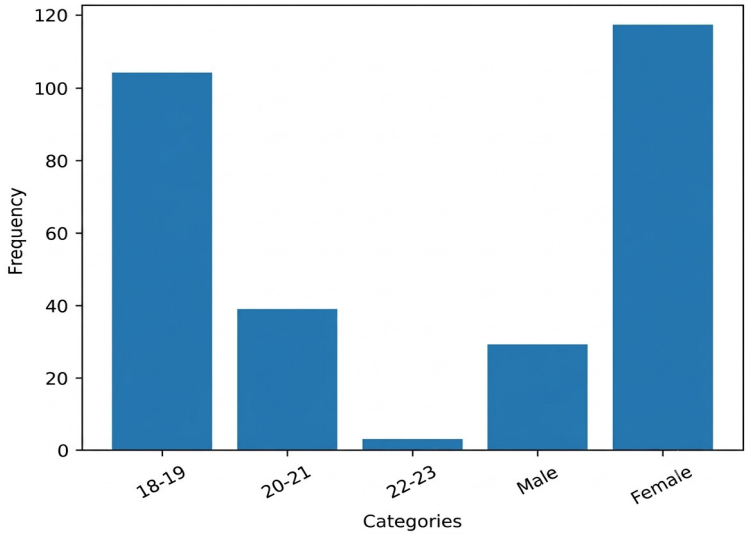

Figure 1. Profile of the Respondents According to their Age and Sex

Level of Impact of AI-driven Learning Tools Utilization

The level of students' perception of artificial intelligence (AI)-driven learning tools utilization is presented in terms of four dimensions: personalized learning, adaptive learning, interactive practice, and collaborative learning. Overall, the results indicate a high level of perception (M = 3.16, SD = 0.35), suggesting that BEEd students generally recognize the value of AI-powered tools in enhancing their learning experience. Among the four dimensions, adaptive learning obtained the highest mean (M = 3.20), followed by personalized learning (M = 3.16), while both interactive practice and collaborative learning registered equal means (M = 3.14). This distribution reflects consistently positive perceptions across all domains of AI-driven learning.

Personalized learning yielded high to very high ratings, with students strongly agreeing that AI tools help them choose learning activities aligned with their interests and find relevant content that supports their learning goals. Similarly, adaptive learning results indicate that students perceive AI as responsive to their individual learning needs, particularly in providing feedback and adjusting content difficulty. Interactive practice also received high ratings, highlighting the role of AI in promoting engagement through simulations, activities, and practice exercises. Meanwhile, collaborative learning recorded some of the highest individual item means (up to M = 3.31), indicating that AI tools significantly facilitate peer interaction, knowledge sharing, and collaborative problem-solving.

These findings suggest that AI-driven learning tools are effective in supporting student-centered and flexible learning environments, which are essential in modern teacher education. The high perception across all dimensions indicates that AI can enhance not only individual learning pathways but also social and interactive aspects of learning. For Philippine state universities and colleges (SUCs), these results support the integration of AI technologies into the BEEd curriculum as part of digital transformation initiatives aligned with CHED and DOST priorities. Furthermore, the strong performance of adaptive and collaborative learning dimensions highlights the potential of AI to develop both independent and cooperative learning skills, which are critical competencies for future educators.

Ng et al., (2023) explored teachers' AI digital competencies and twenty-first century skills, emphasizing that AI competencies enable teachers to design and implement adaptive, learner-centered instruction and to foster collaboration among students. This supports the link between AI-enabled adaptability and both individual and social learning outcomes. Likewise, Trevisan et al., (2024) discussed drivers of digital realties for ongoing teacher professional learning, including big data, AI, and learning analytics, highlighting AI-driven professional learning environments and dashboards as catalysts for collaborative practice and

reflective reasoning. This underpins how AI tools can mediate collaborative professional growth and collective instructional practices, aligning with future educator competencies.

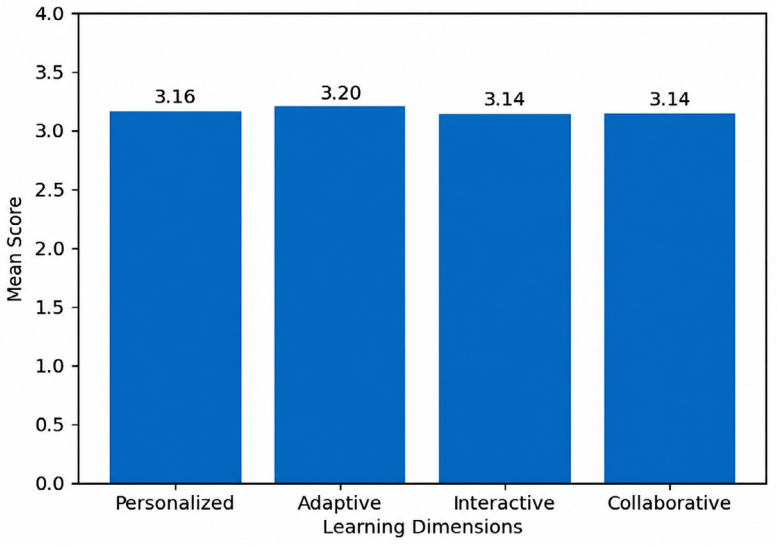

Figure 2. Level of Artificial Intelligence-Driven Learning Tools Utilization by Dimension

Level of Students Perception on Critical Thinking Skills

The level of students' perception of their critical thinking skills is presented across three domains: analysis, creating, and evaluating. Overall, the results indicate a high level of critical thinking (M = 3.11, SD = 0.40) among BEEd students. Among the domains, creating obtained the highest mean (M = 3.14), followed by analysis (M = 3.11), while evaluating recorded the lowest, though still high, mean (M = 3.09). This distribution reflects a consistently strong self-assessment of higher-order thinking skills across all cognitive domains.

The analysis domain shows that students are capable of identifying assumptions, evaluating sources, and examining problems from multiple perspectives, with all indicators rated at a high level. The creating domain yielded the highest ratings, indicating that students are particularly confident in generating innovative ideas, adapting concepts to new contexts, and developing creative solutions. Meanwhile, the evaluating domain, although slightly lower in mean, still demonstrates that students possess the ability to assess arguments, determine the reliability of information, and distinguish between fact and opinion. The consistently high ratings across all items suggest that students perceive themselves as competent in executing complex cognitive tasks aligned with higher-order thinking skills.

These findings suggest that BEEd students are developing the critical thinking competencies necessary for effective teaching practice in the 21st-century learning environment. The relatively higher scores in the creating domain indicate a strong potential for innovation and adaptability, which are essential in designing learner-centered and context-responsive instruction. However, the slightly lower mean in the evaluating domain highlights the need to further strengthen students' skills in judgment, evidence-based reasoning, and critical evaluation. For Philippine state universities and colleges (SUCs), these results underscore the importance of integrating instructional strategies—such as problem-based learning, inquiry-based approaches, and AI-supported learning tools—that continuously enhance all dimensions of critical thinking, ensuring that future educators are well-equipped for dynamic and technology-driven classrooms.

Based on the research works of Muthmainnah et al., (2022), KESGİN, (2025), Lin et al., (2022), and Yan et al.,(2025), the generative AI, adaptive feedback, and AI-assisted collaboration tools have demonstrated potential to enhance critical thinking when embedded in pedagogy aligned with inquiry and problem-based tasks. AI-enabled environments can scaffold reasoning, support evidence-based argumentation, and facilitate collaborative inquiry by providing real-time feedback and structuring tasks that promote argumentation and analysis.

Table 1: Level of Students' Perception on Critical Thinking Skills

Domain	Indicator	Mean	SD	Interpretation
ANALYSIS	Identify assumptions in arguments	3.09	0.42	High
	Evaluate credibility of sources	3.12	0.42	High
	Critique reasoning of others	3.11	0.42	High
	Analyze problems from multiple perspectives	3.08	0.42	High
	Identify cause-and-effect relationships	3.14	0.42	High
	Sub-Mean	3.11	0.42	High
CREATING	Generate innovative solutions	3.11	0.39	High
	Develop creative approaches	3.18	0.39	High
	Brainstorm new ideas	3.14	0.39	High
	Communicate creative ideas	3.12	0.39	High
	Adapt ideas to new contexts	3.15	0.39	High

Test on Significant Difference in the Perceived Level of Students AI-driven Learning Tools Utilization and Critical Thinking Skills

The test of significant difference in the perceived level of AI-driven learning tools utilization and critical thinking skills is presented based on age and sex. The results consistently show that all computed p-values are greater than the 0.05 level of significance, indicating that there are no statistically significant differences across both demographic variables. For AI-driven learning tools utilization, all dimensions—including personalized, adaptive, interactive, and collaborative learning—yielded non-significant results for both age (p-values ranging from 0.58 to 0.78) and sex (p-values ranging from 0.08 to 0.45), including the overall mean. Similarly, for critical thinking skills, all domains—analysis, creating, and evaluating—also showed non-significant differences across age and sex, with p-values ranging from 0.30 to 0.73.

These findings suggest that students' perceptions of AI-driven learning tools and their critical thinking skills are statistically comparable regardless of demographic characteristics. This implies that both younger and older students, as well as male and female respondents, exhibit similar levels of engagement with AI technologies and comparable abilities in higher-order thinking skills. The absence of significant variation indicates that demographic factors such as age and sex do not substantially influence how students perceive or benefit from AI-driven learning environments.

The implications of these findings are particularly important for curriculum design and policy development in Philippine higher education institutions, especially within state universities and colleges (SUCs). The results support the implementation of uniform and inclusive AI integration strategies, as the benefits of AI-driven learning appear to be equally accessible across diverse student groups. This reinforces the idea that AI can serve as an equitable educational tool that supports inclusive learning environments. Furthermore, institutions may focus more on enhancing pedagogical approaches and technological infrastructure rather than differentiating interventions based on demographic variables, ensuring that all students develop critical thinking skills necessary for effective teaching and lifelong learning.

As supported by Allison et al., (2025), Adegoke et al., (2025), Yang & Jimenez-Luque, (2025), and McMahon & Firestone, (2024), the institutions can maximize AI impact by prioritizing pedagogical design (e.g., inquiry-driven, problem-based learning) and robust technological infrastructure, rather than differentiating interventions by demographic groups, to achieve broad-based development of critical thinking skills among all students.

Table 2. Test on Significant Difference in the Perceived Level of Students AI-driven Learning Tools Utilization and Critical Thinking Skills.

AI-Driven Learning Tools Utilization	p-value	Interpretation
Age		
Personalized Learning	0.58	Not Significant
Adaptive Learning	0.64	Not Significant
Interactive Learning	0.73	Not Significant
Collaborative Learning	0.78	Not Significant
Sex		
Personalized Learning	0.45	Not Significant
Adaptive Learning	0.08	Not Significant
Interactive Learning	0.14	Not Significant
Collaborative Learning	0.11	Not Significant
Critical Thinking		
Age		Not Significant
Analysis	0.38	Not Significant
Creating	0.30	Not Significant
Evaluating	0.57	Not Significant
Sex		
Analysis	0.73	Not Significant
Creating	0.60	Not Significant
Evaluating	0.37	Not Significant

Test on Significant Relationship Between AI-driven Learning Tools and Critical Thinking Skills

The relationship between AI-driven learning tools utilization and critical thinking skills was examined using Spearman's rho correlation. The results revealed a moderate positive correlation ($r = 0.574$), which is statistically significant at the 0.01 level ($p < 0.01$). This indicates that as students' utilization of AI-driven learning tools increases, their level of critical thinking skills also tends to improve.

The positive direction of the correlation suggests that AI-driven learning tools—such as adaptive, interactive, collaborative, and personalized systems—play a meaningful role in enhancing higher-order cognitive skills. The moderate strength of the relationship implies that while AI is an important contributing factor, critical thinking is also influenced by other variables such as teaching strategies, learner motivation, and academic environment.

The implications of this finding are significant for teacher education and policy development in Philippine higher education institutions. It supports the integration of AI technologies as pedagogical enablers that can foster analytical, creative, and evaluative thinking among pre-service teachers. However, the moderate correlation also highlights the need for balanced instructional design, where AI tools are complemented by inquiry-based learning, reflective practice, and guided instruction. For SUCs, this underscores the importance of investing in both technological infrastructure and faculty capability-building programs, ensuring that AI is used strategically to enhance—not replace—students' cognitive development.

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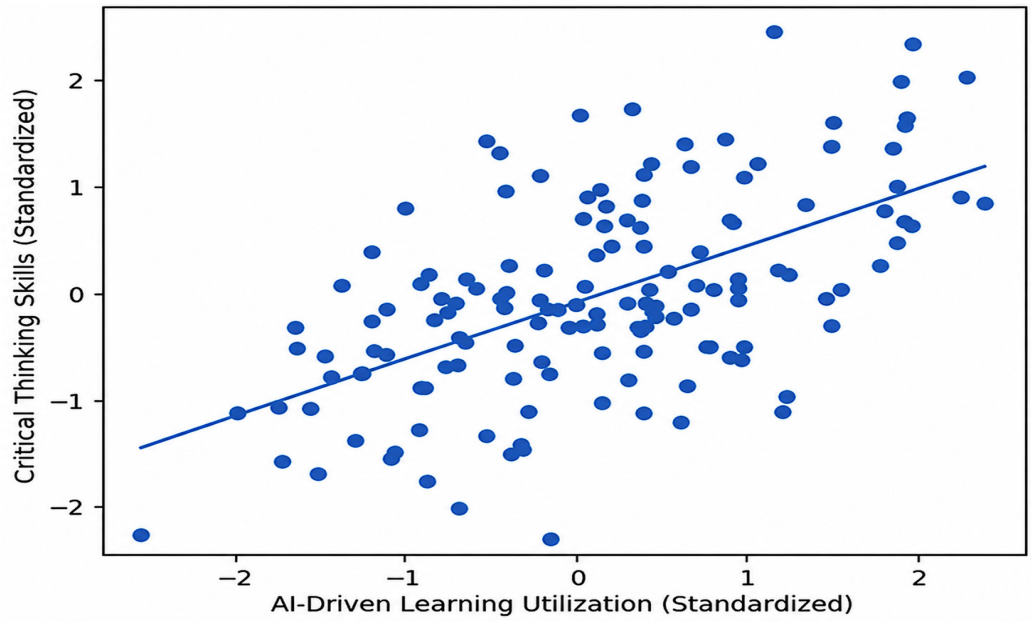

Figure 3. Scatter plot with regression line on Relationship Between AI-driven Learning Tools and Critical Thinking Skills'

CONCLUSIONS

The integration of artificial intelligence in teacher education should extend beyond providing access to emerging technologies and emphasize their purposeful, responsible, and pedagogically appropriate use. AI can support learning when it encourages pre-service teachers to analyze information, generate ideas, evaluate evidence, and exercise independent judgment rather than rely on automated responses. Teacher education institutions should therefore prepare future educators to use AI critically and ethically while maintaining human judgment at the center of teaching and learning. Developing AI competence alongside critical thinking can help pre-service teachers make informed decisions about when, why, and how to use AI in educational contexts. Such preparation is essential for ensuring that AI complements rather than replaces reasoning, creativity, reflection, and professional judgment. Future research may extend the inquiry through performance-based measures of critical thinking and longitudinal, experimental, or multi-institutional designs. These approaches can provide a broader understanding of how AI-supported learning can be appropriately incorporated into future teacher preparation.

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