HERR The Higher Education Research Review Vol 8, No. 1 (2024)
ISSN (Print): 2508-013X | ISSN (Online): 2815-2271

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

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ABSTRACT This study examined the relationship between artificial intelligence (AI)-driven learning tools utilization and the critical thinking skills of pre-service teachers in a Philippine state college. Specifically, it investigated the level of students' perception of AI-enhanced learning across four dimensions—adaptive, personalized, interactive, and collaborative learning—and their corresponding levels of critical thinking skills in terms of analysis, creating, and evaluating. A descriptive-comparative and correlational research design was employed, involving 146 first-year Bachelor of Elementary Education (BEED) students at Agusan del Sur State College of Agriculture and Technology. Data were collected using an adapted and validated questionnaire and analyzed using descriptive statistics and non-parametric tests, including Spearman's rho, Mann–Whitney U, and Kruskal–Wallis. Findings revealed a high level of AI-driven learning tools utilization (M = 3.16) and a high level of critical thinking skills (M = 3.11). No significant differences were observed across age and sex, indicating that AI-supported learning is inclusive and equally beneficial among diverse student groups. A statistically significant moderate positive correlation ($r = 0.574$, $p < 0.01$) was found between AI utilization and critical thinking skills, suggesting that increased engagement with AI technologies contributes to the enhancement of higher-order cognitive abilities. Regression analysis further indicated that AI utilization explains approximately 32.9% of the variance in critical thinking skills. The study concludes that AI-driven learning tools serve as effective pedagogical enablers that support student-centered and flexible learning environments in teacher education. It is recommended that higher education institutions integrate AI technologies into the curriculum, provide faculty training, and establish ethical and pedagogical guidelines to maximize their impact. Future research may explore longitudinal and experimental designs to further validate the causal effects of AI on cognitive development.

INTRODUCTION

Artificial Intelligence (AI) has emerged as a transformative force in education, enabling personalized, adaptive, and data-driven learning experiences. AI-driven tools such as intelligent tutoring systems, automated feedback mechanisms, and collaborative platforms enhance student engagement and support differentiated instruction (Holmes et al., 2019; Luckin, 2020). These innovations align with current Philippine higher education priorities, particularly the digital transformation agenda promoted by CHED and DOST.

Scholarly discourse highlights both the opportunities and risks of AI integration in education. Studies suggest that AI enhances learning outcomes by facilitating interactive and collaborative environments (Zawacki-Richter et al., 2019) and promoting higher-order thinking skills when used appropriately (Song & Kong, 2021). However, concerns have been raised regarding academic integrity, over-reliance on AI, and potential decline in independent thinking (Selwyn, 2019; Aoun, 2020; Williamson & Piattoeva, 2022). These dual perspectives underscore the need for empirical validation of AI's role in fostering critical thinking.

Despite global advancements, there remains a scarcity of localized research examining AI's pedagogical impact in Philippine teacher education. Most existing studies are situated in international contexts (OECD, 2021), with limited focus on pre-service teachers in state colleges and universities (SUCs). Specifically, there is insufficient evidence on how AI learning dimensions—adaptive, collaborative, interactive, and personalized—relate to critical thinking domains such as analysis, creation, and evaluation.

This study aims to address this gap by investigating the relationship between AI-driven learning tools and the critical thinking skills of BEED students at ASSCAT. The findings are expected to inform curriculum development, institutional policy, and faculty training programs aligned with national education and research priorities.

METHODOLOGY

Research Design

This study employed a descriptive-comparative and correlational research design to systematically examine both the relationships between variables and the differences across selected demographic groups. The descriptive component enabled a comprehensive characterization of respondents' perceptions of AI-driven learning tools and their levels of critical thinking skills, while the comparative aspect facilitated the identification of variations based on demographic factors such as age and sex.

Furthermore, the correlational design was utilized to determine the direction and strength of the association between AI utilization and critical thinking skills. This integrated approach is methodologically appropriate as it allows for both robust quantitative description and rigorous inferential analysis, thereby providing a holistic understanding of how AI-driven learning influences higher-order thinking skills among pre-service teachers within the context of Philippine higher education.

Sampling Method and Respondents

A universal sampling technique was employed, encompassing all 146 first-year Bachelor of Elementary Education (BEED) students enrolled at Agusan del Sur State College of Agriculture and Technology (ASSCAT). This approach was deemed appropriate given the manageable population size and the study's intent to achieve comprehensive coverage of the target group. The inclusion criteria were as follows: (1) currently enrolled in the BEED program, (2) with prior exposure to AI-driven learning tools as part of their academic experience, and (3) willing to participate voluntarily in the study. By including the entire population that met these criteria, the study ensured maximum representativeness, reduced the likelihood of sampling bias, and enhanced the internal validity and reliability of the findings. This methodological choice strengthens the generalizability of results within the institutional context of ASSCAT and similar state colleges and universities (SUCs) in the Philippines.

Research Instrument

The study utilized an adapted and contextualized survey instrument based on the work of Jia and Tu (2024), designed to capture both the extent of AI-driven learning utilization and the level of critical thinking skills among respondents. The instrument comprised two major sections: (1) AI-Driven Learning Tools, which included indicators on adaptive, collaborative, interactive, and personalized learning; and (2) Critical Thinking Skills, covering the domains of analysis, creating, and evaluating, consistent with higher-order cognitive processes. All items were measured using a 4-point Likert scale ranging from low to high levels of agreement to ensure clarity of responses and eliminate neutral bias. Prior to data collection, the instrument underwent content validation by subject matter experts in education and educational technology to ensure alignment with the study objectives and constructs. Additionally, reliability testing was conducted to establish internal consistency, thereby ensuring that the instrument produced stable and dependable measurements suitable for inferential analysis within the context of Philippine teacher education.

Data Collection Procedure

Prior to data collection, formal approval was obtained from the appropriate institutional authorities to ensure compliance with academic and ethical standards. The data collection process was conducted systematically to maintain rigor and reliability. Initially, respondents were given a brief orientation outlining the purpose of the study, procedures, and their rights as participants. This was followed by the administration of the questionnaires during regular class hours, ensuring maximum participation and minimal disruption to academic activities. Completed questionnaires were retrieved immediately after administration to ensure a high response rate and minimize the risk of data loss or incomplete responses. Subsequently, the collected data were subjected to preliminary screening and validation, including checks for completeness, consistency, and accuracy of responses. This structured procedure enhanced the overall quality and integrity of the dataset, thereby supporting robust and credible analysis.

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 from the study at any point without any form of penalty or disadvantage. To uphold data privacy and protection, confidentiality and anonymity were rigorously maintained through the use of coded identifiers, ensuring that 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

Data were analyzed using both descriptive and inferential statistical techniques to ensure a comprehensive examination of the study variables. Descriptive statistics, including frequency counts, percentages, weighted means, and standard deviations, were employed to summarize the respondents' demographic profile, as well as their levels of AI-driven learning utilization and critical thinking skills. These measures provided an overall characterization of the data and facilitated clear interpretation of trends and distributions.

For inferential analysis, non-parametric statistical tests were utilized due to the ordinal nature of the data. Specifically, Spearman's rho was applied to determine the strength and direction of the relationship between AI-driven learning tools and critical thinking skills. The Mann–Whitney U Test was used to examine significant differences between groups based on sex, while the Kruskal–Wallis Test was employed to assess variations across age groups. These statistical procedures ensured robust and appropriate analysis, enabling the study to draw valid conclusions regarding relationships and group differences within the dataset.

RESULTS AND DISCUSSION

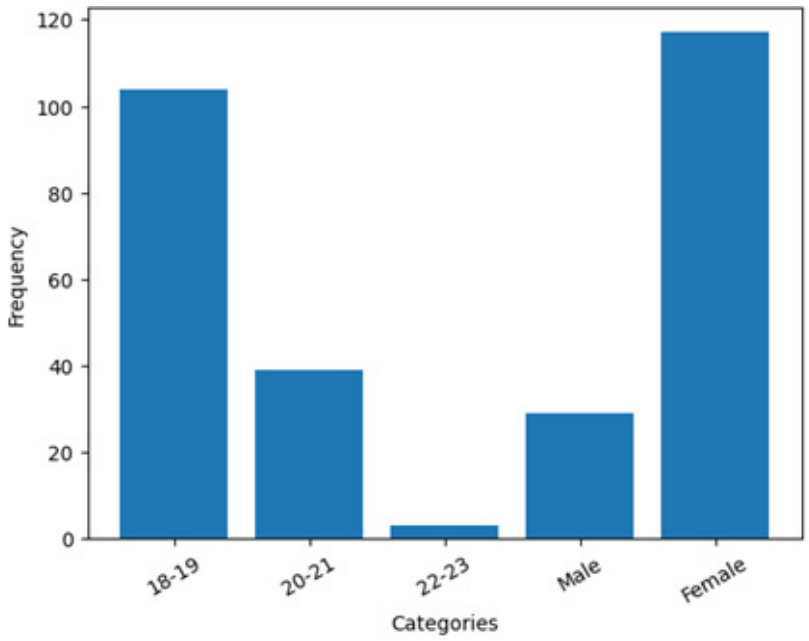
Demographic Profile of Respondents

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 (Liu et al., 2025; Zhang, 2024; Wąsacz et al., 2025).



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.

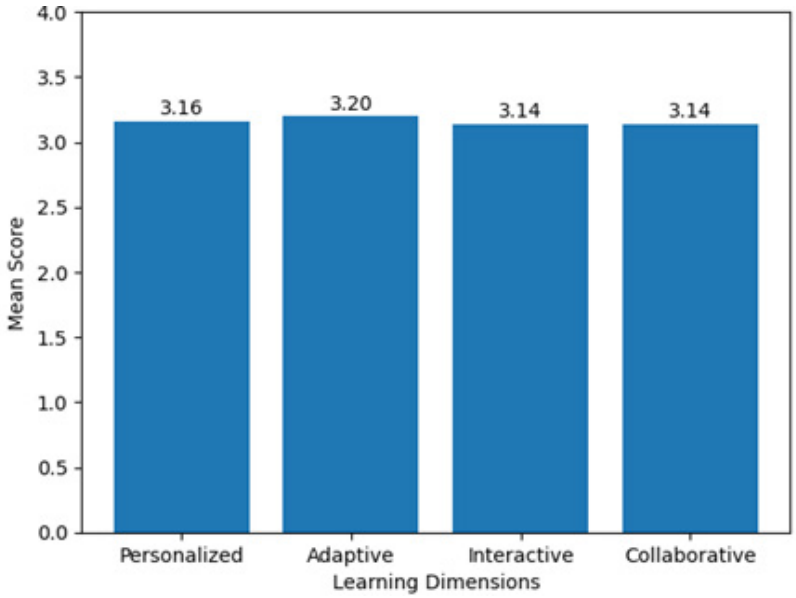


Figure 2. Level of Artificial Intelligence-Driven Learning Tools Utilization by Dimension

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.

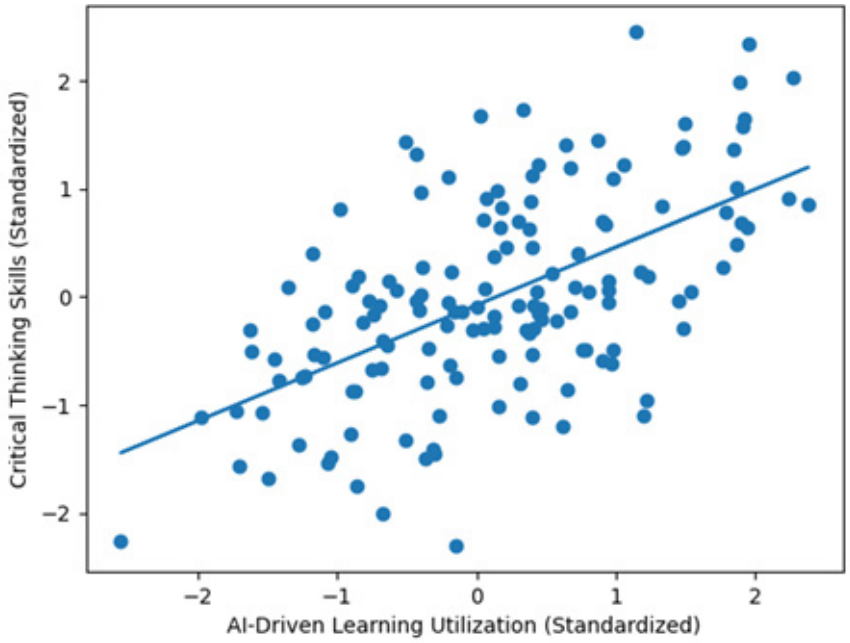


Figure 3. Scatter plot with regression line on Relationship Between AI-driven Learning Tools and Critical Thinking Skills'

CONCLUSIONS

This study established that AI-driven learning tools are significantly associated with the development of critical thinking skills among first-year BEED students. The findings revealed that students exhibit a high level of engagement with AI-enhanced learning environments across adaptive, personalized, interactive, and collaborative dimensions, alongside a high level of critical thinking competencies in terms of analysis, creating, and evaluating. Notably, the results demonstrated a statistically significant moderate positive relationship between AI utilization and critical thinking skills, indicating that increased exposure to AI-supported learning contributes to the enhancement of higher-order cognitive abilities. Furthermore, the absence of significant differences across age and sex suggests that AI-driven learning is an inclusive and equitable instructional approach applicable to diverse student groups.

Overall, the study affirms that artificial intelligence serves as a valuable pedagogical tool that supports student-centered, flexible, and interactive learning environments in teacher education. However, while AI contributes meaningfully to cognitive development, it should be strategically integrated with sound pedagogical practices to maximize its benefits. These findings provide empirical support for the integration of AI technologies in Philippine teacher education programs and underscore the need for balanced, ethical, and well-guided implementation to effectively prepare future educators for technology-driven learning environments.

RECOMMENDATIONS

Based on the findings of the study, it is recommended that teacher education institutions, particularly state universities and colleges (SUCs), strategically integrate AI-driven learning tools into the Bachelor of Elementary Education (BEED) curriculum to enhance students' critical thinking skills. This integration should be aligned with CHED's Outcomes-Based Education (OBE) framework and supported by institutional policies that promote the ethical, responsible, and pedagogically sound use of artificial intelligence in instruction.

Faculty members should be provided with capacity-building programs and continuous professional development on AI-enhanced pedagogy, focusing on the effective use of adaptive, collaborative, interactive, and personalized learning technologies. Training initiatives may be supported through partnerships with agencies such as the Department of Science and Technology (DOST), particularly under digital innovation and education technology programs, to ensure that instructors are equipped with the necessary competencies to facilitate AI-supported learning environments.

Educational administrators are encouraged to invest in technological infrastructure, digital learning platforms, and AI-enabled systems that support flexible and student-centered learning. Institutions should also establish monitoring and evaluation mechanisms to assess the effectiveness of AI integration in improving learning outcomes, particularly in the development of higher-order thinking skills. These mechanisms may include periodic assessment, learning analytics, and evidence-based policy adjustments.

Moreover, curriculum developers should incorporate inquiry-based, problem-based, and reflective learning strategies alongside AI tools to ensure a balanced approach to teaching and learning. This will help prevent over-reliance on AI and promote the development of independent reasoning, creativity, and evaluative judgment among students.

Finally, future researchers are encouraged to conduct longitudinal and experimental studies to further examine the causal effects of AI on critical thinking skills, as well as explore additional variables such as motivation, digital literacy, and instructional design. Expanding the study across different institutions and academic programs will also enhance the generalizability of findings and contribute to the growing body of knowledge on AI in Philippine higher education.

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