International Journal of Didactical Studies
Onlinefirst Article, 2026
https://doi.org/10.33902/ijods.202635874

Research Article

Effects of artificial intelligence on pre-service teachers' mathematics learning outcomes in colleges of education

Vivian Maanu[1], Francis Ohene Boateng[2] and Ernest Larbi[3]

[1]*Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana (ORCID: 0009-0003-1164-5541)*
[2]*Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana (ORCID: 0000-0003-0197-7385)*
[3]*Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana (ORCID: 0000-0003-3652-5223)*

Despite the growing body of research on pre-service teachers' perceptions and attitudes towards artificial intelligence, little is known about how artificial intelligence-assisted instruction affects pre-service teachers' engagement, problem-solving skills, and mathematics education outcomes at Ghanaian colleges of education. Pre-service teachers need to be attuned to integrate artificial intelligence in their teaching and learning when given the nod. This correlational quantitative study selected 296 Level 300 Mathematics Education students. Data was collected using a structured questionnaire. A structural Equation Modeling was performed to response the hypothesized paths. The study revealed that artificial intelligence usage had a significant positive effect on students' engagement. Moreover, artificial intelligence usage had a significant positive effect on students' performance and problem-solving. The findings of this study underscore the transformative potential of artificial intelligence in educational settings.

Keywords: Artificial intelligence; Engagement; Performance; Pre-service teachers; Problem-solving; Learning outcome

Article History: Submitted 5 May 2025; Revised 11 July 2025; Published online 6 March 2026

1. Introduction

Digital machines performing tasks akin to intelligent beings, termed as Artificial Intelligence [AI], have evolved over the years, particularly in the technological era of this 21st century. This surge in AI has garnered global interest for its potential to revolutionize various societal aspects, including education. Nations are actively advancing their AI industries and exploring their implementation in education to enhance learning experiences (Davis et al., 2024).

Merino-Campos (2025) posited that AI transcends mere replication of human intellect and instead facilitates individualized learning, adapting to each student's unique needs across diverse dimensions—countering the common misconception that AI simply mimics human thought processes. The integration of Artificial Intelligence in education has transformed the learning landscape, offering unprecedented opportunities for personalized instruction, automated assessment, and data-driven decision-making (Ayeni et al., 2024). The report by the National Education Association (2024) concurred that AI-assisted instruction has the potential to revolutionize the education sector by providing personalized learning experiences for students.

Recent examinations of AI technologies—including chatbots, robots, and intelligent tutoring systems—indicate that their role extends beyond adaptive learning experiences; these tools also support teachers in

Address of Corresponding Author

Vivian Maanu, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED), AK644-6263, Kumasi, Ghana.

✉ vivijagri@gmail.com

How to cite: Maanu, V., Boateng, F. O., & Larbi, E. (2026). Effects of artificial intelligence on pre-service teachers' mathematics learning outcomes in colleges of education. *International Journal of Didactical Studies*. Advance online publication. https://doi.org/10.33902/ijods.202635874

understanding student learning processes and offer timely assistance to students anytime, anywhere (Labadze et al., 2023). Altememy et al. (2023) added that AI impact spans various educational domains due to continuous advancements in AI technologies, including learning, teaching, assessment, performance, engagement, and administration. The advent of AI-powered school libraries leverages vast data to tailor resources, meeting individual student needs effectively (Hodonu-Wusu, 2025). AI-assisted instruction has the potential to enhance collaborative learning outcomes by providing personalized support, automating assessment, and facilitating communication (Wang et al., 2025). AI-powered adaptive learning systems can adjust the difficulty level of course materials, provide real-time feedback, and offer personalized recommendations for further learning (Rizvi, 2023).

Mathematics is a subject that poses unique challenges for both students and educators. Many students experience mathematics anxiety, which can hinder their ability to learn and perform well in the subject. Additionally, students often have varying levels of proficiency in mathematics, making it difficult for educators to provide the individualized attention that each student needs (Prediger, 2024). AI has the potential to address these challenges by offering personalized learning experiences and reducing the administrative burden on educators. One of the primary ways AI can support mathematics education is through adaptive learning technologies. These technologies analyze students' performance in real-time and adjust the content to match their individual needs. For example, if a student is struggling with algebraic equations, the AI system can offer additional practice problems, explanations, and resources to help the student grasp the concept (Qurohman, 2024).

Despite the growing body of research on pre-service teachers' perceptions and attitudes toward Artificial Intelligence (Pokrivcakova, 2023), there is a significant knowledge gap regarding the impact of AI-assisted instruction on pre-service teachers' learning outcomes in mathematics education at Colleges of Education in Ghana. Recent studies have also examined AI literacy among pre-service teacher (Net, 2025). However, there is an inadequacy of research on the impact of AI-assisted instruction on pre-service teachers' learning outcomes in mathematics education, even though the integration of AI in teacher education programs is crucial to prepare preservice teachers for the digital age. The inadequacy of research on the effectiveness of AI-assisted instruction in promoting preservice teachers' learning outcomes in mathematics education deserves to be explored. Nyante et al. (2024), reports that there is a need to improve the quality of teacher education programs in Ghana to meet the demands of the 21st-century education system. As a result, this study aims to investigate how AI usage influences pre-service teachers' learning outcomes in mathematics, particularly engagement, performance, and problem-solving in the Colleges of Education in Ghana. This underscores the pressure on practicing teachers to compete effectively in higher education, leveraging technological advancements to maximize their potential. Since AI's role in education is multifaceted pre-service teachers need to be attuned to integrate into their teaching and learning practices when offered the nod.

2. Literature Review

2.1. AI Usage and Student Engagement

Laranjeira and Teixeira (2025) observed that student engagement is the key to academic success and well-being, involving active participation and investment in learning. Engaged students are motivated, achieve academic success, and remain in school. Classroom interactions fostering collaboration, critical thinking, and practical knowledge application enhance engagement. Educators utilizing creative teaching methods, technology, and student-centered approaches facilitate active learning and sustained engagement (Bhardwaj et al., 2025).

According to Asad et al. (2020), technological integration has the potential to enhance learning processes for both students and educators by increasing engagement and interaction, enhancing soft skills, and promoting collaboration while also reducing costs and risks for universities. Ayeni et al. (2024) found that computer systems are able to provide personalized guidance, support, or feedback to students with the use of artificial intelligence technologies. These technologies include the ability to replicate human intellect to draw inferences, judgments, or predictions.

Multiple studies on the use of AI-enabled robots in enhancing student engagement in physical education, computer science, and mathematics in K-12, and higher educational institutions have been done in different contexts (Van Mechelen et al., 2023). It was observed that students with lower academic achievements reported that engaging with AI Robots enhanced their feeling of safety and productivity, while also reducing their feeling of shame. Moreover, learners of language were also observed to have their engagement increased by autonomous scoring systems based on image and speech recognition technologies (Jiang et al.,

2022). AI-aided assessment incorporated active learning strategies since it was considered more reliable, and students enjoyed the active feedback with no delays.

Through virtual reality education—which incorporates VR technology to create immersive learning environments that improve engagement and academic outcomes—it has been shown that AI can deliver tailored learning experiences while providing students with real-time assistance and feedback (Pitura et al., 2024). Similarly to virtual education, educational AI-based games leverage game-based integration to foster higher levels of engagement and improve learning outcomes (Engin, 2023; McLaren & Nguyen, 2022). Bond et al. (2024) proposed that future research should focus on developing AI as an advanced learning context—exploring process-designs within the learning sciences paradigm—and refining AI algorithms to enable tailored learning interventions, moving beyond tool-centric perspectives toward integrated educational environments. Hence, this study hypothesised that Artificial intelligence usage has a significant positive effect on students' engagement. Based on these discussions, we hypothesized that:

H_1: Artificial intelligence usage has a significant positive effect on students' engagement.

2.2. AI Usage and Student Performance

Throughout a semester, students' learning outcome or academic performance helps decision-makers, academic staff, and educational administrators to accurately assess students, instructors, and the institution in a variety of courses (Akintayo et al., 2024). Academically gifted students typically have high self-esteem and confidence, low anxiety and despair, sociable tendencies, and are less prone to substance abuse, such as alcohol. Academic performance is said to be influenced by several individual and family factors in addition to the quality of the institution, including socioeconomic status, English language ability, attendance, job, high school grades, and academic self-efficacy. Additionally, there is a relationship between academic accomplishment and variables including parental involvement, family size, study hours, and competencies of a teacher (Ma et al., 2022).

Recent studies have reported encouraging results in increasing students' academic success and retention, as well as aiding teachers in instructional design and teaching strategy improvement. Institutions in some countries are being incentivized, and organizations are funded to implement AI-driven individualized learning systems designed to foster higher student performance through enhanced cognitive engagement and to address educational disparities by providing tailored support to disadvantaged populations (Iyer et al., 2024; Subramanian et al., 2025). The attention triggered by artificial intelligence is broad and encompasses the entire domain of education: learning, teaching, assessment, and even institutional management (Chaudhry & Kazim, 2022). The research, which focused on the role of artificial intelligence in enhancing learning outcomes, reported that AI not only enhances the performance of the mainstream but also the performance of special needs students (Hopcan et al., 2023). For instance, an Artificial Intelligence-based braille instructor was made for teaching the visually impaired students, and it was observed that when teachers used the AI tutor, the pupils responded significantly quicker and more accurately.

Most of the researchers claim that AI can boost the students' achievements, but only when the participation of teachers participate in the teaching and learning activities (Wu & Yang, 2022). Moreover, apart from improving the quality of students' learning in the classroom, there is a possibility that the use of Artificial Intelligence technologies would reduce the level of students' indifference to a great extent. They have been able to establish the learning state of the students, assist program officers or teachers in academic intervention, and eventually reduce students' dropping out. Based on these discussions, we hypothesized that:

H_2: Artificial intelligence usage has a significant positive effect on students' performance.

2.3. AI Usage and Student Problem-solving

Lin and Chen (2024) opined that students should be aware of AI's potential to bolster their creativity and learning processes. Emerging research indicates how AI can enhance skills commonly associated with creativity, such as curiosity, perseverance, and attentiveness (Oktradiksa et al., 2021). Poquet et al. (2024) assert that AI in education aims to foster problem-solving and creativity skills through collaborative interactions with AI systems rather than solely focusing on knowledge acquisition within specific domains.

Additionally, Lin and Chen (2024) examine Korean educators' perceptions of AI in education, noting that experienced teachers acknowledge AI's potential to enhance creativity. Hence, AI in education could address concerns related to the decline of creativity, particularly by emphasizing the creative process and problem-solving skills. This may aid in enhancing students' creative thinking abilities and comfort level with utilizing AI, thereby adequately preparing them for the contemporary workforce.

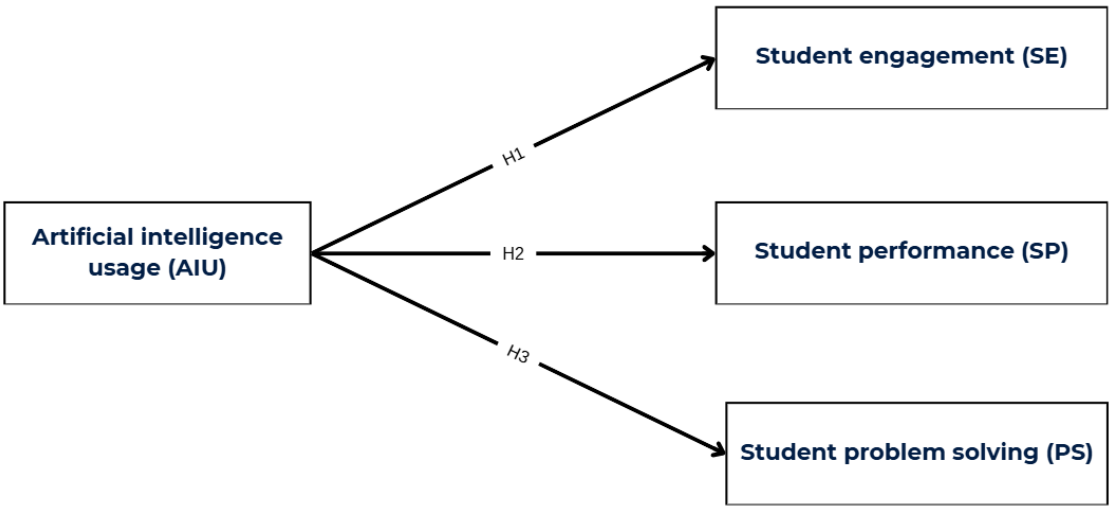
Artificial Intelligence is a powerful tool for improving critical thinking skills in education. The use of AI in educational contexts like paper writing, lesson preparation, among others, through generative AI apps, for example, ChatGPT, Gemini, Gamma, and other AI, is used in exploring existing content and even generating new material (Dimitriadou & Lanitis, 2024). These technologies enable students to delve deeper into subjects by offering insights and generating ideas that can challenge their thinking and foster creativity, leading to improved learning outcomes. Kim et al. (2022) wrote that AI helps teachers by providing structures, ideas, and resources. They observed that when teachers integrate AI tools into their instruction, it significantly enhances critical thinking—not only through providing diverse instructional approaches but also by empowering students to explore, discuss, and sharpen their own analytical skills (Walter, 2024).

However, the use of AI in education comes with its challenges. AI can pose threats to students or teachers, one of which is that it can prevent critical thinking skills for students or teachers. Muthmainnah et al. (2022) stated a refutation that AI cannot help students in critical thinking. It is caused by the automatic and easy process of searching for information, students are less encouraged to do further analysis and evaluate the search results. Due to this phenomenon, the learning environment becomes passive for students to use their critical thinking skills. The argument is also supported by Chiu et al. (2024), who explains that if students do not comply with reading the basic context of a material of a lesson before using AI, then it does not encourage students to criticize the output of the AI results they get. Therefore, there is a need to interrogate it further. Hence, this study hypothesised that Artificial intelligence usage has a significant positive effect on students' problem-solving. Based on these discussions, we hypothesized that:

H_3: Artificial intelligence usage has a significant positive effect on students' problem-solving.

In addressing these hypotheses, the conceptual framework, as shown in Figure 1, was developed.

Figure 1
Conceptual Framework



As can be seen from the Figure 1, Artificial intelligence usage shows a direct effect on students' engagement, students' performance, and students' problem-solving. Finally, Artificial intelligence usage represents the independent variable while students' engagement, students' performance, and students' problem-solving represent the dependent variables.

3. Method

3.1. Design

This study, grounded in a correlational research design, aimed to examine the extent to which artificial intelligence usage impacts various aspects of students' academic experiences. Specifically, it focused on exploring how the integration of AI tools and technologies influences student engagement, academic achievement, and their ability to solve problems effectively. The research was carefully structured to identify patterns and relationships between the frequency or nature of AI usage and the cognitive and affective outcomes observed among participants.

3.2. Participants

The investigation targeted pre-service teachers enrolled at Akrokerri College of Education, situated in the Ashanti Region of Ghana. The population of this study consisted of 303 Level 300 students from the Bachelor of Education (BEd) Mathematics Education program. As future educators, these students provided a relevant and insightful population for understanding the potential educational benefits of AI in teacher training institutions. By focusing on this specific group, the study not only explored the current level of AI integration in teacher education but also highlighted how such technologies might enhance learning engagement, improve performance outcomes, and foster essential skills like critical thinking and problem-solving among those preparing to enter the teaching profession.

3.3. Data Collection

The questionnaire survey was used as the instrument for data collection, utilizing the 5-point Likert Scale for dependent variable [DV] and independent variable [IV] sections. Questionnaire items for Artificial Intelligence Usage were adopted from Yurt and Kasarci (2024). As for the dependent variables' sections, the items were adopted from Hart et al. (2011) for the Student Engagement variable. Items for Problem-solving were adopted from Yeung et al. (2023), and items for Student's Learning Outcome (students' performance) variable were adopted from Asim et al. (2022). There were 10 items under each variable.

The demographic characteristics of the respondents showed that there were 194 (65.5%) males and 102 (34.5%) females. The average age of respondents was 23 years. In terms of AI usage for study purposes, 44.3% (n = 131) of the respondents agreed to using AI always for study purposes. Out of the remaining respondents, 34.1% (n = 101) used AI occasionally and 21.6% (n = 64) respondents rarely used AI for study purposes.

3.4. Data Analysis

A total of 300 questionnaires were distributed to respondents. After a week of the collection period, 98.7% of the return rate was achieved, and a total of 296 questionnaires were analyzed using IBM SPSS (v. 27) software and IBM Amos (v. 2) software. The analyses carried out for this research are both descriptive and inferential. First and foremost, SPSS (v. 27) was used to exercise exploratory factor analysis [EFA] and reliability analysis. After performing the exploratory factor analysis, the measurement item(s) whose loading exceeded their minimum threshold of 0.5 and loaded at their rightful constructs were used to perform the confirmatory factor analysis. The confirmatory factor analysis was run in IBM Amos (v. 23) software. After the confirmatory factor analysis, discriminant validity was assessed using an add-in tool from IBM SPSS (v. 27) software. Structural equation modelling [SEM] was run in IBM Amos (v. 23) software to respond to the research hypothesis.

3.5. Validity and Reliability

3.5.1. Assessing exploratory factor analysis

Exploratory Factor Analysis was used as a statistical technique to identify the underlying structures in the dataset by analyzing the relationships among the variables. The analysis was conducted using SPSS (v.27). The purpose of this analysis was to assess the interconnected components and determine how each observable variable corresponded to its relevant latent variable. As cited by Jr and Shuck (2015), Exploratory factor analysis can be described as a method to analyze interrelated factors. Asare and Larbi (2025), and Asare and Boateng (2025) suggests that EFA is used to explore the nature of factors underlying a set of variables before further analysis. Table 1 presents the Exploratory Factor Analysis and KMO and Bartlett's test results.

A KMO measure of sampling adequacy and Bartlett's test of sphericity were conducted to evaluate assumptions for the associated factors in the underlying structure. The KMO measure of 0.866 which is significantly above the required 0.5, indicates a strong relationship among items (Table 1). Hair et al. (2014) consider this a satisfactory value, confirming the strong inter-item relationships. Bartlett's Test of Sphericity was used to determine the significance of the correlations among variables, which is a necessary condition for performing exploratory factor analysis. Bartlett's test of sphericity was significant, with an approximate Chi-square value of 9465.663 and 136 degrees of freedom, with a p-value of <.001, indicating sufficient correlation for factor analysis. The determinant's coefficient was calculated as $1.60E-12$. Items presenting issues were iteratively removed, with fit indices analyzed each time.

Table 1
Exploratory Factor Analysis

Rotated Component Matrix				
Measurement Items	Component			
	1	2	3	4
AIU5		.948		
AIU6		.869		
AIU7		.935		
AIU8		.904		
SE1			.944	
SE2			.937	
SE4			.845	
SE5			.932	
PS2				.920
PS3				.925
PS4				.929
SP1	.935			
SP2	.934			
SP4	.914			
SP8	.919			
SP9	.931			
SP10	.930			

KMO and Bartlett's Test		
TVE		91.143
Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		.866
Bartlett's Test of Sphericity	Approx. Chi-Square	9465.663
	df	136
	Sig.	<.001
Determinant		1.60E-12

Note. AIU: AI Usage; SE: Student Engagement; PS: Problem-solving; SP: Student Performance.

3.5.2. Assessing confirmatory factor analysis [CFA]

CFA was conducted employing the 2023 version of AMOS to confirm the measurements identified during the EFA. Data were collected from 296 samples, and four factors of the measurement model were tested. Several adjustments were made to improve the model, including the removal of items with low factor loadings. After these adjustments, the overall model showed a p-value of $< .001$, a normed Chi-square of 227.373 with 104 degrees of freedom, a CFI of 0.987, and an RMSEA of 0.058. The CFI value is .987, exceeding 0.90, indicates that the model is valid and fits well with the data. Additionally, the RMSEA value of 0.058, being below 0.08, indicates an acceptable fit. This confirms that the underlying factors of the four constructs are valid and sufficient. Table 2 and Figure 2 represent the Confirmatory Factor Analysis and Model Fit Indices results, respectively.

3.5.3. Evaluating discriminant validity

This study examined the Discriminant Validity by comparing the square root of Average Extracted variance [AVEs] to the correlation coefficients. Convergent validity measures the degree to which measurement items in the same construct are related to each other, while discriminant validity measures the extent to which measurement items are uncorrelated with measurement items in different constructs. The discriminant validity scores were produced using the CFA output using the plugin tool provided in Amos (v. 23). Discriminant validity is achieved when the smallest √AVE is greater than the largest correlation coefficient (Amoako et al., 2022). Table 3 presents the discriminant validity results.

Table 2
Confirmatory Factor Analysis (CFA)

Model Fit Indices: CMIN = 227.373; DF = 104; CMIN/DF = 2.186; TLI = .983; CFI = .987; GFI = .933; RMR = .031; RMSEA = .058; PClose = .102	*Std. Estimate*
AIU: CR = .964; CA = .961; AVE = .869;	
AIU5	.984
AIU6	.857
AIU7	.976
AIU8	.906
SE: CR = .953; CA = .952; AVE = .837;	
SE1	.964
SE2	.927
SE4	.797
SE5	.960
SP: CR = .981; CA = .983; AVE = .837;	
SP1	.953
SP2	.942
SP4	.946
SP8	.926
SP9	.954
SP10	.962
PS: CR = .976; CA = .976; AVE = .932;	
PS2	.925
PS3	.981
PS4	.989

Figure 2
Confirmatory Factor Analysis (CFA)

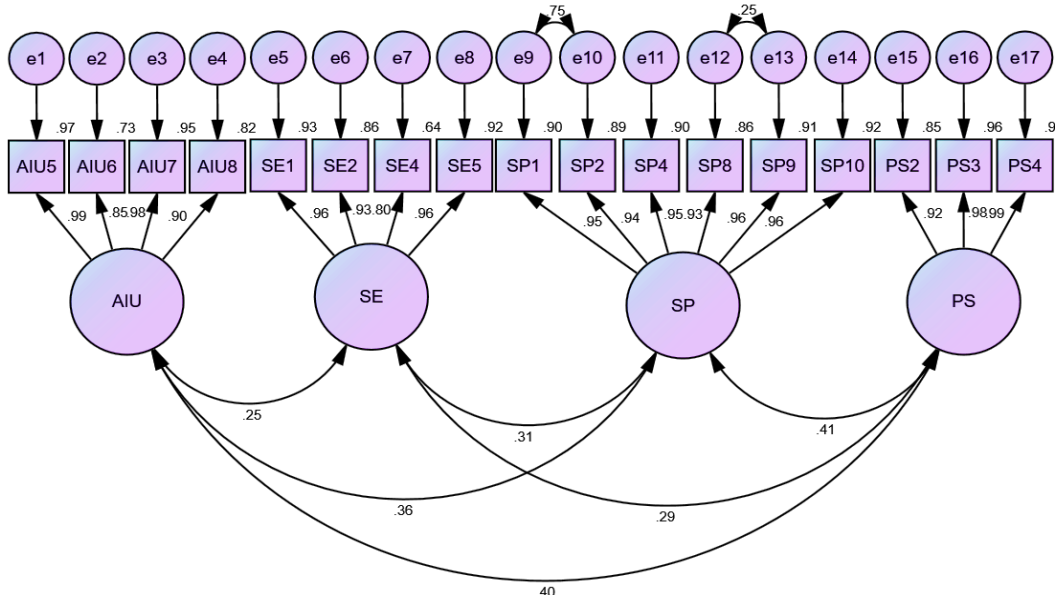


Table 3
Discriminant Validity

Variables	*CR*	*AVE*	*AIU*	*SP*	*SE*	*PS*
AIU	.964	.869	***.932***			
SP	.981	.897	.357	***.947***		
SE	.953	.837	.243	308	***.915***	
PS	.976	.932	.405	.403	.289	***.965***

As shown in Table 3, the smallest √AVE value was .915, while.405 showed the highest correlation coefficient. Therefore, this discriminant validity was achieved on the dataset. The researcher evaluated the convergent validity of the observed variables by calculating the Average Variance Extracted. Convergent validity evaluates how well a measure of a new scale correlates with other measures of the same construct (Trochim & Donnelly, 2006). According to Roemer et al. (2021), Convergent validity is obtained when the Average Variance Extracted from the observed variables is greater than or equal to 0.5 and the Composite reliability [CR] is greater than or equal to 0.7. The Average Variance Extracted and composite reliability for all constructs met the corresponding thresholds, indicating that convergent validity was attained in this study.

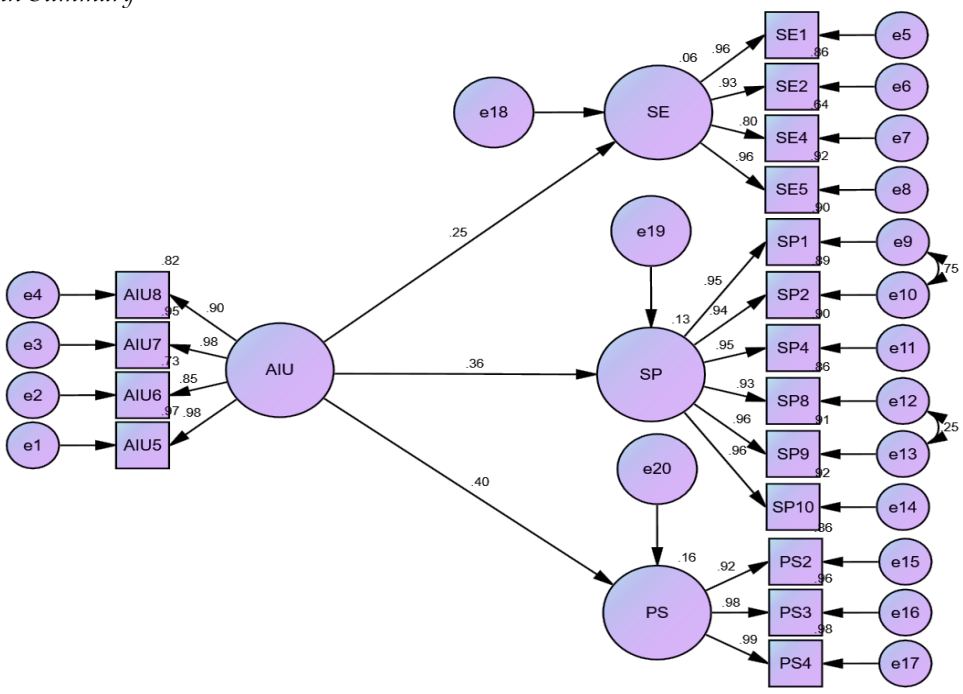
4. Findings

To respond to the research questions, structural equation modelling was run in Amos (v. 23) software. This will enable the researchers to determine the effect of the independent variables on the dependent variable. Table 4 and Figure 3 present the results for the path analysis that corresponds to the research hypothesis under study.

Table 4
Path Summary

Path Summary	*Std. Estimate*	*S.E.*	*C.R.*	*P-value*
AIU→SE	.248	.045	4.703	.001
AIU→SP	.360	.045	7.044	.001
AIU→PS	.402	.040	7.991	.001

Figure 3
Path Summary



4.1. Hypothesis 1: Artificial intelligence usage has a significant positive effect on students' engagement

The first research hypothesis seeks to determine whether Artificial intelligence usage has a significant positive effect on students' engagement. As depicted in Table 4, the analysis results showed that Artificial Intelligence usage had a positive, direct, significant effect on students' engagement at a *p*-value less than 1% ($\beta = 0.248$; $CR = 5.511$). Artificial intelligence had 24.8% positive effect on students' engagement.

4.2. Hypothesis 2: Artificial intelligence usage has a significant positive effect on students' performance

The two-research hypothesis seeks to determine whether Artificial intelligence usage has a significant positive effect on students' performance. As depicted in Table 4, the analysis reveals a direct, positive, and statistically significant impact of artificial intelligence usage on student performance, with a *p*-value of less

than 1% ($\beta = 0.360$; $CR = 8.000$). This indicates that 36% the variance in student performance can be accounted for by the quality of the artificial intelligence usage. Based on the findings presented in Table 4, Hypothesis 2, which posits that "Artificial intelligence usage has a significant positive effect on students' performance," is therefore confirmed in this study.

4.3. Hypothesis 3: Artificial intelligence usage has a significant positive effect on students' problem-solving

The third research hypothesis seeks to determine whether artificial intelligence usage has a significant positive effect on students' problem-solving. As depicted in Table 4, the analysis reveals a direct, positive, and statistically significant impact of artificial intelligence usage on student problem solving, with a *p*-value of less than 1% ($\beta = 0.402$; $CR = 10.050$). This indicates that artificial intelligence had 40.2% positive impact on students' problem-solving. Based on the findings presented in Table 4, Hypothesis 3, which posits that "Artificial intelligence usage has a significant positive effect on students' problem-solving," is therefore confirmed in this study.

5. Discussion

The analysis of results showed that Artificial Intelligence usage had a positive, direct, significant effect on students' engagement, a direct, positive, and statistically significant impact on student performance, and a direct, positive, as well as a statistically significant impact on student problem-solving. Similarly, Ma' amor et al. (2024) found that AI usage for study purposes significantly influences students' engagement and academic performance. Thus, AI for education has become a trend among students, which is used to facilitate students' engagement in learning sessions and exploration of knowledge, as well as enabling students to search for information that supports better comprehension and thus improves their academic performance compared to conventional methods. Also, Nguyen et al. (2024) found that AI-driven technologies enhance student engagement by offering personalized learning experiences, timely feedback, and interactive environments, which collectively promote deeper involvement in postsecondary education. Similarly, Helmiatin et al. (2024) reported that the use of Artificial Intelligence for academic purposes significantly and directly improves student engagement, positively influencing how actively students participate in their learning. Opesemowo and Ndlovu (2024) indicate that AI integration in high school mathematics education provides personalized instruction, adaptive assessment, interactive learning environments, and real-time feedback — components that could positively influence learning experiences. Rehman and Kang (2024) demonstrated that ChatGPT, an AI tool, had a substantial and beneficial effect on student engagement in online learning environments, particularly by increasing motivation and participation. However, Wang and Wang (2024) did not directly establish a significant effect of AI usage on student engagement. Instead, their study emphasized the mediating role of AI in the relationship between academic engagement and student mental health.

The study also found that Artificial intelligence usage had a significant positive effect on students' performance. The finding is consistent with other empirical studies. For instance, Tin et al. (2024) found that the use of Artificial Intelligence for academic purposes significantly enhances students' engagement and academic performance, indicating a positive influence on their overall learning outcomes. Similarly, Alomari and Jabr (2020) reported that three AI-related variables had a significant impact on students' academic performance, the beneficial role of AI in shaping students' learning experiences, motivation, and attitudes toward education. In line with these findings, Katenova and Turmaganbetova (2024) revealed that AI positively influenced the learning process of students. Furthermore, the study by Pacheco-Mendoza et al. (2023) demonstrated that AI-based tools and applications had a statistically significant and direct effect on students' academic performance, confirming the constructive role of AI in academic achievement.

Finally, the study found that Artificial intelligence usage had a significant positive effect on students' problem-solving. The finding is consistent with other empirical studies. For instance, Putra et al. (2023) demonstrated that incorporating a problem-based learning approach into elementary machine learning education significantly boosted students' problem-solving competencies, notably in decision-making, planning, and creative thinking, emphasizing the importance and relevance of AI education. Similarly, Zhou et al. (2024) reported that the user-friendliness of generative AI tools plays a crucial role in enhancing learners' self-regulation, which in turn supports their problem-solving capabilities. However, they found that students' perceptions of the usefulness and educational value of generative AI did not notably influence problem-solving through self-regulation. Educational AI technologies, such as intelligent tutoring systems and learning analytics, have been shown to enhance students' problem- solving performance, leading to

increased engagement and motivation in higher education environments (Ajani, 2024; Opesemowo & Ndlovu, 2024). In addition, a foundational AI course employing process- oriented assessment significantly enhanced high school students' collaborative problem-solving skills—particularly in joint analysis, solution execution, and reflective evaluation—when compared to conventional textbook-based instruction (Kim et al., 2022). Lastly, Asare et al. (2024) found that integrating AI into high school classrooms enhanced instructional quality and personalized learning experiences, positively affecting problem-solving skills when implemented effectively.

6. Educational Implications and Recommendations

This study adds to the literature on how AI usage for study purposes influences students' engagement, problem-solving, and overall improvement in students' learning outcomes, particularly among pre-service teachers. It is evident from this study that effective use of AI improves mathematical engagement, problem-solving, and academic performance among learners. Cognizant of this, it is imperative for the College of Education Mathematics Curriculum developers to streamline the curriculum to facilitate the use of AI in classroom sessions so that the potential of AI in learning settings can be explored and used ethically by students. Proper strategies and modules can be developed to embed AI elements in delivery and assessment methods as well. Although the usage of AI does significantly improve engagement, problem solving, and academic performance, it is well harnessed if integrated alongside other learner-centred pedagogies facilitated by classroom teachers. A collaborative classroom environment ensures the maximization of the impact of AI in teaching and learning.

7. Conclusion

The study shares the findings of other relevant and related literature on AI usage. AI has evolved, and its impact on the education sector cannot be denied, as there is evidence of its increasing adaptation by students to enhance their learning experiences. AI usage in education, particularly mathematics, has the potential to significantly improve learning effectiveness, engagement, and problem-solving abilities, and thus lead to improved learning outcomes. The findings of this study are evident in that regard and conclude that the use of AI for learning purposes significantly influences learners' engagement, problem-solving, and learning outcomes. Colleges of Education mandated to train pre-service teachers must ensure their learners are prepared on how to use AI ethically for academic purposes, for they to be able to integrate AI in their teaching pedagogies when given the chance to be in service. This can be done through the development of AI-sensitive curriculum, comprehensive strategies, and modules that seamlessly embed AI within the teaching and learning context.

Author contributions: The investigators have adequately given time to the study and agreed with the results and conclusions.

Funding: The was no funding given towards this study.

Declaration of interest: The authors declared that there were no potential conflicts of interest.

Data sharing statement: Data supporting the findings and conclusions are available upon request from the corresponding author.

Ethical statement: The researchers stated that the study was endorsed by the Department of Mathematics Education Research Ethics Committee of Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development (AAMUSTED).

References

Ajani, O. A. (2024). Enhancing problem-solving skills among pre-service teachers in higher education: A systematic literature review. *Journal of Pedagogical Sociology and Psychology, 6*(2), 98–113. https://doi.org/10.33902/jpsp.202424002

Akintayo, O. T., Eden, C. A., Ayeni, O. O., & Onyebuchi, N. C. (2024). Evaluating the impact of educational technology on learning outcomes in the higher education sector: A systematic review. *Open Access Research Journal of Multidisciplinary Studies, 7*(2), 052–072. https://doi.org/10.53022/oarjms.2024.7.2.0026

Alomari, M. A., & Jabr, M. O. (2020). The effect of the use of an educational software based on the strategy of artificial intelligence on students' achievement and their attitudes towards it. *Management Science Letters*,

10(13), 2951–2960. https://doi.org/10.5267/j.msl.2020.5.030

Altememy, H. A., Mohammed, B. A., Hsony, M. K., Hassan, A. Y., Mazhair, R., Dawood, I. I., Al Jouani, I. S. H., Zearah, S. A., & Sharif, H. R. (2023). The influence of the artificial intelligence capabilities of higher education institutions in Iraq on students' academic performance: The role of AI-based technology application as a mediator. *Eurasian Journal of Educational Research*, *104,* 267–282. https://doi.org/10.14689/ejer.2023.104.015

Amoako, T., Sheng, Z. H., Dogbe, C. S. K., & Pomegbe, W. W. K. (2022). Assessing the Moderation Role of ICT in the Relationship between Supply Chain Integration and SME Performance. *Journal of Industrial Integration and Management*, *7*(2), 203–233. https://doi.org/10.1142/S2424862221500160

Asad, M. M., Hussain, N., Wadho, M., Khand, Z. H., & Churi, P. P. (2020). Integration of e-learning technologies for interactive teaching and learning process: an empirical study on higher education institutes of Pakistan. *Journal of Applied Research in Higher Education*, *13*(3), 649–663. https://doi.org/10.1108/JARHE-04-2020-0103

Asare, B., & Boateng, F. O. (2025). Self-awareness and self-regulatory learning as mediators between ChatGPT usage and pre-service mathematics teachers' self-efficacy. *Journal of Pedagogical Research, 9*(2), 38–54. https://doi.org/10.33902/JPR.202530637

Asare, B., & Larbi, E. (2025). Nexus between emotional intelligence and mathematics performance: The role of metacognitive awareness. *Cogent Education*, *12*(1), 2450117. https://doi.org/10.1080/2331186X.2025.2450117

Asare, B., Welcome, N. B., & Arthur, Y. D. (2024). Investigating the impact of classroom management, teacher quality, and mathematics interest on mathematics achievement. *Journal of Pedagogical Sociology and Psychology, 6*(2), 30–46. https://doi.org/10.33902/jpsp.202426232

Asim, H. M., Vaz, A., Mansoori, S., Ahmed, A., Akram, R., Sadiq, S., Hussain, H., & Aziz, A. (2022). Designing of questionnaire for factors that impact student learning outcomes in tertiary education system: an analysis from Pakistan. *International Education Studies*, *16*(1), 16. https://doi.org/10.5539/ies.v16n1p16

Ayeni, O. O., Al Hamad, N. M., Onyebuchi, N. C., Osawaru, B., & Adewusi, O. E. (2024). AI in education: A review of personalized learning and educational technology. *GSC Advanced Research and Reviews, 18*(2), 261–271. https://doi.org/10.30574/gscarr.2024.18.2.0062

Bhardwaj, V., Zhang, S., Tan, Y. Q., & Pandey, V. (2025). Redefining learning: student-centered strategies for academic and personal growth. *Frontiers in Education*, *10*, 1518602. https://doi.org/10.3389/feduc.2025.1518602

Bond, M., Khosravi, H., De Laat, M., Bergdahl, N., Negrea, V., Oxley, E., Chong, S. W., & Siemens, G. (2024). A meta systematic review of artificial intelligence in higher education: A call for increased ethics, collaboration, and rigour. *International Journal of Educational Technology in Higher Education, 21*, 4. https://doi.org/10.1186/s41239-023-00436-z

Chaudhry, M. A., & Kazim, E. (2022). Artificial Intelligence in Education (AIEd): a high-level academic and industry note 2021. *AI and Ethics*, *2*(1), 157–165. https://doi.org/10.1007/s43681-021-00074-z

Chiu, T. K. F., Moorhouse, B. L., Chai, C. S., & Ismailov, M. (2024). Teacher support and student motivation to learn with Artificial Intelligence (AI) based chatbot. *Interactive Learning Environments*, *32*(7), 3240–3256. https://doi.org/10.1080/10494820.2023.2172044

Davis, C., Bush, T., & Wood, S. (2024). Artificial intelligence in education: enhancing learning experiences through personalized adaptation. *International Journal of Cyber and IT Service Management*, *4*(1), 26–32. https://doi.org/10.34306/ijcitsm.v4i1.146

Dimitriadou, E., & Lanitis, A. (2025). *On the potential of using generative artificial intelligence for geometry educational activities (Publicaiton no: 391230545)*. arXiv. https://doi.org/10.48550/arXiv.391230545

Engin, R. A. (2023). *The effect of designing educational digital games on pre-service teachers' some competencies. Journal of Pedagogical Sociology and Psychology, 5*(3), 195–208. https://doi.org/10.33902/jpsp.202323576

Hair Jr., J. F., Gabriel, M. L. D. da S., & Patel, V. K. (2014). AMOS covariance-based structural equation modeling (CB-SEM): Guidelines on its application as a marketing research tool. *Brazilian Journal of Marketing, 13*(2), 44–55. https://doi.org/10.5585/remark.v13i2.2718

Hart, S. R., Stewart, K., & Jimerson, S. R. (2011). The student engagement in schools questionnaire (SESQ) and the teacher engagement report form-new (TERF-N): Examining the Preliminary Evidence. *Contemporary School Psychology*, *15*(1), 67–79. https://doi.org/10.1007/bf03340964

Helmiatin, Hidayat, A., & Kahar, M. R. (2024). Investigating the adoption of AI in higher education: a study of public universities in Indonesia. *Cogent Education*, *11*(1), 2380175.

https://doi.org/10.1080/2331186X.2024.2380175
Hodonu-Wusu, J. O. (2025). The rise of artificial intelligence in libraries: the ethical and equitable methodologies, and prospects for empowering library users. *AI and Ethics*, *5*(2), 755–765. https://doi.org/10.1007/s43681-024-00432-7
Hopcan, S., Polat, E., Ozturk, M. E., & Ozturk, L. (2023). Artificial intelligence in special education: a systematic review. *Interactive Learning Environments*, *31*(10), 7335–7353. https://doi.org/10.1080/10494820.2022.2067186
Iyer, S. S., et al. (2024). Key drivers of artificial intelligence influencing student retention in higher education. *Biomedical Journal of Scientific & Technical Research, 59*(1), 009246. https://doi.org/10.26717/BJSTR.2024.59.009246
Jiang, M. Y. C., Jong, M. S. Y., Wu, N., Shen, B., Chai, C. S., Lau, W. W. F., & Huang, B. (2022). Integrating automatic speech recognition technology into vocabulary learning in a flipped english class for chinese college students. *Frontiers in Psychology*, *13*, 902429. https://doi.org/10.3389/fpsyg.2022.902429
Jr, T. G. R., & Shuck, B. (2015). Exploratory factor analysis : implications for theory , research, and practice. *Advances in Developing Human Resources*, *17*(1), 12-25. https://doi.org/10.1177/1523422314559804
Katenova, M., & Turmaganbetova, K. (2024). Artificial intelligence and business school students' performance. *International Journal of Religion*, *5*(8), 96–101. https://doi.org/10.61707/6wjvxp71
Kim, J., Lee, H., & Cho, Y. H. (2022). Learning design to support student-AI collaboration: perspectives of leading teachers for AI in education. *Education and Information Technologies*, *27*(5), 6069–6104. https://doi.org/10.1007/s10639-021-10831-6
Labadze, L., Grigolia, M., & Machaidze, L. (2023). Role of AI chatbots in education: A systematic literature review. *International Journal of Educational Technology in Higher Education, 20*, 56. https://doi.org/10.1186/s41239-023-00426-1
Laranjeira, M., & Teixeira, M. O. (2025). Relationships between engagement, achievement and well-being: validation of the engagement in higher education scale. *Studies in Higher Education*, *50*(4), 756–770. https://doi.org/10.1080/03075079.2024.2354903
Lin, H., & Chen, Q. (2024). Artificial intelligence (AI)-integrated educational applications and college students' creativity and academic emotions: students and teachers' perceptions and attitudes. *BMC psychology*, *12*(1), 487. https://doi.org/10.1186/s40359-024-01979-0
Ma, L., Liu, J., & Li, B. (2022). The association between teacher-student relationship and academic achievement: The moderating effect of parental involvement. *Psychology in the Schools*, *59*(2), 281–296. https://doi.org/10.1002/pits.22608
Ma'amor, H., Achim, N., Ahmad, N. L., Roszaman, N. S., Anuar, N. N. N. K., Azwa, N. C. A. K., Rahman, S. N., & Hamjah, N. A. A. (2024). The effect of artificial intelligence (AI) on students' learning. *Information Management and Business Review, 16*(3), 856–867. https://doi.org/10.22610/imbr.v16i3S(I)a.4178
McLaren, B. M., & Nguyen, A. (2022). Digital learning games in artificial intelligence in education. In R. Nkambou, R. Azevedo, & J. Vassileva (Eds.), *Handbook of artificial intelligence in education* (pp. 1–31). Springer.
Merino-Campos, C. (2025). The impact of artificial intelligence on personalized learning in higher education: A systematic review. *Trends in Higher Education, 4*(2), Article 17. https://doi.org/10.3390/higheredu4020017
Muthmainnah, Ibna Seraj, P. M., & Oteir, I. (2022). Playing with AI to Investigate Human-Computer Interaction Technology and Improving Critical Thinking Skills to Pursue 21stCentury Age. *Education Research International*, *2022*, 6468995. https://doi.org/10.1155/2022/6468995
National Education Association. (2024). *Report of the NEA Task Force on artificial intelligence in education*. Author.
Net, W. W. W. P. (2025). The relationship between pre-service teachers' attitude towards artificial intelligence (AI) and their AI literacy. *Pegem Journal of Education and Instruction*, *15*(3), 121–131. https://doi.org/10.47750/pegegog.15.03.13
Nguyen, A., Kremantzis, M., Essien, A., Petrounias, I., & Hosseini, S. (2024). Enhancing student engagement through artificial intelligence (ai): understanding the basics, opportunities, and challenges. *Journal of University Teaching and Learning Practice*, *21*(6), 92. https://doi.org/10.53761/caraaq92
Nyante, F., Mensah, G. B., Addy, A., & Akuffo, E. A. (2024). Digital storm: how Ghana defied doubts in nursing and midwifery assessment reform against the odds. *Public Policy and Administration Research*, *14*(1), 61-71. https://doi.org/10.7176/ppar/14-1-06
Oktradiksa, A., Bhakti, C. P., Kurniawan, S. J., Rahman, F. A., & Ani. (2021). Utilization artificial intelligence

to improve creativity skills in society 5.0. *Journal of Physics: Conference Series*, *1760*(1), 12032. https://doi.org/10.1088/1742-6596/1760/1/012032

Opesemowo, O. A. G., & Ndlovu, M. (2024). Artificial intelligence in mathematics education: The good, the bad, and the ugly. *Journal of Pedagogical Research, 8*(3), 333-346. https://doi.org/10.33902/JPR.202426428

Pacheco-Mendoza, S., Guevara, C., Mayorga-Albán, A., & Fernández-Escobar, J. (2023). Artificial intelligence in higher education: a predictive model for academic performance. *Education Sciences*, *13*(10), 990. https://doi.org/10.3390/educsci13100990

Pitura, J., Kaplan-Rakowski, R., & Asotska-Wierzba, Y. (2024). The VR-AI–assisted simulation for content knowledge application in pre-service EFL teacher training. *Education and Information Technologies, 29*(4), 1501–1522. https://doi.org/10.1007/s11528-024-01022-4

Pokrivcakova, S. (2023). Pre-service teachers' attitudes towards artificial intelligence and its integration into EFL teaching and learning. *Journal of Language and Cultural Education*, *11*(3), 100–114. https://doi.org/10.2478/jolace-2023-0031

Poquet, O., Trenholm, S., & Santolini, M. (2024). Forum posts, communication patterns, and relational structures: A multi-level view of discussions in online courses. *Educational Technology Research and Development*, *72*(5), 2655–2678. https://doi.org/10.1007/s11423-023-10262-9

Prediger, S. (2024). Fifty ways to work with students' diverse abilities? A video study on inclusive teaching practices in secondary mathematics classrooms. *International Journal of Inclusive Education*, *28*(2), 124–143. https://doi.org/10.1080/13603116.2021.1925361

Putra, D. A., Meirza Nanda Faradita, & Dewi Masyita Faradillah. (2023). Problem-based learning (pbl) instructional materials for enhancing mathematics learning outcomes of elementary school students. *Education and Human Development Journal*, *8*(2), 1–9. https://doi.org/10.33086/ehdj.v8i2.5018

Qurohman, M. (2024). Enhancing high school students problem solving ability inalgebra through artificial intelligence based learning. *International Journal of Trends in Mathematics Education Research*, *7*(4), 9–17. https://doi.org/10.33122/ijtmer.v7i4.358

Rehman, N., & Kang, M. A. (2024). Exploring the impact of artificial intelligence on students' engagement and motivation in online learning environments. *International Journal of Trends and Innovations in Business & Social Sciences*, *2*(4), 537–548. https://doi.org/10.48112/tibss.v2i4.959

Rizvi, M. (2023). Investigating ai-powered tutoring systems that adapt to individual student needs, providing personalized guidance and assessments. *The Eurasia Proceedings of Educational and Social Sciences*, *31*, 67–73. https://doi.org/10.55549/epess.1381518

Roemer, E., Schuberth, F., & Henseler, J. (2021). HTMT2–an improved criterion for assessing discriminant validity in structural equation modeling. *Industrial Management and Data Systems*, *121*(12), 2637–2650. https://doi.org/10.1108/IMDS-02-2021-0082

Subramanian, K. P., Abrar, M., Aboraya, W., Abdulghafor, R., & Al Husaini, Y. (2025). AI-powered learning pathways: Personalized learning and dynamic assessments. *International Journal of Advanced Computer Science and Applications, 16*(1). http://dx.doi.org/10.14569/IJACSA.2025.0160145

Tin, T. T., Chor, K. Y., Hui, W. J., Cheng, W. Y., Kit, C. J., Husin, W. N. A. A. W., Aitizaz, A., Tiung, L. K., Afolalu, S. A., & Khattak, U. F. (2024). Demographic factors shaping artificial intelligence (ai) perspectives: exploring their impact on university students' academic performance. *Pakistan Journal of Life and Social Sciences*, *22*(2), 12248–12264. https://doi.org/10.57239/PJLSS-2024-22.2.00876

Trochim, W. M. K., & Donnelly, J. P. (2006). *The research methods knowledge base*. Atomic Dog Publishing.

Van Mechelen, M., Smith, R. C., Schaper, M. M., Tamashiro, M., Bilstrup, K. E., Lunding, M., Graves Petersen, M., & Sejer Iversen, O. (2023). Emerging technologies in K-12 education: A future HCI research agenda. *ACM Transactions on Computer-Human Interaction*, *30*(3), 3569897. https://doi.org/10.1145/3569897

Walter, Y. (2024). Embracing the future of Artificial Intelligence in the classroom: The relevance of AI literacy, prompt engineering, and critical thinking in modern education. *International Journal of Educational Technology in Higher Education, 21*, 15. https://doi.org/10.1186/s41239-024-00448-3

Wang, H., Wang, C., Chen, Z., Liu, F., Bao, C., & Xu, X. (2025). Impact of AI-agent-supported collaborative learning on the learning outcomes of University programming courses. In *Education and Information Technologies.* Advance online publication. https://doi.org/10.1007/s10639-025-13487-8

Wang, Y., & Wang, H. (2024). Mediating effects of artificial intelligence on the relationship between academic engagement and mental health among Chinese college students. *Frontiers in Psychology*, *15*, 1477470. https://doi.org/10.3389/fpsyg.2024.1477470

Wu, S. Y., & Yang, K. K. (2022). The effectiveness of teacher support for students' learning of artificial

intelligence popular science activities. *Frontiers in Psychology*, *13*, 868623. https://doi.org/10.3389/fpsyg.2022.868623

Yeung, M. M. Y., Yuen, J. W. M., Chen, J. M. T., & Lam, K. K. L. (2023). The efficacy of team-based learning in developing the generic capability of problem-solving ability and critical thinking skills in nursing education: A systematic review. *Nurse Education Today*, *122*, 105704. https://doi.org/10.1016/j.nedt.2022.105704

Yurt, E., & Kasarci, I. (2024). A questionnaire of artificial intelligence use motives: a contribution to investigating the connection between ai and motivation. *International Journal of Technology in Education*, *7*(2), 308–325. https://doi.org/10.46328/ijte.725

Zhou, X., Teng, D., & Al-Samarraie, H. (2024). The mediating role of generative ai self-regulation on students' critical thinking and problem-solving. *Education Sciences*, *14*(12), 1302. https://doi.org/10.3390/educsci14121302