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# Comparison of AI-Assisted Learning in a Collaborative Environment with Conventional Teaching Methods on Pre-service Teachers' Mathematics Performance

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**ABSTRACT**

Conventional teaching methods still dominate in Colleges of Education in Ghana, relying on rote learning rather than critical thinking or problem-solving. This study adopted a positivist research philosophy, employing scientific and quantitative methods to objectively explore the causal effect of AI-assisted instruction on pre-service teachers' mathematics performance. Utilizing a quasi-experimental design with non-random assignment, two public Colleges of Education in Ghana's Ashanti Region were selected, involving 100 Level 400 students split evenly into experimental and control groups. Pre-tests established baseline performance, and the group with the lower average became the experimental group. The intervention consisted of eight AI-assisted mathematics lessons on linear equations delivered in a collaborative learning environment, while the control group received conventional instruction. Post-test results analyzed using SPSS and Independent Samples t-tests revealed a statistically significant improvement in the experimental group's performance. These findings indicate that AI-assisted instruction in a collaborative setting significantly enhances mathematics achievement among pre-service teachers, highlighting the transformative potential of integrating technology in teacher education.

***Keywords:*** *Artificial Intelligence [AI], AI-Assisted, Collaborative, Performance, Conventional.*

## I. INTRODUCTION

Artificial Intelligence (AI), first defined by McCarthy (1956) as the simulation of human intelligence by machines, is now a transformative force across various industries, including healthcare, transportation, and notably, education. AI technologies such as machine learning, natural language processing, robotics, and computer vision have revolutionized how machines interact with information, enabling them to learn, reason, and adapt. The historical roots of AI trace back to Doroudi (2023) foundational work on machine intelligence and McCarthy's seminal 1956 Dartmouth Conference, which formally launched AI as a field of study. Today, AI is embedded in numerous everyday applications, ranging from virtual assistants like Siri and Alexa to autonomous vehicles and advanced medical diagnostics.

In the field of education, Artificial Intelligence (AI), offers immense potential to transform teaching and learning processes. It can automate administrative tasks like grading, thereby freeing educators to engage more directly with students. More importantly, Artificial Intelligence (AI), supports personalized learning, which is particularly impactful in mathematics education, where learners often exhibit diverse levels of proficiency (Hashim et al., 2022). Adaptive learning systems can respond to individual students' needs by providing tailored content, feedback, and challenges, thereby mitigating issues such as math anxiety and enabling more effective skill acquisition (Hu, 2024). As AI continues to evolve, it is increasingly being viewed as a strategic tool for achieving Sustainable Development Goals through improved educational access, retention, and success (AlSagri & Sohail, 2024).

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However, the integration of Artificial Intelligence (AI), in education faces significant challenges, particularly in developing countries like Ghana. Despite policy-level recognition of technology's importance in early childhood and tertiary education, Artificial Intelligence (AI), adoption remains limited due to infrastructure deficiencies, financial constraints, and inadequate educator training (Mhlanga, 2021). Colleges of education, in particular, struggle with outdated instructional methods, a lack of awareness about AI tools, and limited access to technological resources (Asare et al., 2023) Furthermore, the absence of national policies from institutions like the Ghana Tertiary Education Commission has resulted in inconsistent practices and a lack of clear direction on AI integration into teacher education programs.

To ensure successful adoption, the readiness and professional development of educators are critical. Teachers, especially pre-service mathematics educators, need structured training not only in using AI tools but also in interpreting the data generated for effective instructional decisions. Ethical concerns, including bias, data privacy, and the digital divide, must also be addressed (Kuiler, 2024). This study seeks to explore how AI-assisted collaborative learning environments can enhance mathematics performance among pre-service teachers in Ghanaian colleges of education. By comparing AI-supported methods with conventional teaching approaches, the research aims to provide insights into how AI can create more inclusive, responsive, and effective learning environments, while addressing the urgent need for evidence-based practices in local educational contexts.

- *Research Question*

How does AI-assisted learning in a collaborative environment compare with conventional teaching methods on pre-service teachers' mathematics performance?

## II. LITERATURE REVIEW

The study was underpinned by the Collaborative learning theory. Collaborative learning theory is based on the notion that learning is an inherently social process in which individuals construct knowledge through interaction and shared problem-solving (Vygotsky, 1978). This theory, with roots in Vygotsky's concept of the Zone of Proximal Development (ZPD), suggests that collaborative learning environments allow learners to perform tasks they may not be able to accomplish independently, thus enhancing cognitive development. Collaborative learning is especially relevant in mathematics education, where problem-solving and logical reasoning are core elements, and group work has been shown to improve mathematical understanding (Klang et al., 2021). The incorporation of AI tools into collaborative learning can potentially support these interactions by providing real-time feedback, enhancing communication channels, and personalizing learning trajectories (Alam & Mohanty, 2023).

- *Theories of AI in Education*

Artificial Intelligence (AI) first gained the attention of the U.S. Department of Defense in the 1960s, with early efforts focused on simulating human thought through expert systems and intelligent search mechanisms. The Defense Advanced Research Projects Agency (DARPA) spearheaded these initiatives, laying the groundwork for AI technologies. Since then, AI has evolved rapidly, extending from fictional portrayals of humanoid robots to practical applications in everyday life, such as autonomous vehicles, Google's search engine, and intelligent weapon systems (Ghosh & Singh, 2020). In education, AI has become increasingly influential, transforming traditional classrooms, once dominated by blackboards, into digital learning environments enhanced by projectors and smart technologies. Although the integration of AI in education saw limited progress in the 20th century (Afzaal et al., 2024), more recent developments have demonstrated substantial gains, particularly through virtual assistants and smart learning tools. Studies affirm that AI is now deeply embedded in daily life and has enhanced the accessibility of learning materials through smart devices while streamlining administrative processes in schools, allowing teachers more time to engage with students (Rehan, 2023).

AI's growing impact on education is evident in areas such as administrative automation, grading systems, and admissions processes. Technologies capable of evaluating multiple-choice tests are widely used, although essay grading still presents a challenge, with software engineers actively developing new AI-based solutions (Yeung et al., 2023). Smart content, another major innovation, involves condensing textbooks into interactive study aids such as true/false questions, chapter summaries, flashcards, and virtual lectures. Tools like Cram101 and JustTheFacts101 exemplify this innovation, making learning more efficient and accessible (Assefa, 2024). Additionally, platforms like Netex use AI to support the creation of digital curricula, offering multimedia resources and virtual guidance across educational settings (Hossain et al., 2024). The idea of AI-assisted learning dates back to the 1970s, with educational psychologist Benjamin Bloom's concept of self-tutoring. Since then, Intelligent Tutoring Systems (ITS) have advanced significantly. Notable among these is Carnegie Learning's "Mike," a software that integrates AI and cognitive science to provide personalized tutoring experiences (Akpabio et al., 2024).

- *Artificial Intelligence, Collaborative Learning, and Mathematics Education*

Collaborative learning, characterized by students working together to achieve common academic goals, has long been recognized for fostering critical thinking, problem-solving, and social interaction. The integration of Artificial Intelligence (AI) into this pedagogical approach, particularly for pre-service mathematics teachers, represents a major advancement in teacher preparation. AI tools such as chatbots can facilitate student interactions,

resolve academic queries, and promote active group participation (Abbas et al., 2022). Furthermore, AI can track group dynamics and monitor individual contributions, allowing educators to better manage collaborative learning experiences. Through AI-assisted platforms like ChatGPT, pre-service teachers can refine innovative instructional practices and build competencies needed for 21st-century classrooms. Such systems also simulate classroom scenarios, enabling experiential learning and helping educators anticipate and address common student misconceptions (Asare et al., 2023).

The use of AI technologies, such as machine learning, natural language processing, and data analytics, can personalize instruction, automate administrative tasks, and analyze vast educational datasets to uncover learning trends. In collaborative learning contexts, AI facilitates communication, enhances resource sharing, and provides real-time feedback, all of which contribute to more effective student engagement (Hooda et al., 2022). Empirical studies, including Asare et al. (2023), have demonstrated a significant positive correlation between ChatGPT use and student interest in mathematics, which in turn influences achievement. Their findings reveal that students' interest significantly moderates the relationship between ChatGPT usage and mathematical performance. Similarly, RIZVI (2023) emphasizes that AI systems deliver personalized instruction tailored to students' individual needs, promoting mastery through adaptive assessments and targeted feedback. These systems, enriched with virtual simulations and gratification mechanisms, enhance engagement and make mathematics more accessible. Velázquez and Méndez (2021) further highlighted the role of augmented reality (AR) in making abstract mathematical concepts tangible and interactive.

Despite these advancements, concerns remain about the limitations of AI in replicating the emotional intelligence and empathy provided by human teachers. Issues surrounding data privacy and student information security are also prominent, given the reliance of AI systems on sensitive educational data (Muli, 2024). Melisa et al. (2025) caution that over-reliance on AI may hinder students' independent and critical thinking skills. To address such challenges, scholars like Viberg et al. (2024) advocate for equitable access to AI-powered learning tools and stress the importance of protecting user data. Kenny et al. (2023) call for a sustainable and inclusive implementation framework that integrates diverse educational perspectives.

## III. METHODOLOGY

- *Research Design*

This study adopted a positivist research philosophical stance as it extracts outcomes employing experiments and scientific methods that offer vital insights and knowledge regarding the natural world of realism and truth. The positivist philosophy holds that reality is stable and can be observed and described objectively (Gillani, 2021). This scientific approach aids in the collection of numerical data and its validation through analysis, which is likely to yield generalizable findings (Waite et al., 2014). The research approach adopted in this study is the quantitative research approach. This approach uses numerical measurements of constructs and tests the interactions among them to find patterns and correlations. Waite et al. (2014) observed that the quantitative approach can be most effectively used for situations where there are a large number of respondents available, where the data can be effectively measured using quantitative techniques, and where statistical methods of analysis can be used. The study employed a quasi-experimental design for practical and ethical reasons. A quasi-experiment is an empirical study used to appraise the causal effect of an intervention (treatment) on a target population from which participants are not randomly assigned in groups (Creswell, 2012). Moreover, the research design involved non-random assignment of participants into two groups, namely treatment (experimental) and control groups. This design enabled the researcher to study the cause and effect of integrating AI-assisted learning methods into teaching and learning to improve students' performances (Creswell, 2014). Being an educational institution where randomization was practically impossible, intact groups were used for the experimental and control groups. Collom (2022) opined that a Quasi-experimental design involves a non-random assignment of participants to conditions in a study.

- *Participants*

The setting of the study was the Ashanti Region of Ghana. The Ashanti Region is the third-largest of Ghana's 16 administrative regions. All pre-service teachers in the 8 public colleges of education (CoE) in the Ashanti Region formed the targeted population for the study. Two schools were selected through convincing sampling from different Districts in the region. The sampled schools were selected due to the characteristics they possessed, which were suitable for the study. As a quasi-experimental study, it involved pre-test and post-tests of non-randomized, control, and experimental groups (Souza et al., 2022). The essence of the pre-test is to help establish the baseline performance of the groups and possibly differentiate between the groups before the intervention. The class with the apparent weaker pre-test performance becomes the experimental group, with the control group being the other group with relatively better pre-test performance. Hence, School A was used as the experimental group while School B became the control group. A sample size of 100 (50 each) Level 400 students was derived from the accessible population.

- *Data Collection*

The study made use of performance tests (pre-test and post-test). The performance test was administered in two phases, before and after the intervention. The pre-test was a test administered to the two groups to determine whether students had equivalent knowledge on the topic before the

intervention was carried out. The post-test was a test administered to students in both groups to determine the effectiveness of the intervention. All the items in the pre-test were based on the linear equation topic in the Junior High School Mathematics curriculum, while the items in the post-test were based on the treatment topic, linear equations involving word problems. Klu et al. (2023) concurred that it has been proven effective because if the average score on the post-test is higher than the average score on the pre-test, it is reasonable to conclude that the improvement is due to the intervention.

The treatment started with the writing of teaching guides, like lesson plans and lesson notes for teaching. The content was developed according to the mathematics curriculum, containing sets of objectives specifically outlined to the teachers, clear direction, and the kind of expected specific outcomes required from the topics. Again, the teaching guides encompass a lot of suggestions and examples that teachers follow in their presentation of lessons. The daily lesson plans were given to mathematics educators for face validation.

The researcher introduced AI-assisted instruction in a collaborative environment of teaching and learning strategy to the experimental group, while the control group was taught using the conventional approach. A period of four weeks was used for the treatment. There were eight lessons in all for both control and experimental groups, and each lesson lasted for two hours. The post-test immediately followed the treatment to ascertain the success or otherwise.

- *Validity Test*

Content validity was assured for the pre-test and post-test by seeking the help of two mathematics Tutors from the two schools and three experienced mathematics Educators to evaluate the pre-test and the post-test and make recommendations to the instruments. Creswell (2012) assert that content validity is a method of measuring or determining a consensus among experts about the quality of a specific test item. Reliability is verified using external and internal consistency. The Cronbach's alpha for the pretest was 0.75, and that of the post-test was 0.84, and these values were high enough to attest to the reliability of the test (Shrestha, 2021).

- *Data Analysis*

After the treatment and data collection period, the data collected from respondents were processed and analyzed to find answers to the research question. The Statistical Package for Social Sciences (SPSS, Version 27.0) was the main software used to help in the analysis of the research data. Inferential statistics were used to analyze the data, where an Independent Samples t-test at a confidence interval of 95% (significance level of $p< 0.05$) by comparing the pre-test and post-test of participants was used. The researcher gave due consideration to the legal framework governing the conduct of research (Creswell & Creswell, 2017).

## IV. RESULTS

The study sought to find a distinction between pre-service teachers' mathematics performance when taught mathematics using AI-assisted learning in a collaborative environment and the conventional teaching approach. Pre-tests were given to the participants before the intervention. Table 1 shows the Independent Sample T-Test of the results

Table 1 Independent Sample T-Test Results for Pre-Test Scores of the Control and Experimental Group

| Test | Group | Mean | Std. Deviation | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| Pre-test | Control | 9.30 | 1.11 | 1.656 | 98 | 0.101 |
| | Experimental | 8.82 | 1.72 | | | |

Source Field Data (2024)

Table 1 shows a mean score of 9.30 ($SD$ = 1.11) for the Control group and a mean score of 8.82 ($SD$ = 1.72) for the experimental group. This shows that the control group performed better before the intervention. The higher standard deviation of the experimental group, however, shows more variability in the test results. The t-statistic value of 1.656, at a two-tailed significance level of 0.101 ($p > 0.05$), shows a non-statistically significant difference between the two groups' pre-test scores. Notwithstanding, the difference in the mean scores became the yardstick for the categorization of the participants into Control and Experimental Groups.

After the categorization of the participants into groups, the experimental group was introduced to AI-assisted instruction in a collaborative environment while the control group was taught using the conventional method. The results of the post-test conducted are presented in Table 2

Table 2 Independent Sample T-Test Results for Post-Test Scores of the Control and Experimental Groups

| Test | Group | Mean | Std. Deviation | t | Df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|
| Post-test | Control | 10.06 | 1.65 | -51.050 | 98 | 0.022 |
| | Experimental | 24.08 | 1.03 | | | |

Source: Field Data (2024)

An Independent Sample t-test was conducted to compare the mean scores of the control group ($Mean$ = 10.06, $SD$ = 1.65) and the experimental group ($Mean$ = 24.08, $SD$ = 1.03), showing a statistically significant difference between the two groups $t(98) = -51.050$, $p < 0.05$. This finding suggests that the experimental group performed significantly better than the control group on the post-test. The negative t-value indicates that the mean score of the experimental group was higher than that of the control group. The low p-value ($p < 0.05$) reinforces the conclusion that this difference is statistically significant, implying that the intervention applied to the experimental group had a substantial effect on their performance compared to the control group.

## V. DISCUSSION

The present study investigated the impact of AI-assisted learning on students' mathematics performance compared to conventional teaching methods, using a pre-test/post-test control group design. Initially, the pre-test results indicated a marginally higher performance by the control group; however, this difference was not statistically significant. This suggests that before the intervention, both groups were relatively equivalent in terms of mathematical ability, supporting the internal validity of the experiment.

Following the intervention, the experimental group, which received instruction through AI-assisted learning platforms, exhibited a significantly higher post-test mean score than the control group. The t-value obtained was highly significant, indicating that the observed improvement was unlikely to be due to chance. These findings align with recent empirical evidence emphasizing the effectiveness of AI-integrated pedagogical approaches in enhancing mathematics learning outcomes. For instance, studies by Rane (2024) and Dabingaya (2022) assert that AI technologies can personalize learning experiences, adapt to student needs, and offer immediate feedback, thereby improving comprehension and performance in mathematics.

Moreover, the substantial gains observed in the experimental group can be attributed to the dynamic and interactive nature of AI tools, which foster learner engagement and self-regulated learning (Hilpert et al., 2023). AI platforms often incorporate gamified elements, problem-solving scaffolds, and real-time analytics, all of which contribute to a deeper conceptual understanding and retention of mathematical concepts (Kassenkhan et al., 2025). This is particularly important given the cognitive demands of mathematics learning, which benefits from adaptive feedback and individualized instruction.

These findings are consistent with the work of El Fathi et al. (2025), who found that AI-supported interventions positively influence students' metacognitive skills and performance across STEM subjects. Similarly, a meta-analysis by Jing et al. (2025) concluded that AI-driven learning environments significantly outperform traditional instructional models in mathematics achievement across various educational levels. In the current study, the AI-assisted learning environment may have provided students with more opportunities to engage in formative assessment and personalized support, leading to improved outcomes.

Similarly, Kim et al. (2022) found that AI tools, when integrated into teaching and learning, can alleviate collaboration challenges by bridging perceptual gaps, clarifying objectives, and promoting deeper understanding, leading to collaborative learning, which enhances students' intellectual autonomy, creativity, and digital literacy skills with improved academic performance. Kim and Kim (2022) found that AI tools were particularly useful for clarifying complex concepts and providing immediate solutions. AI support potentially created a more comprehensive learning experience since post-test scores showed improved mathematical skills and a deeper comprehension of intricate calculus concepts (Tashtoush et al., 2025).

Furthermore, Kovalenko and Baranivska (2024) found that AI tools make learning and remembering language concepts easier and provide individualized learning that meets various learning requirements, leading to improved language learning outcomes, engagement, and individualization. Lin and Chen (2024) and Bright et al. (2024) also found that AI applications stimulated creativity by introducing new ideas and problem-solving techniques, enhanced engagement through interactive elements, provided personalized feedback, and supported emotional well-being, leading to improved performance.

The comparative analysis of ChatGPT and traditional teaching methods in EFL instruction by Bilal and Safdar (2023) and Asare & Boateng (2025) found that ChatGPT showcased significant enhancements in writing skills and conversational proficiency, underscoring its value as a complementary tool in language learning. Comparatively, Maanu et al. (2025) corroborated that while traditional education boasts time-tested pedagogical approaches, the potential benefits of AI-driven education are too significant to ignore. AI promises personalization and can complement the established merits of traditional methods. Notwithstanding, it is essential to understand how best to utilize AI techniques alongside traditional methods for the academic success of both educators and learners, since the ideal educational system, which incorporates elements of both AI-based and traditional education, is key to establishing a strong educational foundation for the future.

## VI. CONCLUSION

This study adopted a positivist research philosophy and a quantitative, quasi-experimental design to investigate the impact of AI-assisted learning in a collaborative environment on pre-service teachers' performance in mathematics. Grounded in objective observation and measurement, the approach provided empirical evidence through pre-test and post-test assessments. The results from the pre-test showed no statistically significant difference between the control and experimental groups, validating the fairness of the group assignment. Following the four-week intervention, the experimental group, which received AI-assisted instruction, demonstrated a significantly higher performance than the control group. This statistically significant outcome confirms the effectiveness of AI-based collaborative learning in enhancing students' understanding and application of linear equations involving word problems.

The findings affirm that integrating AI-assisted instructional methods into mathematics education can lead to substantial gains in student performance, particularly when implemented in an interactive and collaborative learning setting. The significant improvement observed in the experimental group post-intervention highlights the transformative potential of educational technologies in teacher preparation programs. Furthermore, the methodological rigor of using a quasi-experimental design, validated instruments, and inferential statistical techniques contributes to the reliability and generalizability of the study's findings. It is recommended that educators and policymakers consider adopting AI-supported instructional strategies to complement traditional teaching methods, especially in resource-constrained environments like teacher training colleges in Ghana.

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