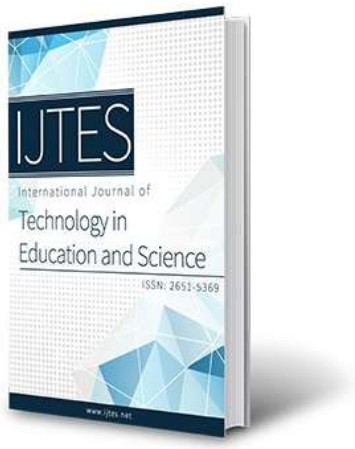

www.ijtes.net

AI-Assisted Collaborative Learning in Mathematics Education: A Qualitative Approach

Ernest Frimpong Akosah
Peki College of Education, Ghana

To cite this article:

Akosah, E.F. (2025). AI-assisted collaborative learning in mathematics education: A qualitative approach. *International Journal of Technology in Education and Science (IJTES), 9*(3), 416-433. https://doi.org/10.46328/ijtes.634

IJTES International Journal of Technology in Education and Science
2025, Vol. 9, No. 3, 416-433 https://doi.org/10.46328/ijtes.634

AI-Assisted Collaborative Learning in Mathematics Education: A Qualitative Approach

Ernest Frimpong Akosah

Article Info

Article History

Received:
21 February 2025
Accepted:
30 June 2025

Keywords

AI-assisted learning
Collaborative learning
Pre-service mathematics
Teachers
Case study
Technology engagement
Teacher education
Qualitative research

Abstract

The integration of Artificial Intelligence (AI) in collaborative learning environments has transformed educational practices, yet little is known about pre-service mathematics teachers' perceptions and engagement with such technology. This study aims to address this gap by exploring how pre-service teachers perceive and engage with AI-assisted collaborative learning, identifying factors that influence their experiences. Using a qualitative phenomenological design, we conducted semi-structured interviews with a purposive sample of ten pre-service mathematics teachers. Data were analyzed thematically, yielding three primary themes: engagement in AI-assisted learning, technology comfort and experience, and design of AI tools. Findings reveal that while participants recognize the potential of AI to enhance collaborative learning, their engagement is shaped by prior technology exposure, ease of tool use, and group dynamics. Participants cited the benefits of AI for facilitating peer interaction but also raised concerns regarding technical support and usability. This study contributes to the literature by highlighting the unique challenges pre-service teachers face with AI tools in collaborative settings. Recommendations include the integration of comprehensive technology training within teacher education programs and the development of user-friendly AI tools tailored for collaborative learning to support effective engagement and pedagogical outcomes.

Introduction

Education is still moving away from traditional classroom settings and toward more virtual ones. Teaching and learning methods using digital technology are being adopted by many basic educational institutions. Our daily lives now heavily rely on these digital technology. They alter our methods of communication, interaction, socialization, and information gathering (Vuorikari et al., 2022). Artificial intelligence (AI) has become a game-changing technology in business, industry, and society because to the concurrent advancements in digitalization, processing power, and data availability (Holmes et al., 2019). Globally, all industries are being impacted by rapid technology advancements, hence it is imperative that labor skills be updated as quickly as possible (Gómez-Gamero, 2019; Mena-Guacas et al., 2023). Information and communication technologies are currently essential to the development of education because of their adaptability and versatility (García, 2021). In this regard, the trend of artificial intelligence (AI) utilization is drastically altering many facets of society, including educational

institutions (Vera, 2023). Artificial Intelligence (AI) presents new opportunities to improve teaching and learning, and technological developments are increasingly influencing the subject of mathematics education. Recent years have seen the introduction of AI into educational settings as a way to promote personalized learning, adaptive instruction, and real-time feedback—all of which are especially beneficial in disciplines like mathematics that call for sophisticated problem-solving and critical thinking abilities (Holmes et al., 2019). Research on artificial intelligence is now underway (Zawacki-Richter et al., 2019). AI has the potential to significantly impact four domains in an educational setting, according to Zawacki-Richter et al. (2019): Student assessment and evaluation, intelligent tutoring systems, adaptive systems and personalization, and student profiling and achievement prediction. AI's more problematic characteristics, such employment market disruptions and the effective transmission of false information, suddenly seem much more conceivable to the public than its potentially beneficial qualities, like personalized learning (Farrokhnia et al., 2023). Thus far, AI's influence on the daily operations of elementary and secondary education has been minimal. Researchers and educators are just starting to investigate the best ways to use AI to influence teaching and learning in the classroom (Hwang et al., 2020; Luckin et al., 2022). The authors believe that AI-assisted solutions have the ability to help pre-service math teachers who are dealing with a classroom full of kids that require personalized feedback and assistance. Artificial intelligence (AI) has the potential to function as a smart, individualized tutor by identifying a student's difficulties with problem solving and offering step-by-step instructions when necessary. AI can also recognize multiple student strategies and maintain multiple interpretations of student behavior (Aleven et al., 2009). AI-assisted solutions for math pre-service teachers not only offer dynamic, responsive learning environments but also make cooperation easier, which is essential for building the abilities required in a contemporary classroom (Akosah et al., 2024).

One significant development in higher education has been the usage of collaborative learning platforms to assist student-centered learning strategies (Fu & Hwang, 2018). Moodle and other AI-assisted collaborative learning technologies are still widely used by educators. According to Straková and Cimermanová (2018), a collaborative learning AI-assisted tool is an interactive technology that facilitates efficient online communication and information processing between students. These solutions remove obstacles that impede cooperation, such as time and location difficulties. In fact, a lot of academics think that using these systems improves students' academic performance, learning process, and knowledge development (Alonso et al., 2015). Above all, they offer educational institutions an economical way to encourage students' involvement and active participation in class activities (Koranteng & Wiafe, 2019). According to Neumann & Hood (2009), user satisfaction determines academic engagement with AI-assisted collaborative learning. In the teaching of mathematics, collaborative learning has long been acknowledged as a successful educational strategy. It promotes collaborative problem-solving, active participation, and the growth of communication and interpersonal skills (Lee, & Paul, 2023; Hossain et al., 2012). By offering personalized prompts, tracking progress, and promoting knowledge exchange among students, the incorporation of AI into collaborative learning has the potential to improve interactions (Luckin et al., 2022).

Since schools and instructors have a significant impact on how extensively AI technology is used in society and who will profit from it, it's critical to learn more about how teachers view and use AI-assisted collaborative

learning and what factors affect their experiences. Even though AI has a lot of potential, it is still not widely used in teacher preparation programs, particularly in mathematics instruction. The impact of AI-assisted tools on pre-service teachers' collaborative learning experiences and attitudes toward AI in education in general is not well understood (Baker, 2016). To be explicit, when we talk about "AI-assisted tools," we mean tools for assessment and evaluation, intelligent tutoring systems, adaptive systems for customisation, and tools for profiling and predicting student progress (Zawacki-Richter et al., 2019). By tailoring instruction to each student's requirements and preferences, AI provides the benefit of customizing learning (Cárdenas et al., 2023). It may evaluate each student's behavior, style, strengths, and shortcomings using AI-assisted tools, offering tailored comments and suggestions (Delgado et al., 2024; García-Peñalvo et al., 2023).

Problem Statement

As AI technologies gain traction in educational spaces, there is a pressing need to understand how these tools impact the perceptions, engagement, and learning outcomes of pre-service teachers. Currently, few studies focus specifically on the role of AI in facilitating collaboration among pre-service mathematics teachers, leaving educators with limited insights into best practices and potential pitfalls (Ertmer & Ottenbreit-Leftwich, 2019, Delgado et al., 2024). Although collaborative learning is a foundational aspect of teacher training, pre-service mathematics teachers often face unique challenges when engaging in collaborative learning environments facilitated by AI, such as balancing traditional mathematical practices with AI-driven insights and adjusting to new instructional approaches (García-Peñalvo et al., 2023). These challenges highlight an essential gap in our understanding of how AI shapes not only the learning experience but also the attitudes and engagement levels of future mathematics educators. This study aims to address this gap by examining the perceptions, attitudes, and engagement of pre-service mathematics teachers in AI-assisted collaborative learning environments. Using a qualitative approach with a case study design, the research seeks to gain a comprehensive understanding of how AI can support collaborative learning in teacher training contexts.

The qualitative component of the study, in particular, focuses on exploring participants' subjective experiences with AI tools, highlighting their perceptions, engagement factors, and the challenges they encounter in collaborative settings. This in-depth exploration will provide valuable insights into the role of AI in enhancing collaborative learning among future educators and inform strategies for effective integration of AI in teacher training programs. Unlike previous studies (Ertmer & Ottenbreit-Leftwich, 2019, Farrokhnia et al., 2023) that explore AI in general educational settings, this research specifically examines AI’s impact on collaborative learning dynamics in a pre-service mathematics education context, making it a unique addition to the literature. By identifying key factors that influence engagement and perceptions in AI-supported environments, this study provides actionable insights for designing AI-facilitated collaborative learning experiences that can improve teacher preparedness in mathematics education. Moreover, the findings can guide the development of training programs that leverage AI to foster active engagement, collaborative problem-solving skills, and positive attitudes toward technology among pre-service teachers. This study thus advances our understanding of the intersection between AI, collaborative learning, and mathematics teacher preparation, offering a novel perspective on effective technology integration in education.

Purpose of Study

The study aims to explore how pre-service teachers perceive and engage with AI-assisted collaborative learning, identifying factors that influence their experiences.

Research Questions

1. What are the perceptions and attitudes of pre-service mathematics teachers towards AI-assisted collaborative learning environments?
2. What factors influence the engagement of pre-service mathematics teachers in AI-assisted collaborative learning environments?

Literature Review

Technology has emerged as a crucial component of education in recent years. Teaching and learning methods that encourage active and constructivist learning are now prioritized. As a result, collaborative learning platforms like Moodle, Blackboard Collaborate, Google Classroom, and others have had to be developed (Motaghian et al., 2013). Constructivist learning is made possible for students by these AI-assisted resources (Koranteng et al., 2013). As a result, they remove the time and distance constraints that have mostly prevented students from working together in conventional learning settings (Koranteng et al., 2020). In fact, there is proof that using these AI-assisted resources improves student performance (Islam, 2013). According to many educators, children who participate in more academic activities will be better able to attain these learning objectives (Ko, 2016).

Theoretical Framework

The theory underpins this study is the Collaborative learning theory. Collaborative learning theory underpins the notion that learning is inherently a 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 (Fu & Hwang, 2018). 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 (Luckin et al., 2022).

Perception of Pre-Service Teachers

Perception is a social act of mental imprint, which is noticing the actions of others through observation. It helps the individual build an understanding of the thoughts or intentions of others by observing their behaviours (Grezes & Gelder, 2009). Social perception is one's ability to recognise the action(s) of others without them knowing it. Through perception, students have perceived mathematics as challenging to do and that a teacher's attitude could

have caused their failure and, therefore, develop either a negative or positive attitude towards the subject or the mathematics teacher (Wasike et al., 2013). Building on Collaborative Learning Theory, this study conceptualizes perceptions and attitudes as foundational to pre-service teachers' willingness to engage with AI-assisted tools. Positive perceptions about the usefulness and ease of AI tools are expected to influence their attitudes toward collaborative learning in mathematics. Perceptions are also likely to impact their confidence and enthusiasm for using AI in classroom settings (Davis, 1989; Vygotsky, 1978).

Engagement of Pre-Service Teachers

Engagement is defined as the effort and devotion one commit towards academic activities (Zhao et al., 2004). It is the total effort students exert towards learning. Also, engagement is understood as an outcome influenced by both self-efficacy and environmental factors within AI-supported collaborative settings (Meishar-Tal & Pieterse, 2017). Pre-service teachers with higher confidence in their technical skills and belief in the AI tools' effectiveness are anticipated to engage more actively in collaborative activities. This engagement is critical to fostering a shared learning environment where pre-service teachers can collaboratively solve complex mathematical problems (Bandura, 1997). Due to flexibilities and benefits associated with using collaborative AI – assisted tools, it is easy to assume that students actively engage in academic activities on these AI – assisted tools. Yet, students' participation and involvement in academic activities is relatively low on collaborative learning AI – assisted tools (Meishar-Tal & Pieterse, 2017). They are much more engaged in social activities rather than actual academic activities. Meanwhile, studies that uncover predictors on Engagement on collaborative learning systems is scarce.

Empirical Studies

Globally, AI-assisted learning tools have been widely studied, with numerous findings underscoring their potential to foster collaboration and improve educational outcomes. A study by Holmes et al. (2019) in the United States showed that AI tools enhanced collaborative problem-solving among mathematics teachers by providing personalized feedback, allowing students to interact in real time, and offering insights into individual learning styles. The study highlighted that AI could significantly support mathematics instruction by enabling pre-service teachers to engage more actively and develop critical problem-solving skills.

Similarly, research by Lai, (2021) in Taiwan revealed that AI-assisted environments improved communication and group dynamics in teacher training programs. His findings suggested that AI tools, when well integrated, encouraged pre-service teachers to share ideas more openly, facilitated collaborative reflection, and helped resolve conflicts through data-driven insights. These benefits contributed to a more positive attitude toward collaborative learning and AI, aligning with the Technology Acceptance Model. However, challenges such as dependency on technology and issues related to data privacy were also noted, emphasizing the need for structured guidelines and ethical considerations when using AI in educational settings.

Finally, a study by Prilop et al., (2020) found that the use of digital tools in teacher training programs positively affected collaborative learning outcomes by enabling real-time feedback and promoting shared learning

experiences among pre-service teachers. However, this study also highlighted challenges such as limited technological infrastructure and a lack of familiarity with advanced tools like AI, which can hinder effective collaboration in learning environments.

Conceptual Framework

Based on the theoretical and empirical literature, this study's conceptual framework is designed to explore the complex interactions among perceptions, engagement, and outcomes in AI-assisted collaborative learning environments. The framework aligns with the research questions and addresses the following key concepts:

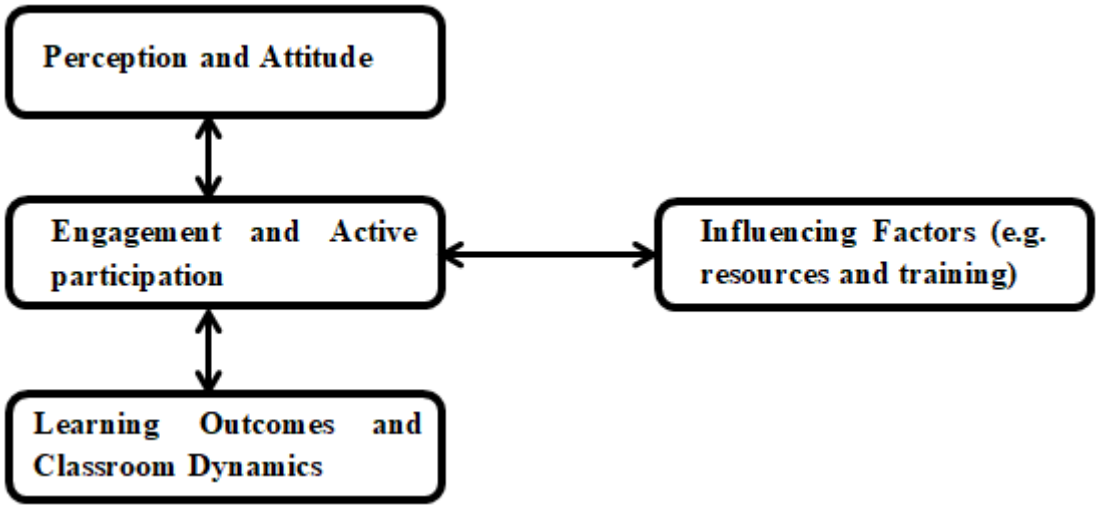

Figure 1. Conceptual Framework: AI–Assisted Collaborative Learning for Pre-service Mathematics Teachers

Source: Field survey, 2024

Perceptions and attitudes of pre-service teachers towards AI-assisted collaborative learning environments lead to *engagement and active participation* in collaborative learning activities. *Engagement and active participation* further influences, *learning outcomes and classroom dynamics* within AI-assisted settings. However, *influencing factors* (such as resources and training) also play a role in shaping *engagement and active Participation* in these environments.

Method

Research Paradigm

An interpretivist paradigm, which places emphasis on comprehending participants' subjective experiences and interpretations within their educational setting, served as the foundation for the qualitative study. According to interpretivism, people's meanings and perceptions are influenced by their interactions with their surroundings, and reality is socially created (Rehman & Alharthi, 2016). This paradigm fits in nicely with the study's objectives, which include examining how pre-service math teachers view and interact with AI-assisted collaborative learning and how different contextual elements affect their involvement. The study can delve deeply into teachers' attitudes, beliefs, and lived experiences in AI-facilitated learning environments by using an interpretivist method, which

captures subtleties that would not be apparent by using only quantitative data (Creswell & Creswell, 2018). This is essential to comprehending how educators perceive and react to the dynamics of AI-enhanced collaborative learning.

Research Design

The phenomenological technique, a qualitative research design that emphasizes comprehending participants' lived experiences and their interpretations of them, was selected (Van Manen, 2017). Because it focuses on analyzing the meanings pre-service teachers ascribe to their experiences in AI-assisted learning environments, particularly in collaborative settings, phenomenology is perfect for this study. Research questions that center on attitudes, perceptions, and the subjective elements driving participation in AI-enhanced collaborative learning are well-suited for this methodology. In order to identify and comprehend the underlying themes that define participants' experiences, the researcher in a phenomenological study must engage extensively with their narratives, frequently through interviews and thoughtful conversations. This method examines the meanings and contextual elements impacting pre-service teachers' interactions with AI tools, going beyond merely recounting experiences. The phenomenological method offers a deep, comprehensive understanding of the contextual and personal elements influencing pre-service teachers' attitudes toward and participation in AI-assisted collaborative learning (Vargas, 2023). A phenomenological method enables an examination of these distinctive components and their impact on participants' experiences, as this study focuses on how contextual factors like training, resource availability, and classroom dynamics affect teacher involvement (Merriam & Tisdell, 2015).

Participants

Three educational colleges of education in Ghana's third-largest region, the Ashanti Region, served as the study's sites. It occupies 10.2% of Ghana's land area and is situated in the southern region of the country. With a total population of 4,780,380, the region is the most diverse in Ghana. The Ashanti Region is well-known for producing cocoa and gold bars. Kumasi serves as the region's capital. The area is separated into 27 districts and shares borders with six other regions of Ghana. The group of examples from which the researcher wants to draw generalizations is known as the target population. This is the unit from which a sample is needed and is actually examined (Kothari, 2017). All level 200–400 pre-service math instructors at Akrokeri College of Education, Offinso College of Education, and Wesley College of Education for the 2024 academic year were the target population.

Sample & Sampling Techniques

Nine (9) pre-service mathematics teachers from three educational institutions in Ghana's Ashanti Region made up the study sample. Both male and female pre-service math teachers made up the sample and were pre-service math instructors in education colleges taught in basic schools. Before enrolling in the college of education as primary and JHS pre-service math instructors, they all completed their elementary, middle, and high school education. At these four levels, they have all encountered mathematics. Due to their focus on mathematics at that level, they

will all eventually graduate to teach mathematics in primary schools. In their fourth year of training, they will all participate in a full semester of teaching after completing a six-week supported teaching program in schools each semester. Their perspectives and experiences with mathematics for AI-assisted collaborative learning must therefore be disregarded. The willingness of the student-teacher to take part in the study was the initial selection criterion. Cconvenience sampling was combined with multi-stage deliberate sampling (Omona, 2013).

Pre-service teachers were available at various levels, therefore the multi-stage purposeful sampling was both appropriate and intentional for sampling each level. Once more, pre-service mathematics teachers who were available and eager were the target of the convenience strategy. Only nine (9) of the fifteen pre-service teachers who were supposed to take part in the study really agreed and did. In-depth interviews were done to ensure that the data reached points of saturation and sufficiency, which is circumstances in which adding more participants, had no discernible effect on the outcome, in order to prioritize quality over number (Shaheen et al., 2019). Nine pre-service math instructors participated in the study; six of them were male and three were female. Two of the male participants were from each of the three education colleges, while the female participants came from Akrokerri College of Education and Wesley College of Education, respectively. They were between the ages of 21 and 32.

Data Collection and Analysis Procedures

Using a semi-structured interview questionnaire, interviews were used to gather qualitative data. The principal and the director of the student department were informed of the purpose of the study in order to obtain their consent to have their pupils participate in the research. To ascertain the amount of primary school kids to choose from each level, inquiries were conducted regarding the year groups that were available on campus at the time. Following the selection, those student-teachers who made themselves accessible took part in the study after being informed of its goal. The decision to use interviews as a data collection method was informed by the goal and purpose. To enable a comprehensive investigation of the issue, open-ended questions were employed. For convenience and the ability to observe nonverbal clues, in-person interviews were done. Participants were selected based on their desire to take part, and confidentiality, anonymity, and respect were guaranteed by adhering to ethical guidelines.

Expert perspectives and the body of existing research were reviewed in order to construct the interview questions. To guarantee its robustness, the interview technique was improved over several rounds (Nowell et al., 2017). The duration of the interviews ranged from 34 to 39 minutes. To reduce inaccuracies, the researcher painstakingly transcribed the recorded interviews. Both the transcribed interviews and the others were played back to the sign language interpreter to ensure accuracy. To facilitate analysis, the transcribed interviews were then color-coded. Thematic analysis was used to analyze the data, and structured coding and code creation were employed to satisfy the study goals. In structured coding, questions that were related to passages with phrases were labeled with those terms, or the other way around (Belotto, 2018). This was accomplished by interacting with the data for a long time.

Trustworthiness

It is impossible to overstate the value and reliability of rigor in qualitative research since it guarantees that participant comments and experiences are accurately represented. In a qualitative study, it also guarantees that the researchers' conclusions accurately reflect the responses of the participants (Creswell & Creswell, 2018). Credibility—the degree to which the data set and its analysis are credible or authentic—was used to address issues of trustworthiness. Studies have shown that credibility, transferability, dependability, and confirmability are the primary tactics to assure rigor in qualitative studies (Sjoberg et al., 2020), despite the fact that there are other ways to ensure trustworthiness in qualitative research. For this reason, these measures have been selected. When interpretative research's conclusions are recognized and accepted, it gains credibility (Sjoberg et al., 2020).

Careful data management and analysis, the use of different data sources or collection methods to validate findings, and extensive fieldwork can all improve interpretive research. To guarantee reliability, the interview data was meticulously transcribed, precise contact and interview records were kept, and thorough notes on theoretical and methodological decisions were kept for convenient review. Due vigilance was maintained throughout the study to guarantee its validity. Using an authorized procedure, the analysis was conducted thematically. Because of the thorough descriptions of the study environment ("thick description") and the data's structures, assumptions, and techniques, readers can independently evaluate the findings' transferability (Creswell & Creswell, 2018).

This study includes thorough descriptions of the contextual elements related to the research site, techniques, analysis, and participant histories in order to facilitate the findings' transferability to other sites (Creswell & Creswell, 2018). The researchers took the time to describe the data gathering procedure in order to establish reliability and enable other independent researchers to do the study in other jurisdictions. When two researchers independently use the same evidence and a comparable process and come to the same conclusions or observations on different times, their interpretation of the data is considered reliable.

While test-retest reliability concentrates on the agreement between two observations made by a single researcher, inter-rater reliability deals with the degree of agreement among multiple researchers. This study gave justifications for methodological, theoretical, and analytical decisions made throughout so that the reader may assess the reasoning behind the conclusions. The idea of "inter-subjectivity" is employed to assess if study participants concur with the researcher's findings because interpretive research lacks objective reality. If study participants agree with the researcher's conclusions after reading a paper or report, they are considered confirmed. After the data was transcribed, participants received the interview data to confirm. This was done to make sure that none of the material that each participant submitted had been altered, paraphrased, or summarized.

Ethical Considerations

Construction of the instrument was done in consultation with experts and with approval from Institutional Review Board of Akenten Appiah – Menka University of Skills Training and Entrepreneurial Development with reference number (AAMUSTED/IERC/2024/026) on 21st May, 2024 was obtained. All participants completed informed

written consent before being recruited in this study. An approval from Ethics guidelines for human experimentation was adhered to.

Data Analysis

Thematic content analysis is essential to qualitative analysis. One qualitative analytical technique for finding, examining, and summarizing patterns in gathered data is thematic analysis. Thematic analysis aids in both the comprehension of collected data and its structure and thorough description (Kiger & Varpio, 2020). Thematic content analysis was used in conjunction with data collecting to analyze the data. A modified version of the Braun and Clarke method of data analysis was used to examine the gathered information. The six steps of thematic analysis are as follows, according Braun and Clarke (2006), as referenced in Byrne (2022): "becoming familiar with the data, creating preliminary codes, looking for themes, evaluating themes, defining and labeling themes, and creating a report, as shown in Table 1.

Table 1. Thematic Analysis

S/N	Phase	Description of the process
1.	Familiarizing yourself with your data.	Transcribing data (if necessary), reading and re-reading the data, noting down initial ideas.
2.	Generating initial codes:	Coding interesting features of the data in a systematic fashion across the entire data set, collating data relevant to each code.
3.	Searching for themes	Collating codes into potential themes, gathering all data relevant to each potential theme.
4.	Reviewing themes	Checking if the themes work in relation to the coded extracts (Level 1) and the entire data set (Level 2), generating a thematic ‘map’ of the analysis.
5.	Defining and naming themes	Ongoing analysis to refine the specifics of each theme, and the overall story the analysis tells, generating clear definitions and names for each theme.
6.	Producing the report	The final opportunity for analysis. Selection of vivid, compelling extract examples, final analysis of selected extracts, relating back of the analysis to the research question and literature, producing a scholarly report of the analysis.

Source (Braun & Clarke, 2006)

The responses were initially verbatim transcribed after being elicited in the English language. After that, the interview transcripts were read several times over. After completing the thematic analysis process, the research team produced primary and secondary themes that shaped the study report and offered precise responses to the research questions. (Source: Thompson, 2022).

Results

The analysis was targeted at finding answers the research questions;

1. What are the perceptions and attitudes of pre-service mathematics teachers towards AI-assisted collaborative learning environments?
2. What factors influence the engagement of pre-service mathematics teachers in AI-assisted collaborative learning environments?

Table 2. Identification of Main Themes and Sub – Themes

Main Themes	**Sub - Themes**	**Some Participants Responses**
1. Engagement in AI – assisted learning	1.1 Positive experience	"*The tool provided hints and guided us through complex equations*." (PT 1) "*AI facilitated our group discussions, making the experience engaging*." (PT 3) "*The AI tool adjusted based on our input, enhancing collaboration*." (PT 4)
	1.2 Enhancing factors	"*Personal interest boosts motivation*." (PT 2) "*Peer collaboration creates a positive atmosphere*." (PT 9) "*Facilitator involvement provides support.*" (PT 8)
	1.3 Hindering factors	"*Technical issues disrupted our collaboration*." (PT 7) "*Lack of support on using tools hindered engagement*." (PT 1) "*Group dynamics affect my willingness to participate*." (PT 5)
2. Technology comfort and	2.1 Prior experience	"*Comfort with technology positively influences engagement.*" (PT 6)

Main Themes	Sub - Themes	Some Participants Responses
experience		"*Limited exposure made me hesitant initially.*" (PT 4) "*Previous experience with online platforms enhances engagements.*" (PT 8)
	2.2 Influence on engagement	"*Understanding AI functions increases willingness to collaborate.*" (PT 9)
3. Design of AI tools	3.1 Usability	"*User – friendly designs encourage exploration.*" (PT 3) "*Intuitive features make collaboration easier.*" (PT 7)
	3.2 Interactive elements	"*Gamification keeps me interested.*" (PT 6) "*Customization enhances my experience.*" (PT 5)

Source: Field survey, 2024

The semi-structured interviews conducted with nine pre-service mathematics teachers yielded rich qualitative data, which were analyzed thematically. The responses revealed three main themes regarding perceptions and engagement in AI-assisted collaborative learning environments: engagement in AI-assisted learning, technology comfort and experience, and design of AI tools as shown in table 2. Each theme consists of sub-themes that provide a nuanced understanding of participants' experiences.

Engagement in AI-assisted Learning

Participants expressed diverse experiences regarding AI-assisted collaborative learning. Positive experiences were frequently highlighted, with many respondents noting that AI tools facilitated productive collaboration among peers. For instance, one participant remarked, "*The AI facilitated our group discussions, making the experience engaging*," (PT3). This sentiment was echoed by another participant, who stated, "The tool provided hints and guided us through complex equations," (Teacher 1). Conversely, hindering factors were also identified, particularly technical issues and a lack of support. One teacher shared, "*Technical issues disrupted our collaboration*," (PT7), indicating that such challenges could undermine the effectiveness of AI-assisted learning environments. Moreover, concerns regarding group dynamics emerged, with one participant noting, "*Group dynamics affect my willingness to participate*," (PT5).

Technology Comfort and Experience

The level of comfort with technology significantly influenced participants' engagement in AI-assisted learning environments. Respondents indicated that prior experience with technology shaped their willingness to engage with AI tools. As one teacher explained, "*Comfort with technology positively influences engagement,*" (PT 6),

highlighting the importance of familiarity in enhancing participation. However, some participants also voiced concerns about their limited exposure to technology, which initially made them hesitant. One respondent stated, "*Limited exposure made me hesitant initially*," (PT4), emphasizing the need for preparatory training in technology use.

Design of AI Tools

Participants emphasized the role of the design of AI tools in facilitating engagement. Usability emerged as a critical factor, with many teachers stating that user-friendly interfaces encouraged exploration and collaboration. One teacher commented, "*User-friendly designs encourage exploration*," (Teacher 1), while another added, "Intuitive features make collaboration easier," (PT3). Additionally, the interactive elements of AI tools, such as gamification, were noted to maintain interest and motivation. One participant remarked, "*Gamification keeps me interested*," (PT6), suggesting that the design of AI tools can significantly impact user engagement.

Discussion

The primary aim of this research was to explore the perceptions and engagement of pre-service mathematics teachers in AI-assisted collaborative learning environments. The findings from this study provide valuable insights into the perceptions and engagement of pre-service mathematics teachers in AI-assisted collaborative learning environments. The study identified three main themes: engagement in AI-assisted learning, technology comfort and experience, and design of AI tools. The identified themes align with existing literature that emphasizes the importance of both technological factors and human elements in educational technology (García-Peñalvo et al., 2020; Nussbaum et al., 2021). The findings indicate that while pre-service teachers recognize the potential of AI tools to enhance collaborative learning, their experiences are significantly influenced by their prior technology experiences, the usability of the tools, and the dynamics of group collaboration.

The findings from this study align with existing literature regarding the benefits of AI in educational settings. Similar to the work of Dillenbourg (2016), which highlights the role of collaborative learning in enhancing educational outcomes, participants in this study expressed positive perceptions of AI-assisted learning as a facilitator of peer interaction. However, unlike Dillenbourg's findings, which focused primarily on the theoretical underpinnings of collaborative learning, this research provides practical insights into the lived experiences of pre-service teachers, showcasing the real-world implications of AI technologies in collaborative contexts. Conforming with Hammouri & Abu-Shanab (2018) and Al-Samarraie et al. (2017), the findings further underline the importance of the information and service delivered on collaborative software. To reiterate, students' behaviour on collaborative learning AI – assisted tools depends on how well the tools augment learning. Therefore, students become discontent when the necessary support is unavailable or information available on collaborative learning AI – assisted tools misaligns with their needs. Similarly, Koranteng et. al. (2019) reflect that, because students actively communicate and interact on this platform, accurate information is needed to foster learning. Ultimately, this affects the time students devote to learning. It is however, imperative that institutions and developers of collaborative learning AI – assisted tools provide information that is relevant to students' academic activities.

Furthemore, the emphasis on technology comfort as a determinant of engagement supports previous research by Cober et al., (2015), which indicated that familiarity with technology can enhance students' participation in technology-enhanced learning environments. In contrast, while some studies suggest that technology use can be uniformly beneficial (Hwang & Chen, 2017), the current findings reveal a more nuanced perspective. Participants reported both enhanced engagement due to their comfort with technology and challenges stemming from limited exposure, suggesting that not all pre-service teachers are equally prepared to navigate AI tools effectively. This finding highlights the need for differentiated training approaches in teacher education programs to address varying levels of technological proficiency. The study's insights into the design of AI tools also echo findings from Fernandez (2024), who noted that user-friendly design significantly impacts learner engagement. However, while Fernandez emphasized design as a standalone factor, this study reveals it as part of a broader ecosystem involving personal experience and collaborative dynamics. For instance, respondents highlighted the importance of intuitive interfaces and gamification features as key elements that not only attract them to use AI tools but also enhance their collaborative experiences. This suggests that a multifaceted approach to AI tool design could be more effective in fostering engagement than previously recognized.

Conclusion

In conclusion, this research underscores the complex interplay between perceptions, technological comfort, and the design of AI tools in shaping pre-service mathematics teachers' engagement in AI-assisted collaborative learning environments. The findings demonstrate that while there is a general enthusiasm for AI tools among pre-service teachers, significant barriers exist that can hinder their effective utilization. The study contributes to the existing literature by offering insights into the specific experiences of pre-service teachers, highlighting both the potential benefits and the challenges associated with integrating AI in educational contexts.

Implications and Recommendations

The implications of this research are manifold. First, it is crucial for teacher education programs to incorporate comprehensive technology training that not only enhances comfort levels with AI tools but also prepares future educators to address potential technical challenges in collaborative settings. Furthermore, institutions should prioritize the design of AI tools to ensure they are user-friendly and engaging, employing principles of good design and gamification to motivate learners. Additionally, fostering an environment that encourages collaboration among peers can help mitigate concerns related to group dynamics, as highlighted by the participants in this study. Collaborative training sessions could be instrumental in developing both technological skills and interpersonal dynamics essential for effective group work. Finally, further research is needed to explore the long-term effects of AI-assisted collaborative learning on teaching practices and student outcomes. Future studies could examine the role of specific AI features in enhancing collaboration and learning, providing a clearer picture of how these technologies can best support educational objectives. By addressing these recommendations, educational stakeholders can better prepare pre-service mathematics teachers to leverage AI tools in their future classrooms, ultimately contributing to improved teaching practices and student learning outcomes.

Reference

Akosah, E. F., Boateng, F. O., Arhin, J., & Obeng, B. A. (2024). Assessing the readiness of preservice mathematics teachers to learn Euclidean geometry. *International Journal of Didactical Studies*, *5*(1), Article 24863. https://doi.org/10.33902/ijods.202424863

Aleven, V., McLaren, B. M., & Sewall, J. (2009). Scaling Up Programming by Demonstration for Intelligent Tutoring Systems Development: An Open-Access Web Site for Middle School Mathematics Learning. *IEEE Transactions on Learning Technologies*, *2*(2), 64-78. https://doi.org/10.1109/TLT.2009.22

Al-Samarraie, H., Teng, B. K., Alzahrani, A. I., & Alalwan, N. (2017). E-learning continuance satisfaction in higher education: a unified perspective from instructors and students. *Studies in Higher Education*, *43*(11), 2003–2019. https://doi.org/10.1080/03075079.2017.1298088

Bandura, A. (1997). *Self-efficacy: The exercise of control.* W. H. Freeman.

Belotto, M. J. (2018). Data analysis methods for qualitative research: Managing the challenges of coding, interrater reliability, and thematic analysis. *The Qualitative Report, 23*(11), 2622-2633. https://doi.org/10.46743/2160-3715/2018.3492

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

Byrne, D. (2022). A worked example of Braun and Clarke's approach to reflexive thematic analysis. *Quality & Quantity*, *56*(3), 1391–1412. https://doi.org/10.1007/s11135-02101182-y

Cárdenas, E.P.Z., Guaraca, D. P. S., Yánez, E. H. A, & Albán, A. L. M. (2023). The role of artificial intelligence in teaching-learning in higher education. *Knowledge Pole*, 8(3), 3028-3036. https://polodelconocimiento.com/ojs/index.php/es/article/vi ew/5542

Cober, R., Tan, E., Slotta, J., So, H. J., & Könings, K. D. (2015). Teachers as participatory designers: Two case studies with technology-enhanced learning environments. *Instructional Science*, *43*, 203-228. https://doi.org/10.1007/s11251-0149339-0

Creswell, J. W., & Creswell, J. D. (2018). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches*. SAGE Publications.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319–340. https://doi.org/10.2307/249008

Delgado, D. F. N., Campo-Carrasco, L., Sainz D. L. M. M. & Extabe-Urbieta, J. M. (2024). Application of Artificial Intelligence (AI) in Education: The benefits and limitations of AI perceived by teachers in primary education, secondary education and higher education. *Interuniversity Electronic Journal of Teacher Training*, 27(1), 207-224. https://doi.org/10.6018/reifop.577211

Dillenbourg, P. (2016). The evolution of research on digital education. *International Journal of Artificial Intelligence in Education*, *26*, 544-560. https://doi.org/10.1007/s40593-0160106-z

Ertmer, P. A., & Ottenbreit-Leftwich, A. T. (2019). Teacher technology change: How knowledge, confidence, beliefs, and culture intersect. *Journal of Research on Technology in Education*, 42(3), 255–284.

Farrokhnia, M., Banihashem, S. K., Noroozi, O., & Wals, A. (2023). A SWOT analysis of ChatGPT: Implications for educational practice and research. *Innovations in Education and Teaching International*, 1–15. https://doi.org/10.1080/14703297.2023.2195846

Fernandez, P. M. (2024). Evaluating UX design principles in a Haaga-Helia UAS Moodle course, a self-directed usability testing approach. https://urn.fi/URN:NBN:fi:amk2024050910358

Fu, Q. K., & Hwang, G. J. (2018). Trends in mobile technology-supported collaborative learning: A systematic review of journal publications from 2007 to 2016. *Computers & Education*, *119*, 129-143. https://doi.org/10.1016/j.compedu.2018.01.004

García-Peñalvo, J. F., Llorens-Largo, F., & Vidal, J. (2023). The new reality of education in the face of advances in generative artificial intelligence. *RIED-Ibero-American Journal of Education Distance*, *27*(1), 1-27. https://doi.org/10.5944/ried.27.1.37716

García V. J. J. (2021). Implication of artificial intelligence in virtual classrooms for higher education. *Orbis Tertius UPAL*, *5*(10), 31-52. https://doi.org/10.59748/ot.v5i10.98

Gómez-Gamero, M. E. (2019). Soft Skills Competencies for the new Millennium. *Divulgare*, *11*(1), 1-5. https://doi.org/10.29057/esa.v6i11.3760

Hammouri, Q., & Abu-Shanab, E. (2018). Exploring factors affecting users' satisfaction toward E-learning systems. *International Journal of Information and Communication Technology Education (IJICTE)*, *14*(1), 44-57. https://10.4018/IJICTE.2018010104

Holmes, W., Bialik, M., & Fadel, C. (2019). *Artificial intelligence in education – Promises and im-plications for teaching and learning.* The Center for Curriculum Redesign.

Hossain, M. A., Tarmizi, R. A., & Ayud, A. F. M. (2012). Collaborative and Cooperative Learning in Malaysian Mathematics Education. *Indonesian Mathematical Society Journal on Mathematics Education*, *3*(2), 103-114. http://www.jims-b.org/b

Hwang, G. J. & Chen, C. H. (2017). Influences of an inquiry-based ubiquitous gaming design on students' learning achievements, motivation, behavioral patterns, and tendency towards critical thinking and problem solving. *British Journal of Educational Technology*, *48*(4), 950-971. https://doi.org/10.1111/bjet.12464

Hwang, G.-J., Xie, H., Wah, B. W., & Gašević, D. (2020). Vision, challenges, roles and research issues of Artificial Intelligence in Education. *Computers and Education: Artificial Intelligence*, *1*, 100001. https://doi.org/10.1016/j.caeai.2020.100001

Islam, A. N. (2013). Investigating e-learning system usage outcomes in the university context. *Computers & Education*, *69*, 387-399. https://doi.org/10.1016/j.compedu.2013.07.037

Kiger, M. E., & Varpio, L. (2020). Thematic analysis of qualitative data: AMEE Guide No. 131. *Medical Teacher*, *42*(8), 846–854. https://doi.org/10.1080/0142159X.2020.1755030

Koranteng, F.N., Wiafe, I. (2019). Factors that Promote Knowledge Sharing on Academic Social Networking Sites: An Empirical Study. *Educ Inf Technol,* 24, 1211–1236. https://doi.org/10.1007/s10639-018-9825-0

Koranteng, F. N., Wiafe, I., & Kuada, E. (2013). An Empirical Study of the Relationship Between Social Networking Sites and Students' Engagement in Higher Education. *Journal of Educational Computing Research*, *57*(5), 1131-1159. https://doi.org/10.1177/0735633118787528

Lai, C. L. (2021). Exploring university students' preferences for AI-assisted learning environment. *Educational Technology & Society*, *24*(4), 1-15.

Lee, J., & Paul, N. (2023). A Review of Pedagogical Approaches for Improved Engagement and Learning Outcomes in Mathematics. *Journal of Student Research*, *12*(3).

https://doi.org/10.47611/jsrhs.v12i3.5021

Luckin, R., George, K., & Cukurova, M. (2022). *AI for School Teachers*. CRC Press. https://doi.org/10.1201/9781003193173

Meishar-Tal, H., & Pieterse, E. (2017). Why do academics use academic social networking sites?. *International Review of Research in Open and Distributed Learning*, *18*(1), 1-22. https://doi.org/10.19173/irrodl.v18i1.

Mena-Guacas, A. F., Vázquez-Cano, E., Fernández-Márquez, E., & López-Meneses, E. (2023). Artificial intelligence and its scientific production in the field of Education. *Formación Universitaria*, *17*(1), 155-164. http://dx.doi.org/10.4067/S0718-50062024000100155

Merriam, S. B., & Tisdell, E. J. (2015). *Qualitative research: A guide to design and implementation*. John Wiley & Sons.

Motaghian, H., Hassanzadeh, A., & Moghadam, D. K. (2013). Factors affecting university instructors' adoption of web-based learning systems: Case study of Iran. *Computers & Education*, *61*, 158-167. https://doi.org/10.1016/j.compedu.2012.09.016

Neumann, D. L., & Hood, M. (2009). The effects of using a wiki on student engagement and learning of report writing skills in a university statistics course. *Australasian journal of educational technology*, *25*(3). https://doi.org/10.14742/ajet.1141

Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods, 16*(1), 1-13. https://doi.org/10.1177/1609406917733847

Nussbaum, M., et al. (2021). The future of learning: AI in education. *International Journal of Educational Technology in Higher Education*, 18(1), 1-14.

Omona, J. (2013). Sampling in qualitative research: Improving the quality of research outcomes in higher education. *Makerere Journal of Higher Education, 4*(2), 169-185. https://doi.org/10.4314/majohe. v4i2.4

Prilop, C. N., Weber, K. E., & Kleinknecht, M. (2020). Effects of digital video-based feedback environments on pre-service teachers' feedback competence. *Computers in Human Behavior*, *102*, 120-131. https://doi.org/10.1007/s11423-016-9438-5

Rehman, A. A. & Alharthi, K. (2016). An introduction to research paradigms. *International Journal of Educational Investigations, 3*(8), 51-59.

Shaheen, M., Pradhan, S., & Ranajee, R. (2019). Sampling in qualitative research. In M. Gupta, M. Shaheen, & K. P. Reddy (Eds.), *Qualitative techniques for workplace data analysis* (pp.25-51). IGI Global. https://doi.org/10.4018/978-1-5225-5366-3.ch002

Sjoberg, G., Orum, A. M., & Feagin, J. R. (2020). *A case for the case study*. The University of North Carolina Press. https://muse.jhu.edu/pub/12/monograph/book/77227

Straková, Z., & Cimermanová, I. (2018). Critical thinking development—A necessary step in higher education transformation towards sustainability. *Sustainability*, *10*(10), 3366. https://doi.org/10.3390/su10103366

Thompson, J. (2022). *A guide to abductive thematic analysis*. https://napierrepository.worktribe.com/output/2865363/a-guide-to-abductivethematic-analysis

Van Manen, M. (2017). But is it phenomenology?. *Qualitative health research*, *27*(6), 775-779. https://doi.org/10.1177/1049732317699570

Vargas, N. (2023). *Secondary ELA Teacher Perceptions of the Use of Artificial Intelligence as an Instructional Tool*. Lamar University-Beaumont.

Vera, F. (2023). Integration of Artificial Intelligence in Higher education: Challenges and opportunities. *Transform electronic Journal, 4*(1), 17-34. https://www.revistatransformar.cl/index.php/transformar/article/view/84

Vuorikari, R., Kluzer, S., & Punie, Y. (2022). *DigComp 2.2 - The Digital Competence Framework for Citizens*. https://doi.org/10.2760/115376

Vygotsky, L. S. (1978). *Mind in society: The development of higher psychological processes.* Harvard University Press.

Zawacki-Richter, O., Marín, V. I., Bond, M., & Gouverneur, F. (2019). Systematic review of research on artificial intelligence applications in higher education – where are the educators? *International Journal of Educational Technology in Higher Education*, *16*(1), 39. https://doi.org/10.1186/s41239-019-0171-0

Zhao, CM., Kuh, G.D. (2004). Adding Value: Learning Communities and Student Engagement. *Research in Higher Education, 45*, 115–138 https://doi.org/10.1023/B:RIHE.0000015692.88534.de

Author Information

Ernest Frimpong Akosah

https://orcid.org/0000-0002-9792-5311

Peki College of Education

Ghana

Contact e-mail: *akferst@gmail.com*