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Comparative Effect of Collaborative and Traditional Learning Strategies on Senior High School Students' Performance in Circle Theorems

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Abstract

This study examined the comparative effects of collaborative learning and the traditional learning strategy on senior high school students' performance in circle theorems. The motivation stemmed from persistent concerns about low achievement in geometry among Ghanaian students, often attributed to reliance on teacher-centered instructional approaches. Guided by the principles of social constructivism, the study adopted a quantitative paradigm with a quasi-experimental design. Two intact classes were purposively selected from Senior High School B and Senior High School A. In total, 152 students participated, comprising 76 in the experimental groups (collaborative learning) and 76 in the control groups (traditional lecture method). The intervention involved problem-solving in structured groups, peer explanation and facilitated discussion during four weeks, whereas the control group was provided with a regular lecture-based instruction. A one-item researcher designed Circle Theory Performance Test comprising 20 items in multiple choices format was used to gather data. The independent samples t-test was employed to test the difference between groups in terms of post-test scores. The findings revealed that students exposed to collaborative learning significantly outperformed their counterparts taught with the traditional method, suggesting that collaborative approaches promote deeper conceptual understanding and problem-solving skills in geometry. The study concludes that collaborative learning is a more effective instructional strategy for teaching circle theorems at the senior high school level. It recommends that mathematics teachers integrate structured peer learning approaches into classroom instruction to enhance learning outcomes.

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Introduction

Mathematics remains one of the most fundamental disciplines for developing logical reasoning, critical thinking, and problem-solving skills. It is indispensable for academic success and is widely recognized as a gateway to careers in science, technology, engineering, and mathematics (STEM) fields. Beyond these domains, mathematics equips learners with analytical and quantitative competencies essential for 21st-century global citizenship, where technological advancement and innovation increasingly rely on strong mathematical foundations (OECD, 2019). Despite its significance, global learning outcomes indicate that mathematics continues to pose substantial challenges to students, with geometry consistently emerging as one of the weakest areas (NCTM, 2020; Jablonski & Ludwig, 2023).

Geometry is particularly critical because it provides the foundation for advanced mathematical concepts such as trigonometry, calculus, and algebra, and also supports applications in fields like engineering, architecture, computer graphics, and design. Within geometry, Circle Theorems are of central importance, covering key relationships such as angles at the center and circumference, cyclic quadrilaterals, and tangent properties. These concepts not only cultivate spatial reasoning and higher-order thinking but also feature prominently in external assessments, including the West African Senior School Certificate Examination (WASSCE). Yet, evidence consistently shows that students struggle to grasp these theorems, often exhibiting misconceptions or avoiding such questions altogether (Thamae, 2022; Emelda et al., 2024).

The problem is particularly important in Ghana, where mathematics performance at the senior high school level remains a persistent concern. Although mathematics is a core subject and a prerequisite for higher education and professional pathways, students' outcomes in national examinations continue to fluctuate. According to the Ministry of Education's Education Sector Performance Report in 2024, the percentage of candidates who obtained credit passes (A1–C6) in Core Mathematics showed an inconsistent pattern between 2020 and 2023: 65.71% in 2020, dropping sharply to 54.11% in 2021, then improving to 61.39% in 2022 and 62.23% in 2023. Similarly, the proportion of students who scored F9 rose from 13.40% in 2020 to a worrying 20.11% in 2021, before declining to 10.48% in 2022 and further to 8.90% in 2023 (Enoch, 2023). When compared with other core subjects such as Social Studies, Integrated Science, and English Language, mathematics consistently emerged as one of the most challenging areas for students (Enoch, 2023).

Beyond overall performance, successive WAEC Chief Examiners' Reports have repeatedly identified Circle Theorems as among the most poorly understood and challenging topics in Core Mathematics. Students not only avoid these questions but also demonstrate deep-seated misconceptions, reflecting gaps in both procedural fluency and conceptual understanding (Aidoo-Bervell, 2021). These persistent weaknesses suggest that prevailing teaching approaches may not be effectively addressing the demands of this crucial area of geometry.

A key contributing factor is the widespread reliance on traditional instructional strategies. Teacher-centered methods often characterized by rote memorization, chalk-and-talk delivery, and minimal student participation promote surface learning but fail to foster the reasoning, collaboration, and problem-solving abilities necessary

for mastering geometry (Shrestha, 2022). While such approaches may facilitate short-term recall, they do not adequately address the deeper conceptual understanding required for Circle Theorems. This limitation has sparked global calls for pedagogical reform, with international frameworks such as UNESCO (2021) advocating for learner-centered, interactive strategies that actively engage students in constructing mathematical meaning.

One promising approach is collaborative learning, which is rooted in Vygotsky's (1978) socio-constructivist theory. This perspective emphasizes the social nature of learning, where knowledge is co-constructed through interaction, dialogue, and shared problem-solving. Collaborative learning encourages students to articulate reasoning, confront misconceptions, and engage in peer-to-peer teaching processes shown to significantly enhance comprehension and retention (Gillies, 2016). Empirical evidence supports its effectiveness: Sekhar and Goud (2024) conducted a case study among computer science students, showing that collaborative learning techniques in Python programming enhanced both engagement and comprehension compared to conventional lecture-based teaching. Similarly, Dong et al. (2021) demonstrated that a flipped classroom model enriched by collaborative learning led to improved outcomes in community nursing education, underscoring the relevance of interaction and situational learning in professional training. In the Ghanaian context, Mensah-Wonkyi and Adu (2016) similarly found that collaborative approaches promote deeper understanding and critical thinking compared to conventional methods. Similarly, Akendita et al. (2024) investigated the effect of socio-constructivist mathematics teaching on students' mathematics achievement found that socio-constructivist mathematics teaching which is characterized by collaborative learning, significantly enhanced students' mathematics achievement. Another study conducted by Mifetu (2023) using activity method to address students' problem-solving difficulties in circle geometry and found that students' performance in circle got improved.

This study is both theoretically and practically important. Theoretically, it adds to the socio social-constructivist views by offering empirical data on the effectiveness of collaborative learning in improving the knowledge of students concerning abstract geometry concepts, the Circle theorems, which have hitherto been a neglected area in previous studies using the Ghanaian schools as the sample. In practice, the results would inform mathematics educators and curriculum designers to incorporate student centered methods, which would encourage more profound conceptual knowledge, critical thinking and problem solving. The evidence that would be created would aid both the Ghana Education Service (GES) and the National Council on Curriculum and Assessment (NaCCA) to foster collaborative and activity-based teaching in accordance with national education reforms. In general, the research would improve the teaching process, influence the choice of the curriculum, and add to the international discussion on the effective mathematics study pedagogies.

Despite this evidence of the importance and its effectiveness, a notable gap persists in empirical research that directly compares the impact of collaborative and traditional instructional strategies on students' performance in Circle Theorems. While prior studies in Ghana have examined mathematics achievement more broadly, very few have focused specifically on geometry, and even fewer on Circle Theorems an area with distinct conceptual demands and persistent examination weaknesses. Furthermore, existing studies often rely on single-school samples, which limits the generalizability of their findings (Assan-Donkoh et al., 2019; Enoch, 2024). Little is known about how these strategies function across different school contexts, leaving a critical gap in evidence-

based pedagogical recommendations.

This study, therefore, addresses this gap by comparatively examining the effects of collaborative and traditional learning strategies on senior high school students' performance in Circle Theorems, using two senior high schools located in different settings. Grounded in socio-constructivist theory, the study makes both theoretical and practical contributions: it tests the applicability of collaborative learning for abstract mathematical concepts in diverse contexts, while also offering concrete insights for teachers, curriculum developers, and policymakers seeking to improve mathematics instruction in Ghana. By situating the comparison across two schools, the study not only responds to a persistent area of student difficulty but also strengthens the robustness and transferability of its findings. Ultimately, this work contributes to broader efforts aimed at enhancing mathematics learning outcomes in Ghana and other similar educational contexts worldwide.

Objective of the Study

To determine whether there is a significant difference in students' performance in circle theorems between those taught using the traditional learning strategy and those taught using the collaborative learning strategy.

Research Hypothesis

There is no significant difference in students' performance in circle theorems between those taught using the traditional learning strategy and those taught using the collaborative learning strategy.

Theoretical Foundation

Social Constructivism Theory

Social Constructivism is a learning theory rooted in the works of Lev Vygotsky (1978), who proposed that knowledge is co-constructed through social interaction and communication. Unlike traditional theories that emphasize individual cognition, social constructivism views learning as a collaborative endeavor, where learners build understanding through engagement with others in their cultural and social context. One of the central tenets of this theory is the Zone of Proximal Development (ZPD), which represents the gap between what a learner can do independently and what they can accomplish with support from a more knowledgeable peer or teacher (Vygotsky, 1978). In educational practice, the ZPD underpins the value of guided interaction, where teachers or peers provide scaffolding that enables learners to achieve more complex understanding than they could alone. Social constructivism also emphasizes the importance of language and dialogue in learning, advocating for environments where students can articulate, defend, and reflect on their thinking (Saleem et al., 2021). This theoretical framework has been widely adopted in mathematics education because it promotes active participation, reasoning, and problem-solving through discourse. In the context of mathematics instruction, particularly in teaching geometry topics like circle theorems, social constructivism has been shown to support conceptual development. For example, Engelbrecht and Oates (2022) argue that when students are engaged in meaningful mathematical dialogue and collaborative problem-solving, they are more likely to internalize complex ideas.

Similarly, Khormi (2023) emphasizes that learning geometry through discussion and peer collaboration helps students visualize relationships between geometric figures and articulate their reasoning, which fosters deeper understanding.

Collaborative learning aligns strongly with social constructivist principles. When students work in groups to explore circle theorems, they do not only share answers but also justify their solutions, question their peers, and revise their thinking based on feedback. These practices enhance both procedural fluency and conceptual understanding, which are critical for academic success in mathematics (Shrestha, 2022) Furthermore, research suggests that socially mediated learning environments can bridge gaps in student performance by providing equitable opportunities for learners to engage with content at their own level of understanding while being supported by peers and teachers (Memon & Memon, 2025). This is particularly relevant in settings where students come from diverse backgrounds, as is common in Ghanaian senior high schools. Through collaborative activities, students construct knowledge that is both personal and shared, leading to improved mathematical reasoning and achievement (Sujatha & Vinayakan, 2022).

The Social Constructivism Theory is appropriate for this study because it provides a robust explanation of how collaborative learning strategies can influence students' academic performance, especially in challenging mathematics topics like circle theorems. The theory's emphasis on social interaction, dialogue, and scaffolded learning directly supports the collaborative learning framework being implemented in this research. According to Minarni and Napitupulu (2020) constructivist-based instruction, particularly when grounded in group work and dialogic inquiry, fosters higher-order thinking and retention of mathematical concepts. Additionally, the theory offers a strong foundation for interpreting the role of student collaboration in both urban and rural school contexts, where access to instructional resources may differ. By adopting social constructivism, this study acknowledges that learning is not merely about individual cognition but also about co-constructing knowledge through peer interaction. This makes it a suitable theoretical lens for analyzing the comparative effect of collaborative and traditional learning strategies on students' geometry performance. Recent studies have reaffirmed the relevance of socio-constructivist approaches in mathematics teaching. For instance, Akendita et al. (2024) demonstrated that socio-constructivist instruction significantly improved students' mathematics achievement, with mathematics self-efficacy serving as a mediating factor. This finding highlights the potential of socially oriented instructional strategies, such as collaborative learning, to foster deeper engagement and improved performance in mathematics.
Traditional Learning Strategy and the Collaborative Learning Strategy

Several studies have compared traditional learning strategies with collaborative approaches across different educational contexts, consistently demonstrating the value of student-centered methods. Sekhar and Goud (2024) conducted a case study among computer science students, showing that collaborative learning techniques in Python programming enhanced both engagement and comprehension compared to conventional lecture-based teaching. Similarly, Dong et al. (2021) demonstrated that a flipped classroom model enriched by collaborative learning led to improved outcomes in community nursing education, underscoring the relevance of interaction and situational learning in professional training.

The effectiveness of collaborative learning is not confined to technical or professional courses. Shadrack and Ogheneakoke (2020s) investigated social studies classrooms in Delta State, finding that students exposed to collaborative strategies outperformed those taught through traditional methods. Al-Mubireek (2021) further corroborated these findings in a TESOL context, where cooperative learning significantly enhanced students' achievement relative to lecture-based instruction. Likewise, Mendo-Lázaro et al. (2022) showed that cooperative learning positively influenced university students' academic goals, promoting motivation and achievement beyond content mastery.

Comparative studies in the health sciences also affirm the limitations of traditional instruction. Gudadappanavar, Benni, and Javali (2021) found that game-based collaborative learning was more effective than conventional teaching for medical students in pharmacology, leading to greater retention and engagement. Extending to the post-pandemic era, Sun et al. (2025) highlighted how computer-supported collaborative learning environments improved both cognitive outcomes and student interaction compared to solitary study, reinforcing the adaptability of collaborative strategies in digital contexts. Recent studies also emphasize the role of collaboration in fostering critical thinking and transferable skills. Mugabekazi et al. (2025) revealed that integrating collaborative strategies into the primary school curriculum significantly improved learners' communication and critical thinking abilities. In a broader perspective, Bhardwaj et al. (2025) argued that collaborative, student-centered learning strategies not only support academic performance but also enhance personal growth, indicating their relevance to holistic education. Similarly, Akendita et al. (2024) found that students exposed to socio-constructivist mathematics instruction significantly outperformed those taught using conventional approaches, further supporting the view that collaborative and socially mediated learning environments enhance mathematics achievement. Although traditional learning strategies remain widely used, the cumulative evidence suggests that collaborative methods offer superior benefits across disciplines, levels of education, and learning environments. The consistency of these findings highlights the importance of shifting from teacher-centered to student-centered approaches in order to maximize both academic and developmental outcomes.

Methodology

This study adopted a quantitative research approach within the positivist paradigm, focusing on the collection and analysis of numerical data to test hypotheses and examine relationships between variables. The approach was appropriate for systematically measuring the effect of collaborative learning on students' performance in circle theorems, as it emphasized objectivity, reliability, and generalizability. Structured instruments such as pre-tests and post-tests were employed, alongside inferential statistics, to generate empirical evidence on learning outcomes.

The research employed a quasi-experimental non-equivalent pre-test–post-test control group design to evaluate the impact of collaborative learning on senior high school students' performance. This design was chosen because full random assignment of participants was not feasible in natural classroom settings, but the use of intact classes and pre-tests helped establish equivalence between groups and enhanced validity. The quasi-experimental design allowed the researcher to compare an experimental group taught using collaborative learning with a control group

taught using the traditional lecture method, thereby providing practical feasibility while maintaining scientific rigor (Beigzadeh et al., 2024). The population for the study consisted of second-year Core Mathematics students from two senior high schools in the Ashanti Region of Ghana: Senior High School A, located in an urban setting, and Senior High School B, situated in a semi-rural area. These schools were purposively selected due to accessibility, willingness to participate, and comparability in curriculum and teaching staff. The accessible population comprised four intact SHS 2 classes, with each school providing one control group and one experimental group. This produced a total of 152 students, with 79 in the control groups and 73 in the experimental groups.

The intervention was a four-week instructional intervention that utilized a quasi-experimental study design that involved pre-test and post-test. Two senior high schools were to be used: Senior High School A (urban) and Senior High Technical School B (rural). There were two intact classes in every school which were selected. A single class was used as an experimental group (collaborative learning strategy) and the other one as a control group (traditional lecture method).Prior to the intervention, a pre-test comprising of 20 multiple-choice questions on Circle Theorems was given to the two groups to create a baseline of equivalence between them in mathematical performance. The identical instrument, redesigned to a post-test, was applied at the end of the instructional period in order to determine the achievement gains that could be attributed to the teaching strategy. The students were put into small groups in the experimental groups. The lessons were in a structured format that entailed teacher introduction of concepts, group-problem solving and peer explanations, and class-wise discussion and reflection. The teacher played a facilitative role, mainly guiding discussions, clarifying misconceptions, and monitoring participation. On the other hand, the control groups were taught using the conventional lecture-based method. Lessons involved teacher explanation, and board demonstrations, with minimal student interaction. The two groups studied the same contents of the Circle themes of the same four weeks, with the same lesson objectives, materials and tests to provide the instructional continuity.

A purposive sampling technique was used in selecting both the schools and the intact classes, in line with the quasi-experimental design which does not permit random assignment of individuals. At Senior High School A, one General Arts class was designated as the experimental group and another as the control group, while the same arrangement was applied at Senior High School B. This ensured instructional continuity while minimizing disruptions to normal school activities, and it also guaranteed that participants possessed the relevant characteristics needed for the study. The two intact classes constituted the sample for the study. The primary data collection instrument was a researcher-designed mathematics achievement test on circle theorems, which contained twenty multiple-choice items. The questions were based on the SHS 2 Core Mathematics syllabus and covered key concepts such as angles in a semicircle, cyclic quadrilaterals, tangents, and alternate segment theorem. Items were structured at different cognitive levels knowledge, comprehension, and application allowing the instrument to measure both recall and problem-solving abilities. The test was administered as a pre-test to determine baseline knowledge and as a post-test to measure learning gains after the intervention.

Validity and reliability of the test were carefully established. Content validity was ensured through a table of specifications and expert review by two experienced SHS mathematics teachers and one university mathematics

education lecturer (Homuame, 2021). Ambiguous items were revised based on their feedback. Reliability was assessed through a pilot test involving twenty SHS 2 students from a different but comparable school, and the Kuder-Richardson 20 (KR-20) formula yielded a coefficient of 0.82, indicating high internal consistency (Ole et al., 2021).Data analysis was conducted using SPSS version 23. Descriptive statistics such as means, standard deviations, and frequencies were computed to provide an overview of students' performance. Inferential statistics were carried out using independent samples t-tests at a 0.05 level of significance. One hypothesis was tested: whether there was a difference in performance between students taught with collaborative learning and those taught with traditional methods. The analysis enabled the study to test cause-and-effect relationships systematically and draw valid conclusions.

The study adhered strictly to ethical considerations to safeguard participants' rights and well-being. Informed consent was sought from school authorities, parents or guardians, and the participating students. Confidentiality and anonymity were maintained by coding responses and avoiding the use of personal identifiers in reporting. Participation was voluntary, and students were informed that they could withdraw at any point without consequences. Data were securely stored and used solely for academic purposes. The intervention posed no harm but was designed to enhance the teaching and learning of mathematics. These measures ensured that the study was conducted responsibly, with transparency and academic integrity.

Results

The Difference in the Academic Performance of Students in the Experimental and Control Groups before the Treatment at SHS A. This section presents the results of an independent samples t-test conducted to determine whether there was any statistically significant difference in academic performance between the experimental and control groups prior to the intervention. The analysis focused on pre-test scores obtained from both groups at Senior High School A, where the collaborative learning strategy was later introduced. Establishing the absence of a significant difference at this stage ensures that both groups started at a comparable academic level before the treatment was applied. The Table 1 below presents the results of an independent t-test conducted to compare the academic performance of students in the experimental and control groups before the treatment.

Table 1. Independent t-Test for Pre-Test Comparison of Academic Performance between Groups at SHS A

Test	Group	N	Mean	SD	t	df	Sig.	Eta Sqrt
Pre-test	Control	39	10.17	2.06	.436	73	.664	.003
	Experimental	36	9.97	2.05				

Source Field Survey (2025)

An independent samples t-test was conducted to determine whether there was a significant difference in academic performance between the control and experimental groups prior to the introduction of the collaborative learning strategy at Senior High School A. This analysis was necessary to establish a baseline equivalence between the two groups. The results, as shown in Table 1, indicate that the control group *(M = 10.17, SD = 2.06),* while the experimental group *(M = 9.97, SD = 2.05).* The t-test revealed that this difference was not statistically significant,

[t (73) = 0.436, p = .664]. This implies that the academic performance of both groups was comparable before the treatment. To determine the strength of the difference, an effect size was computed using eta squared. The result .003, suggests a very small effect size, indicating that the variation in scores between the two groups before the treatment was negligible (Cohen, 1988). Based on these results, the null hypothesis which stated that there is no significant difference in the pre-test academic performance between the control and experimental groups is retained. This finding confirms that any subsequent differences observed in post-test scores are more likely attributable to the intervention rather than initial group disparities.

The Difference in Students' Performance in Circle Theorems between Traditional Learning Strategy and the Collaborative Learning Strategy at SHS A

This section presents the results of an independent samples t-test conducted to examine whether the collaborative learning strategy had a statistically significant effect on students' performance in circle theorems compared to the traditional learning strategy. The analysis is based on the post-test scores of students in the control group (who received traditional instruction) and the experimental group (who were taught using collaborative learning) at Senior High School A. This comparison was aimed at evaluating the effectiveness of collaborative learning in improving students' academic outcomes in geometry.

Table 2. Independent t-Test for Post-Test Comparison of Academic Performance between Traditional and Collaborative Learning Strategies at SHS A

Test	Group	N	Mean	SD	t	df	Sig.	Eta Sqrt
Post-test	Control	39	13.10	1.51	-8.217	73	.000	.48
	Experimental	36	15.88	1.40				

Source Field Survey (2025)

An independent samples t-test was conducted to determine whether there was a statistically significant difference in students' performance in circle theorems between those taught using the traditional learning strategy (control group) and those taught using the collaborative learning strategy (experimental group). This analysis was based on the post-test scores from Senior High School A. As presented in Table 2, students in the control group *(M = 13.10, SD = 1.51).* On the other hand, the experimental group *(M = 15.88, SD = 1.40).* The independent samples t-test yielded a statistically significant result*, [t (73) = -8.217, p < .001],* indicating a clear difference in academic performance between the two instructional approaches.

To assess the magnitude of this difference, an effect size was computed using eta squared. An eta squared value of .48 was noted and indicates a large effect size (Cohen, 1988), suggesting that the learning strategy accounted for a substantial portion of the variance in students' academic performance in circle theorems. Based on this result, the null hypothesis which stated that there is no significant difference in students' performance in circle theorems between traditional and collaborative learning strategies is rejected. This finding implies that the collaborative learning strategy had a significantly greater positive impact on student achievement in the topic compared to the traditional method.

The Difference in the Academic Performance of Students in the Experimental and Control Groups Before the Treatment at SHS B

This section presents the results of an independent samples t-test conducted to determine whether there was any statistically significant difference in academic performance between the experimental and control groups *prior to the intervention***.** The analysis focused on pre-test scores obtained from both groups at SHS B, where the collaborative learning strategy was later introduced. Establishing the absence of a significant difference at this stage ensures that both groups started at a comparable academic level before the treatment was applied. The Table 3 below presents the results of an independent t-test conducted to compare the academic performance of students in the experimental and control groups before the treatment at SHS B.

Table 3. Independent t-Test for Pre-Test Comparison of Academic Performance between Groups at SHS B

Test	Group	N	Mean	SD	t	df	Sig.	Eta Sqrt
Pre-test	Control	40	10.20	2.37	-.657	75	.513	.006
	Experimental	37	10.54	2.17				

Source Field Survey (2025)

An independent samples t-test was conducted to determine whether there was a significant difference in the pre-test scores of students in the control and experimental groups at Senior High School B before the collaborative learning intervention. The results revealed that the control group *(M = 10.20, SD = 2.37)* and the experimental group *(M = 10.54, SD = 2.17)* did not differ significantly in their pre-test performance, *[t (75) = –0.657, p = .513].* The p-value exceeds the alpha level of .05, indicating that the difference in mean scores between the two groups was not statistically significant.

Additionally, the calculated effect size of 0.006 was minimal, suggesting a negligible practical difference between the groups' performances before the intervention (Cohen, 1988). Since $p > .05$, the null hypothesis is retained. This means there was no significant difference in academic performance between the experimental and control groups before the treatment at SHS B. This result confirms that both groups were statistically equivalent in their understanding of circle theorems prior to the intervention, supporting the internal validity of the study for evaluating the impact of collaborative learning.

The Difference in Students' Performance in Circle Theorems between Traditional Learning Strategy and the Collaborative Learning Strategy at SHS B

This section presents the results of an independent samples t-test conducted to examine whether the collaborative learning strategy had a statistically significant effect on students' performance in circle theorems compared to the traditional learning strategy. The analysis is based on the post-test scores of students in the control group (who received traditional instruction) and the experimental group (who were taught using collaborative learning) at SHS B. This comparison was aimed at evaluating the effectiveness of collaborative learning in improving students' academic outcomes in circle theory.

Table 4. Independent t-Test for Post-Test Comparison of Academic Performance between Traditional and Collaborative Learning Strategies at SHS B

Test	Group	N	Mean	SD	t	df	Sig.	Eta Sqrt
Post-test	Control	40	13.28	1.54	-7.542	75	.000	.431
	Experimental	37	15.89	1.51				

Source Field Survey (2025)

An independent samples t-test was conducted to determine whether there was a significant difference in post-test academic performance between students taught using the traditional learning strategy (control group) and those taught using the collaborative learning strategy (experimental group) at Senior High School B. The results showed that students in the experimental group *(M = 15.89, SD = 1.51)* scored significantly higher than those in the control group *(M = 13.28, SD = 1.54)*, *[t (75) = –7.542, p = .000].* The p-value is less than the conventional alpha level of .05, indicating a statistically significant difference in performance between the two groups. To assess the practical significance of this result, eta squared was calculated: This effect size (.431) was noted and indicates a large practical impact, meaning the collaborative learning strategy had a strong influence on student performance in circle theorems (Cohen, 1988). Since $p < .05$, the null hypothesis is rejected. This indicates that a significant difference exists between the academic performances of students taught through traditional versus collaborative learning strategies at SHS B, with collaborative learning proving more effective.

Discussion

The Difference in Students' Performance in Circle Theorems between the Traditional Learning Strategy and the Collaborative Learning Strategy

The findings from this study revealed that students who were taught using the collaborative learning strategy demonstrated significantly higher performance in circle theorems compared to those who received instruction through the traditional learning approach. This trend was consistent across both Senior High School A and Senior High School B, where the experimental (collaborative) groups outperformed the control (traditional) groups with large effect sizes. These results suggest that collaborative learning fosters a deeper understanding and mastery of mathematical concepts, particularly in geometry-related topics such as circle theorems.

The superiority of collaborative learning in this context can be best understood through the lens of Social Constructivist Theory. From the Social Constructivist perspective (Vygotsky, 1978), knowledge is constructed through interaction, dialogue, and shared experiences. The improved performance observed among students in the collaborative groups indicates that peer discussion, joint problem-solving, and scaffolding played a pivotal role in helping students' co-construct meaning. The collaborative environment allowed learners to operate within their Zone of Proximal Development (ZPD), where they were supported by more capable peers or group consensus in making sense of complex geometric relationships.

Empirical studies conducted in Ghana also supports this study findings, for instance Akendita et al. (2024) who examines the influence of Socio-Constructivist Mathematics Teaching on students' mathematics achievement,

found that Socio-Constructivist Mathematics Teaching significantly enhanced mathematics achievement. Sekhar and Goud (2024) conducted a case study among computer science students, showing that collaborative learning techniques in Python programming enhanced both engagement and comprehension compared to conventional lecture-based teaching. Similarly, Dong et al. (2021) demonstrated that a flipped classroom model enriched by collaborative learning led to improved outcomes in community nursing education, underscoring the relevance of interaction and situational learning in professional training. Comparative studies in the health sciences also affirm the limitations of traditional instruction. Gudadappanavar et al. (2021) found that game-based collaborative learning was more effective than conventional teaching for medical students in pharmacology, leading to greater retention and engagement. Extending to the post-pandemic era, Sun et al. (2025) highlighted how computer-supported collaborative learning environments improved both cognitive outcomes and student interaction compared to solitary study, reinforcing the adaptability of collaborative strategies in digital contexts.

Conclusion

The findings of this study provide compelling evidence that collaborative learning is an effective pedagogical strategy for enhancing senior high school students' performance in mathematics, particularly in the topic of circle theorems. Compared to the traditional teaching approach, collaborative learning significantly improved students' understanding and application of geometric concepts. This result reinforces the core premise of Social Constructivist Theory, which emphasizes the importance of learning through social interaction and shared problem-solving. Within a collaborative framework, students benefit from dialogue, peer support, and the collective construction of knowledge, all of which contribute to deeper engagement and improved academic outcomes.

Recommendations

In light of the study's findings, several recommendations are proposed to improve the teaching and learning of mathematics specifically in geometry through the adoption of collaborative learning strategies in senior high schools.

Teacher Training and Professional Development: The Ghana Education Service (GES) and the Ministry of Education should place greater emphasis on equipping mathematics teachers with the competencies required to implement collaborative learning effectively. Training workshops and ongoing professional development programs should not only introduce teachers to the principles of group-based instruction but also provide practical guidance on how to structure, facilitate, and assess collaborative tasks. Teachers must learn to manage group dynamics, scaffold learning during peer interactions, and foster a supportive classroom culture that encourages shared responsibility and active participation.

Curriculum Integration and Instructional Design: Curriculum planners and educational policymakers should incorporate collaborative learning frameworks into the national mathematics curriculum. Instructional materials should include cooperative activities tailored to specific topics especially those like circle theorems, which benefit

from hands-on problem-solving, spatial reasoning, and group discussion. Assessment guidelines should also be adjusted to reflect collaborative competencies, such as teamwork, peer feedback, and joint mathematical reasoning.

Limitations of the Study

This study was limited to two senior high schools in the Ashanti Region of Ghana, which may affect the generalizability of the findings to other schools or regions with different educational contexts. The study employed intact classes due to the quasi-experimental design, which restricted randomization and may have introduced pre-existing differences among groups. In addition, the use of a teacher-developed test on circle theorems, though validated, may not fully capture all dimensions of mathematical performance. Time constraints also restricted the duration of the intervention, limiting the assessment of long-term effects of collaborative learning.

Future Research Direction

While this study has yielded valuable insights into the effectiveness of collaborative learning in enhancing students' performance in circle theorems, several areas remain open for further exploration to enrich the field of mathematics education research. Firstly, future studies should investigate the long-term impact of collaborative learning on students' academic development. Specifically, researchers may examine whether gains in performance are sustained over time and how collaborative learning influences students' retention of mathematical concepts, problem-solving abilities, and attitudes toward mathematics. Longitudinal designs would be particularly useful in assessing whether the benefits of collaboration extend beyond immediate test results. Thirdly, there is a need for qualitative and mixed-methods research to explore the lived experiences of students and teachers engaged in collaborative learning. Interviews, focus group discussions, and classroom observations could uncover nuanced insights into the challenges and opportunities of implementing this approach. Such data would help identify the pedagogical practices, classroom cultures, and teacher competencies that support or hinder the success of collaborative instruction.

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