

## Contextualizing Collaborative Learning: A Comparative Study of Urban and Rural Senior High School Students' Performance in Circle Theorems

Akua Dapaah Boatemaa<sup>1\*</sup>, Yarhands Dissou Arthur<sup>2</sup>, Ebenezer Appiagyei<sup>3</sup>, Benjamin Adu Obeng<sup>4</sup>

<sup>1,2,3,4</sup>Department of Mathematics Education, Akenten Appiah-Menka University of Skills Training and Entrepreneurial Development, Ghana

\*Corresponding author: [dapaahakua25@gmail.com](mailto:dapaahakua25@gmail.com)

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### ABSTRACT

**Purpose** – This study investigated whether school location moderates students' achievement in Circle Theorems when instruction is delivered through collaborative learning in Ghanaian senior high schools. Although collaborative learning is frequently linked to improved mathematics achievement, evidence on its effectiveness across contrasting Ghanaian school contexts remains limited.

**Methodology** – Guided by Social Constructivist learning theory, the study employed a quantitative, quasi-experimental design. Two schools were purposively selected: one urban (School A) and one rural (School B). The sample comprised 152 students ( $n = 76$  per school), with intact classes assigned as experimental and control groups. After the instructional intervention, data were collected using a 20-item multiple-choice Circle Theorems test. An independent-samples t-test was used to compare post-test performance of students taught via collaborative learning across the two locations.

**Findings** – Results showed no statistically significant difference in Circle Theorems achievement between students in the rural and urban schools exposed to collaborative learning. This indicates that collaborative learning, when implemented effectively, produces comparable learning outcomes across settings, suggesting limited contextual influence. The findings support the scalability of collaborative learning as an equity-oriented instructional approach in geometry.

**Novelty** – The study contributes original, context-sensitive evidence by directly comparing the effects of collaborative learning on Circle Theorems achievement across rural and urban Ghanaian senior high schools, addressing a gap in local geometry education research.

**Significance** – Mathematics teachers, curriculum developers, and policymakers may use these findings to justify wider adoption of collaborative learning to strengthen conceptual understanding in geometry and promote equitable achievement across diverse school environments.

**Keywords:** Collaborative learning; Geometry achievement; Ghana; Mathematics education; Rural schools; Urban schools.

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## 1. 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).

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).

The problem is particularly acute 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 (2024), the proportion 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, before improving to 61.39% in 2022 and 62.23% in 2023. At the same time, the percentage of students who scored F9 rose from 13.40% in 2020 to 20.11% in 2021, before declining to 8.90% in 2023 (Enoch, 2023). Compared with other core subjects such as Social Studies, Integrated Science, and English Language, mathematics consistently emerges as one of the most challenging areas for students (Enoch, 2023).

Beyond overall performance trends, successive WAEC Chief Examiners' Reports have repeatedly identified Circle Theorems as among the most poorly understood 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 highlight the inadequacy of prevailing teaching methods in effectively addressing the conceptual demands of this area.

A key factor is the widespread reliance on traditional instructional strategies. Teacher-centered methods often dominated by chalk-and-talk delivery, rote memorization, and minimal student participation tend to promote surface learning while failing to cultivate the reasoning, collaboration, and problem-solving abilities required for mastering geometry (Shrestha, 2022; Ntow & Hissan, 2021). Although such approaches may facilitate short-term recall, they do not sufficiently foster the deeper conceptual understanding needed for Circle Theorems. This limitation has prompted international calls for pedagogical reform, with

frameworks such as UNESCO (2021) advocating learner-centered, interactive strategies that actively engage students in constructing mathematical meaning.

Collaborative learning has emerged as one such promising alternative. Rooted in Vygotsky's (1978) socio-constructivist theory, it emphasizes the co-construction of knowledge through dialogue, peer interaction, and shared inquiry. Collaborative learning enables students to articulate reasoning, confront misconceptions, and engage in peer-to-peer teaching, processes shown to enhance comprehension and retention. Empirical evidence supports its effectiveness across diverse contexts: Sekhar and Goud (2024) found that collaborative strategies in programming improved both engagement and comprehension, while Dong et al. (2021) reported similar benefits in nursing education. In Ghana, Mensah-Wonkyi and Adu (2016) likewise demonstrated that collaborative approaches foster deeper understanding and critical thinking compared to traditional methods.

Despite these positive findings, limited research has examined the impact of collaborative learning on Circle Theorems specifically, or how contextual factors such as school location influence its effectiveness. Most studies in Ghana have examined mathematics performance more broadly, often using single-school samples, which limits the generalizability of findings. Yet, disparities in resources, teacher qualifications, and classroom dynamics between urban and rural schools remain substantial (Edwards-Fapohunda & Adediji, 2024), raising important questions about how collaborative learning strategies function across different educational contexts.

This study therefore situates collaborative learning within its contextual realities by comparing its effects on students' performance in Circle Theorems across two distinct educational environments: one urban senior high school and one rural senior high school. By contextualizing collaborative learning, the study investigates not only its potential to improve understanding of Circle Theorems but also how differences in school settings shape its outcomes. Grounded in socio-constructivist theory, the research makes both theoretical and practical contributions: it tests the adaptability of collaborative learning for abstract mathematical concepts across diverse contexts and provides evidence-based insights for teachers, curriculum developers, and policymakers seeking to strengthen mathematics education in Ghana. Ultimately, this study, contextualizing collaborative learning: a comparative study of urban and rural senior high school students' performance in circle Theorems, aims to contribute to more equitable and context-sensitive pedagogical practices that enhance mathematics learning outcomes nationwide and in comparable international contexts.

The research Hypothesis is that there is no significant difference in students' performance in circle theorems under the collaborative learning strategy between students in urban and rural schools.

## **2. Methods**

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- and post-tests, were employed, along with 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 study population 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 A, situated in a rural area. These schools were purposively selected based on accessibility, willingness to participate, and curriculum and teaching staff comparability. 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 group and 73 in the experimental group.

A purposive sampling technique was used to select both schools and 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 ensured that participants possessed the relevant characteristics needed for the study.

The primary data collection instrument was a researcher-designed mathematics achievement test on circle theorems, consisting of 20 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 the 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.

The test's validity and reliability 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, including means, standard deviations, and frequencies, were computed to provide an overview of students' performance. Inferential statistics were conducted using independent-samples t-tests at the 0.05 level of significance. One hypothesis was tested: whether there was a difference in performance between students in urban and rural schools under collaborative learning. 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. These measures ensured that the study was conducted responsibly, with transparency and academic integrity.

### 3. Results and Discussion

#### 3.1. Results

##### 3.1.1 Preliminary Analysis

Before proceeding with the main hypothesis testing, it was necessary to conduct preliminary analyses to determine whether the data met the assumptions required for parametric tests, such as the independent-samples t-test. These assumptions include the normality of the data, homogeneity of variances across groups, and independence of observations.

To assess the normality of score distributions, the Shapiro-Wilk and Kolmogorov-Smirnov tests were employed for all relevant groups across the two schools.

**Table 1 - Test for Normality Across Experimental Groups for Various Tests**

Test	School Type	Kolmogorov-Smirnova			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Experimental	(Urban)	.143	36	.062	.928	36	.022
Group Test	(Rural)	.210	37	.000	.899	37	.003

Table 1 compared the normality of post-test scores across experimental groups in both schools. While Adventist SHS showed a marginal deviation from normality ( $p = .022$ ), the data from Akrofuom indicated a violation ( $p = .003$ ).

Despite these few instances of non-normality, the decision to proceed with parametric tests was justified. This is because most sample sizes were reasonably large, many exceeding 30, which satisfies a key condition for applying the Central Limit Theorem. According to Ghasemi and Zahediasl (2012) and Lumley et al. (2002), the independent-samples t-test is robust to moderate violations of the normality assumption, particularly when sample sizes are above 30 or when groups are relatively equal in size. Therefore, given the sufficient sample sizes and minor deviations, the data were considered suitable for t-test analysis.

The second assumption, the homogeneity of variances, was tested using Levene's Test across all relevant groups, which checks whether the variances of the groups being compared are statistically equal.

**Table 2 - Levene's Test for Equality of Variances**

Test	F	Sig.
Experimental Groups Post-Test	.831	.365

Table 2 presents the Levene's Test result comparing the experimental groups across both schools (urban) and (rural). The p-value obtained was .365, which again exceeds the .05 significance level. This suggests that the variability in students' post-test scores between the urban and rural experimental groups was not statistically different. Thus, this assumption was equally satisfied when comparing school location. The Levene's Test results in Table 2 above confirm that the assumption of homogeneity of variances was met across experimental groups in the two schools. This supports the validity of applying independent samples t-tests in the subsequent analyses.

The assumption of independence was addressed through the research design. Students were assigned to either the control or the experimental group based on their class grouping, and tests were administered individually. There was no overlap in group membership, and

interactions between groups were minimized during the study. As such, the independence of observations is considered satisfied.

### 3.1.2 The Difference in Students' Performance in Circle Theorems

This section presents the results of an independent samples t-test conducted to determine whether there was a significant difference in academic performance between students from urban and rural schools who were both taught using the collaborative learning strategy. The analysis compares post-test scores across the experimental groups at Senior High School A (urban) and Senior High School B (rural). This comparison was essential to evaluate whether the effectiveness of collaborative learning varied by school location or geographical context.

**Table 3 - Independent t-test for Post-Test Comparison**

Test	School Type	N	Mean	SD	t	df	Sig.	Eta Sqrt
Post-test	Senior High School A (Urban)	36	15.88	1.40	-.009	71	.993	.0000011
	Senior High School B (Rural)	37	15.89	1.50				

An independent samples t-test was conducted to investigate whether there was a significant difference in academic performance between students from urban and rural schools who were both taught using the collaborative learning strategy. The analysis compared the post-test scores of experimental group students from Senior High School A (urban) and Senior High School B (rural) to assess whether school location influenced the effectiveness of the instructional approach. As shown in Table 3, the urban group (Senior High School A) had ( $M = 15.88, SD = 1.40$ ), while the rural group (Senior High School B) had ( $M = 15.89, SD = 1.50$ ). The t-test results showed no statistically significant difference between the two groups [ $t(71) = -0.009, p = .993$ ]. This indicates that students from both urban and rural settings benefited equally from the collaborative learning strategy.

To determine the strength of the observed difference, eta squared was calculated. The resulting eta-square was 0.0000011, which is effectively zero, indicating that school location had no practical effect on students' performance when collaborative learning was applied (Cohen, 1988). Based on this result, the null hypothesis, which stated that there is no significant difference in students' performance under the collaborative learning strategy between urban and rural schools, is retained. This finding suggests that the strategy was equally effective across different school settings, highlighting its potential for wide-scale applicability regardless of geographical context.

## 3.2. Discussion

### 3.2.1 The Difference in Students' Performance in Circle Theorems

The study found no statistically significant difference in performance between students in the urban and rural schools under the collaborative learning strategy. This result indicates that students from both school contexts benefited similarly from collaborative instruction in learning circle theorems. The effectiveness of collaborative learning across these different settings can be understood through both Social Constructivist Theory and Collaborative Learning Theory.

This finding aligns with Social Constructivist Theory (Vygotsky, 1978), which posits that learning is shaped through interaction with others in culturally meaningful contexts. The theory emphasizes that the Zone of Proximal Development (ZPD), the range within which learners can achieve more with guidance, can be activated through peer collaboration regardless of geographic setting. The similar performance outcomes across the two schools

suggest that students in both environments had access to meaningful peer interactions and scaffolding opportunities that fostered mathematical understanding.

The finding that there was no statistically significant difference in students' performance between the urban and rural schools under the collaborative learning strategy suggests that learners in both contexts benefited similarly from the instructional approach. This outcome is consistent with previous studies, which have shown that collaborative learning can minimize contextual disparities in student achievement. For instance, a study conducted in Australia found no significant difference in the academic performance of medical students trained in rural clinical settings compared with their urban counterparts, indicating that location did not disadvantage learners when structured instructional strategies were employed (Worley et al., 2006). Similarly, Adeyinka and Ogunbiyi (2023) reported that the Think-Pair-Share strategy enhanced the academic achievement of both rural and urban secondary school students in Nigeria, with no significant performance gap observed between the two groups. In another study on junior secondary business studies in Nigeria, the application of collaborative teaching methods revealed no significant difference in achievement between public and private schools, which often represent rural and urban contexts, respectively (Osakwe, 2019). Collectively, these studies reinforce the idea that collaborative learning strategies create equitable learning opportunities across different educational environments. They highlight the potential of collaborative approaches to mitigate the effects of contextual disadvantages such as limited resources in rural schools, thereby enabling students from both rural and urban settings to achieve comparable learning outcomes.

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

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 structuring, facilitating, and assessing 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 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.

The study demonstrated that collaborative learning is effective across both urban and rural school settings. To bridge the urban-rural education gap, educational stakeholders should invest in scaling up collaborative instructional approaches in rural schools. This includes providing essential teaching and learning materials, training rural teachers in active learning strategies, and supplying tools for classroom monitoring and evaluation. When supported appropriately, collaborative learning can serve as a low-cost, high-impact method to improve mathematics outcomes in less advantaged areas. In summary, implementing these recommendations can enhance student engagement, promote deeper understanding, and ensure more equitable learning outcomes across gender and location. Collaborative learning,

when systematically embedded in teaching practice and educational policy, holds significant promise for transforming mathematics education in Ghana and beyond.

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 limited the intervention's duration, hindering the assessment of its long-term effects.

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. Secondly, 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.

Additionally, future research could explore context-specific adaptations of collaborative learning. For instance, how do factors such as class size, language of instruction, technological resources, or cultural norms influence the outcomes of collaborative strategies in different educational environments? Comparative studies across different regions, school types, or education systems could help generalize findings and refine best practices. In conclusion, expanding research in these directions would not only validate and deepen the current study's findings but also contribute to the development of more inclusive, effective, and sustainable models of mathematics instruction.

#### **4. Conclusions**

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 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.

The study concludes that collaborative learning is effective across school locations, as demonstrated by similar post-test results between urban (Senior High School A) and rural (Senior High School B) students. Despite differences in infrastructure and access to resources, students in both settings showed significant academic gains under collaborative learning. This supports the theory that social learning and group-based instruction can transcend contextual

limitations when properly implemented. It also highlights the potential of collaborative strategies to promote equity in educational outcomes, particularly in resource-constrained environments. In summary, the study affirms that collaborative learning is not only effective in improving mathematics achievement but also scalable and adaptable across diverse educational contexts. These conclusions have important implications for teaching practices, curriculum design, and educational policy aimed at fostering equitable and effective learning environments.

### Conflict of Interest

The authors declare no conflicts of interest.

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