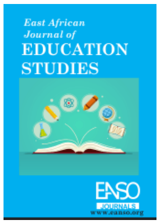

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Original Article

Enhancing Geometry Learning: The Impact of Jigsaw Cooperative Strategy on Ghanaian Senior High School Students' Understanding of Circle Theorems

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ABSTRACT

Geometry plays a crucial role in mathematics education, yet Ghanaian senior high school students consistently struggle with mastering geometric concepts, particularly circle theorems. This study investigates the effectiveness of the jigsaw cooperative learning strategy in enhancing students' comprehension and performance in circle theorems. Guided by Vygotsky's sociocultural theory, which underscores the importance of peer interaction in learning, this quasi-experimental study was conducted in two senior high schools in the Ashanti Region of Ghana. The study comprised 196 students divided into two groups, an experimental group that received instruction through the jigsaw method and a control group that followed traditional teaching approaches. Data collected included pre-tests and post-tests scores and were analysed using a non-parametric Mann-Whitney U test. Findings revealed a significant improvement in students' understanding of circle theorems in the jigsaw group compared to the traditional group, with effect sizes indicating a moderate to large impact. The study concludes that cooperative learning strategies, particularly the jigsaw method, promote active engagement, peer teaching, and deeper conceptual understanding. The findings have implications for mathematics curriculum development and pedagogical practices in Ghanaian schools.

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INTRODUCTION

Geometry is a fundamental branch of mathematics that plays a crucial role in developing logical reasoning, spatial awareness, and problem-solving skills (Trimurtini et al., 2024). Its significance extends beyond academic settings, forming the foundation for disciplines such as engineering, architecture, robotics, and physics. Despite its importance, many students, particularly those in Ghanaian senior high schools, struggle with mastering geometric concepts. Among the various topics in geometry, circle theorems—including angles subtended by arcs, tangent properties, and cyclic quadrilaterals—are particularly challenging due to their abstract nature. Understanding these theorems requires visualization, conceptual reasoning, and practical application, skills that are often underdeveloped due to the limitations of conventional teaching methods (Hershkowitz, 2020; Hissan & Ntow, 2021). and demonstrations, leaving little room for active student engagement or inquiry-based learning (Wheatley, 2018). As a result, students often become passive recipients of information, leading to shallow comprehension, difficulty in applying geometric principles, and low retention of knowledge. These challenges manifest in poor performance in both classroom assessments and national examinations. Reports from the West African Senior School Certificate Examination (WASSCE) consistently highlight geometry, particularly circle theorems, as one of the topics where students perform below expectations (WAEC, 2021).

Mathematics educators and policymakers in Ghana have long expressed concerns regarding students' poor performance in geometry, particularly in topics such as circle theorems. Traditional teacher-centred instructional approaches, which prioritize rote memorization over conceptual understanding, have contributed to students' struggles in visualizing, reasoning, and applying geometric concepts. This has resulted in consistently low scores in both classroom assessments and national examinations, as reflected in WASSCE reports (WAEC, 2021). Despite efforts to improve mathematics instruction, the challenges in geometry education persist, raising questions about the effectiveness of conventional teaching methods.

To address these persistent challenges, there is a growing need for student-centred instructional strategies that foster active participation, collaboration, and deeper conceptual understanding. One such approach is the jigsaw cooperative learning strategy, developed by Aronson in 1978. This method structures learning by dividing students into small groups, where each member is responsible for mastering a specific portion of the content before teaching it to their peers. Through this process, students actively engage with the material, enhance their understanding, and develop essential collaboration and communication skills (Ra'no, 2025).

Research has demonstrated the effectiveness of the jigsaw method in various academic disciplines, with studies highlighting its positive impact on academic performance, motivation, and interpersonal skills

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(Johnson et al., 2024; Gambari et al., 2018). Within the context of geometry education, this strategy enables students to collaboratively explore geometric properties, clarify misconceptions through peer discussions, and construct a deeper understanding of complex topics such as circle theorems. By promoting peer teaching and cooperative learning, the jigsaw method shifts students from passive recipients of information to active participants in their own learning process (Krishna Veni et al., 2020).

Given the limitations of traditional approaches, there is an urgent need to explore alternative instructional strategies that actively engage students, promote deep learning, and enhance problem-solving abilities. The jigsaw cooperative learning strategy has been widely recognized for its potential to improve students' comprehension, motivation, and collaborative skills across different subjects. However, limited research has been conducted on its specific impact on teaching and learning circle theorems in Ghanaian senior high schools.

This study seeks to address this gap by examining the effectiveness of the jigsaw cooperative learning strategy in enhancing students' performance in circle theorems. By investigating whether this approach fosters better conceptual understanding and problem-solving abilities compared to traditional methods, the study aims to provide valuable insights that can inform curriculum development and instructional practices in mathematics education. The findings will contribute to the growing body of research on innovative teaching methodologies and offer practical solutions for improving geometry education in Ghana and beyond.

LITERATURE REVIEW

Theoretical Framework

The study is anchored in Vygotsky's sociocultural theory, which emphasizes the fundamental role of social interaction and cultural tools in cognitive development (Vygotsky, 1978). According to Vygotsky, learning occurs through engagement with more knowledgeable others (MKOs), such as peers, teachers, or technological resources. This interaction fosters knowledge acquisition and enables students to apply learned concepts independently (Wertsch, 1991). A central concept within Vygotsky's theory is the Zone of Proximal Development (ZPD), which explains that students learn more effectively when working with peers or under teacher guidance, as they bridge the gap between their current abilities and their potential capabilities (Vygotsky, 1978).

A key principle of Vygotsky's theory is scaffolding, which refers to the temporary support provided by teachers, peers, or technological tools to assist students in completing tasks they cannot yet accomplish independently (Wood et al., 1976). This support is gradually withdrawn as students develop mastery (Puntambekar, 2022). In cooperative learning strategies like the jigsaw method, scaffolding plays a crucial role in helping students solve complex problems collaboratively, thereby fostering engagement and deeper understanding.

The significance of the ZPD is further highlighted in peer collaboration, where students receive immediate feedback and learn from diverse perspectives. Vygotsky's theory suggests that optimal learning environments encourage student interaction, knowledge exchange, and collaborative problem-solving, making the jigsaw method an effective approach for enhancing these educational experiences.

EMPIRICAL REVIEW

Traditional Teaching Methods

Traditional teaching methods are predominantly teacher-centred, emphasizing direct instruction, where educators deliver structured lectures, demonstrations, and guided exercises (Wheatley, 2018). In this approach, the teacher serves as the primary source of knowledge, while students assume a passive role, receiving information with

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limited opportunities for inquiry, discussion, or exploration. Lessons typically adhere to a fixed curriculum and standardized delivery, prioritizing rote memorization, procedural mastery, and factual recall over conceptual understanding and critical thinking (Hu, 2024).

In this study, the control group followed a traditional lecture-based instructional model. Lessons were conducted through teacher-centred instruction, where students listened, took notes, and solved textbook problems individually. The teacher provided explicit explanations of circle theorems, followed by step-by-step demonstrations of proofs. Students then practised solving exercises independently, with minimal opportunities for peer interaction or group discussions. Unlike the experimental group, the control group did not engage in collaborative problem-solving or interactive visualizations through animations.

One of the major shortcomings of traditional teaching is its inability to accommodate diverse learning styles. Students who learn best through visualization, hands-on activities, and peer collaboration often struggle to grasp abstract geometric concepts, as lessons are typically delivered in a static, text-based format (Hershkowitz, 2020). Geometry, particularly circle theorems, requires students to engage dynamically with spatial relationships, yet traditional methods lack interactive components that facilitate such engagement.

Furthermore, research suggests that teacher-centred instruction fosters surface-level learning, where students memorize formulas and procedures without fully understanding the underlying principles (Boaler et al., 2022). This approach often results in low retention, disengagement, and limited problem-solving abilities, making it difficult for students to apply learned concepts to real-world scenarios. Given these challenges, alternative instructional strategies that promote active participation and conceptual exploration are needed to enhance geometry education in Ghanaian senior high schools.

Jigsaw Cooperative Learning

To address the limitations of traditional instruction, the Jigsaw cooperative learning strategy was introduced as an innovative, student-centred approach to teaching geometry. Developed by Aronson (1978), the Jigsaw method organizes students into small groups, where each member is responsible for mastering a specific portion of the content before teaching it to their peers. Through this process, students actively engage with the material, enhance their understanding, and develop essential collaboration and communication skills (Aronson, 1978).

The Jigsaw method is a widely recognized cooperative learning strategy that promotes both individual accountability and group interdependence, as students rely on each other to achieve a comprehensive understanding of the topic. Research has shown that the Jigsaw method enhances comprehension, motivation, and problem-solving skills by encouraging active engagement, explanation of concepts, and learning reinforcement through peer teaching (Gambari et al., 2018; Johnson & Johnson, 2021).

Studies have demonstrated the effectiveness of the Jigsaw method in improving academic performance, particularly in subjects that require deep understanding and collaboration. For instance, Johnson et al. (2024) reported that students in Jigsaw learning environments developed a stronger grasp of complex topics and exhibited superior problem-solving abilities compared to those in traditional learning settings. Supporting this, Garcia (2022) conducted an experimental study in the Philippines among Grade 12 students, revealing that those taught using the Jigsaw method showed statistically significant improvements in both cognitive ability and engagement (Garcia, 2022). Similarly, Al-Kreimeen (2024) applied the Jigsaw II strategy to female Child Education majors at Al-

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Balqa Applied University in Jordan, showing enhanced thinking skills and cognitive evaluation competencies in the experimental group compared to a control group (Al-Kreimeen, 2024).

In Oman, Renganathan (2020) assessed the Jigsaw puzzle method among general nursing students, where improved academic performance was observed, particularly in second-year students (Renganathan, 2020). Additionally, a U.S.-based study by Dollard and Mahoney (2010) on middle school science curricula found that while test scores were comparable to traditional methods, students reported feeling more engaged and important, highlighting the method's motivational benefits (Dollard & Mahoney, 2010). Furthermore, Jigsaw learning fosters positive classroom dynamics by enhancing students' social skills, self-esteem, and intrinsic motivation, as they take ownership of their learning process (Karacop, 2017). The act of explaining concepts to peers reinforces knowledge retention and promotes active participation.

Research in mathematics education further supports the application of Jigsaw cooperative learning in enhancing students' comprehension of abstract mathematical concepts. In geometry, cooperative learning strategies provide opportunities for students to explore geometric principles, discuss findings with peers, and correct misconceptions through collaboration. This interactive process aligns with the broader educational objective of cultivating higher-order thinking skills, which are essential for mastering challenging topics like circle theorems (Hershkowitz, 2020). Unlike teacher-centred instruction, where students passively receive information, the Jigsaw method encourages inquiry, discussion, and peer teaching, making students more invested in their learning process (Bhosale et al., 2024). This approach fosters accountability, motivation, and deeper cognitive processing, leading to greater retention and comprehension. Cooperative learning environments also create a sense of community, which enhances students' confidence, willingness to participate, and ability to problem-solve collaboratively (Gambari et al., 2018).

Geometry Education in Ghana

Geometry is a fundamental component of the Ghanaian mathematics curriculum, yet it remains one of the most challenging subjects for students, particularly in topics such as circle theorems (Kpotosu et al., 2024). Concepts related to angles subtended by arcs, cyclic quadrilaterals, and tangents require advanced spatial reasoning and visualization skills. However, traditional instructional methods in Ghanaian classrooms are predominantly teacher-centred, relying heavily on lectures and rote memorization rather than fostering conceptual understanding (Armah, 2024).

Reports from the West African Examinations Council (WAEC) have consistently highlighted poor student performance in geometry, particularly in the application of circle theorems (WAEC, 2021). The primary factors contributing to this challenge include the abstract nature of the subject, lack of student engagement in traditional teaching approaches, and limited opportunities for practical application of mathematical concepts (Hassan & Ntow, 2021). As a result, educational researchers have emphasized the need for pedagogical reforms that promote student-centred learning approaches to improve engagement and comprehension (Che Mat & Jamaludin, 2024).

To address these challenges, cooperative learning strategies like the Jigsaw method have been identified as effective alternatives to conventional teaching methods. These strategies encourage active learning, peer collaboration, and enhanced visualization of complex mathematical concepts, making abstract ideas more accessible and comprehensible (Gambari et al., 2014). Although the benefits of Jigsaw cooperative learning are well-documented, limited research has been conducted on its application in teaching circle theorems within Ghanaian classrooms. This study seeks to bridge this gap by examining the impact of the Jigsaw

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method on students' understanding and academic achievement in circle theorems. The findings will contribute to the ongoing discourse on innovative teaching strategies in Ghana and beyond.

RESEARCH METHODOLOGY AND DATA SOURCE

To achieve the objectives of this study, senior high school students from two schools in the Kwabre East municipality of the Ashanti Region, Ghana, were selected. A total of 196 students participated in the research, comprising an experimental group and a control group. The experimental group was taught using the Jigsaw cooperative learning method, whereas the control group received instruction through traditional teacher-centred methods. The study was designed to assess the impact of the Jigsaw method on students' understanding of circle theorems and their overall performance in geometry.

Research Design

This study adopted a quasi-experimental research design, incorporating pre-tests and post-tests to evaluate student performance before and after the instructional intervention. A quasi-experimental approach was chosen because it allows for the assessment of causal relationships in real-world educational settings while accommodating practical constraints, such as the inability to randomly assign students to groups (Creswell & Creswell, 2018). The pre-test and post-test served as the foundation for assessing the effectiveness of two teaching strategies—cooperative learning and traditional instruction—in enhancing students' comprehension of geometric concepts. By measuring changes in students' understanding of circle theorems, this design facilitated an objective evaluation of the extent to which cooperative learning improves mathematical reasoning and problem-solving skills. However, quasi-experimental designs do not involve random assignment, which may introduce potential selection bias due to pre-existing differences between the experimental and control groups (Shadish, Cook, & Campbell, 2002). To mitigate this concern, the study employed matching techniques to ensure that students in both groups were similar in terms of age, gender, and prior academic achievement, as determined by their pre-test scores. This approach aimed to minimize confounding variables that could influence learning outcomes (Dimitrov & Rumrill, 2003).

To further strengthen the validity of the results, statistical techniques were employed to account for baseline differences between the two groups. Specifically, the Mann-Whitney U test—a non-parametric alternative to the independent t-test—was used to compare performance scores because it does not assume normality in the data distribution (Field, 2024). This statistical method is particularly useful when dealing with small sample sizes or ordinal data, as it ranks scores rather than relying on raw values, thereby providing a more robust comparison of students' learning gains (MacFarland & Yates, 2016). By incorporating these methodological safeguards, the study ensured that its findings would offer credible insights into the effectiveness of cooperative learning strategies in mathematics education. The use of quasi-experimental methods, combined with rigorous statistical analysis, provided a balanced approach to evaluating instructional interventions in a classroom setting, where true experimental designs may not always be feasible.

Sample Size and Sampling Strategy

This study employed a purposive sampling approach to identify two senior high schools within the same district—referred to here as School A and School B—that provided a suitable context for implementing the Jigsaw cooperative learning model. These schools were selected based on two key considerations: First, both schools had a well-documented record of student struggles with geometric topics, especially circle theorems, which require high levels of abstraction, deductive reasoning, and the integration of multiple geometric

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properties. This context offered a meaningful opportunity to assess whether the Jigsaw method—characterized by peer instruction and collaborative engagement—could improve conceptual understanding and performance in such challenging content areas. Second, the schools were comparable in terms of instructional resources, student population, and teacher qualifications, ensuring a high degree of consistency for comparative analysis. Their location within the same district also facilitated efficient monitoring by the researcher, allowing for consistent oversight, fidelity of implementation, and timely data collection across both sites. Following selection, the schools were randomly assigned to one of two groups: one implementing the Jigsaw cooperative learning model and the other following a traditional teacher-centred instructional approach. Within each school, purposive sampling was used to select Form 2 Elective Mathematics classes, which cover circle theorems as outlined in Ghana's core mathematics curriculum. Experienced and certified mathematics teachers—holding at least a bachelor's degree and often an MPhil in mathematics or mathematics education—were trained to implement the instructional methods. The lessons were conducted under the supervision of the researcher to ensure methodological integrity and adherence to the study design.

Sample Size Determination

The sample size for this research was established using Yamane's formula, which is suitable for calculating sample sizes in studies involving finite populations. The formula is given as:

$$n = \frac{N}{1 + N \cdot e^2}$$

Where:

- n represents the required sample size
- N denotes the total population size
- e is the desired margin of error (in decimal form)

Parameters Used:

- Total population $N = 724$ (combined enrolment from Schools A and B)
- Calculated sample size $n = 196$

Table 1 below outlines the distribution of the total population by school, the proportional representation of each school, and the corresponding sample size:

Table 1: Composition of the Sample Size Determination

School	Population	Population Proportion	Sample Size
A	351	0.485	95
B	373	0.515	101
Total	724	1.000	196

Based on their respective enrolments—351 students for School A and 373 for School B—the sample was distributed proportionally, yielding 95 participants from School A and 101 from School B. This proportional sampling method ensured that the final sample of 196 accurately represented the composition of the study population across both schools.

Experimental Group (Jigsaw Cooperative Learning Method)

Students in the experimental group were taught using the Jigsaw cooperative learning method, a structured approach to collaborative learning designed to promote both individual responsibility and group interdependence. The students were divided into small groups, with each member

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assigned a specific section of the circle theorems to study independently. This division of content ensured that each student became an "expert" in their designated topic, fostering a sense of accountability for their own learning. Once students had thoroughly examined their respective sections, they reconvened in their original groups to share their findings with their peers. This process of reciprocal teaching encouraged students to articulate their understanding clearly and allowed for the reinforcement of key concepts through discussion and explanation. The collaborative nature of this method facilitated deeper engagement and enhanced comprehension by requiring students to actively process and teach the material to their peers (Aronson, 1978; Johnson & Johnson, 2009).

The Jigsaw method was characterized by several key features that contributed to its effectiveness in learning circle theorems. Small group discussions served as the foundation of the approach, allowing students to research and master specific concepts before presenting them to their group members. This not only cultivated a sense of responsibility but also ensured that each student played an integral role in the collective learning process. Peer teaching was another essential element, as students were required to explain their assigned concepts clearly, reinforcing their own understanding while simultaneously aiding their classmates' learning. Additionally, collaborative problem-solving activities provided students with opportunities to apply their acquired knowledge to different circle theorem problems, further strengthening their conceptual grasp and problem-solving skills. Through these interactive learning experiences, students developed critical thinking abilities and demonstrated higher levels of engagement compared to traditional teacher-centred instruction (Vygotsky, 1978; Bunag, 2024). The active learning strategy embedded in the Jigsaw cooperative method thus proved to be an effective means of enhancing student comprehension and fostering meaningful peer interactions.

Control Group (Traditional Teacher-Centred Instruction)

The control group adhered to a traditional teacher-centred instructional approach, which emphasized direct instruction, teacher-led explanations, and individual problem-solving exercises. In this method, the teacher played a central role in knowledge dissemination, introducing each theorem by first providing its formal definition and proof. Step-by-step demonstrations were employed to illustrate problem-solving techniques, ensuring that students had a clear procedural understanding of mathematical operations. Students were primarily expected to memorize theorems and apply them in structured, individual exercises without engaging in peer discussions or collaborative learning activities. Unlike the experimental group, which incorporated interactive and student-centred strategies, the control group followed a rigid format where learning was largely passive, driven by lectures and textbook assignments rather than exploratory engagement. As a result, student participation was limited, with few opportunities to discuss mathematical concepts, ask questions beyond clarification, or explore geometric relationships in a dynamic setting. This approach ensured structured content delivery and maintained a clear instructional sequence, which has been traditionally valued for its efficiency in covering curriculum content systematically (Clark, 2018). However, the absence of interactive elements meant that students had fewer opportunities to develop a deep conceptual understanding of geometric principles, as research suggests that active engagement and collaborative learning contribute significantly to long-term retention and problem-solving skills (Palisbo et al., 2025). Consequently, while the control group benefited from well-organized instruction and clear explanations, they lacked exposure to the kind of interactive, inquiry-based learning that has been shown to enhance conceptual comprehension and critical thinking in mathematics education (Wartono et al., 2019).

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Study Procedure

The Pre-Test Administration phase involved administering the Circle Theorem Achievement Test (CTAT) to both the experimental and control groups before any instructional intervention took place. This pre-test served as a diagnostic tool to assess students' baseline knowledge of circle theorems, ensuring that any differences observed in the post-test could be attributed to the instructional methods rather than pre-existing variations in understanding (Safreena & Deepa, 2024). During the Instructional Intervention phase, the experimental group was taught using the Jigsaw cooperative learning method, a pedagogical approach that encourages collaborative learning by having students work in small groups to research, discuss, and teach each other different aspects of circle theorems. This method, rooted in social constructivism, fosters deeper engagement and peer-assisted learning, potentially enhancing conceptual understanding and retention (Jamilu et al., 2022). Meanwhile, the control group received instruction through the direct teaching method, where the teacher systematically introduced circle theorem concepts, provided formal definitions and proofs, and facilitated individual problem-solving exercises. This traditional approach emphasizes teacher-led instruction and independent practice, ensuring that students receive structured guidance but with limited peer interaction (Marinšek et al., 2025). Following the instructional phase, the Post-Test Administration involved re-administering the CTAT to both groups. This post-test was designed to measure improvements in students' comprehension and problem-solving abilities related to circle theorems. The results of the pre-test and post-test were systematically analyzed to evaluate the relative effectiveness of the Jigsaw method compared to direct instruction. By comparing the two instructional strategies, the study aimed to determine whether collaborative learning facilitated greater conceptual mastery and problem-solving skills than traditional teacher-centred methods (Johnson & Johnson, 2009).

Validity and Reliability of Measurement Instruments

Content validity of the CTAT was established by aligning the test items with the national mathematics curriculum and subjecting them to expert review by mathematics education specialists to ensure accuracy and relevance. This review process helped refine the assessment by eliminating potential ambiguities and biases. Additionally, a pilot study was conducted with students outside the primary study sample to identify unclear or misleading questions. Necessary modifications were made to ensure that all test items were unambiguous, unbiased, and representative of the intended learning objectives. The reliability of the CTAT was assessed through multiple measures to ensure consistency and stability. Internal consistency was evaluated using Cronbach's alpha coefficient, which yielded a reliability score of 0.85, indicating a high level of internal consistency (Cohen et al., 2018). Furthermore, test-retest reliability was examined by administering the test to a small subset of students on two separate occasions with an appropriate time interval. A high correlation coefficient between the two test administrations confirmed the stability and dependability of the CTAT, demonstrating its robustness as an assessment tool for measuring students' mathematical abilities across different testing instances.

Data Collection

The data collection process was conducted systematically to ensure the accuracy, consistency, and reliability of the study. Data were gathered from both the experimental and control groups through structured assessments administered at two key stages: pre-test and post-test. These assessments were designed to measure students' understanding of circle theorems before and after the instructional intervention, providing quantitative evidence of the

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impact of the Jigsaw cooperative learning approach compared to traditional teacher-centred instruction.

The pre-test was administered at the beginning of the study to establish a baseline measurement of students' knowledge of circle theorems. The test included multiple-choice questions, short-answer questions, and problem-solving tasks, which assessed students' ability to recognize, analyze, and apply fundamental geometric properties related to cyclic quadrilaterals, angles subtended by arcs, and tangent properties. Conducting the pre-test ensured that initial differences in student performance were accounted for, allowing for a more accurate evaluation of learning gains after the intervention. The instructional intervention lasted for a specified period, during which the experimental group received instruction through the Jigsaw cooperative learning method, while the control group was taught using traditional teacher-centred methods. After the intervention, the post-test was administered to both groups. This test was designed to measure students' conceptual understanding, problem-solving skills, and ability to apply circle theorem concepts in various problem-solving contexts. The post-test contained different but equivalent questions to those in the pre-test to avoid potential biases related to test familiarity while maintaining consistency in the assessment of learning outcomes. To ensure the validity of the data collection process, both the pre-test and post-test were conducted under standardized conditions, with uniform administration procedures followed for both the experimental and control groups. Additionally, clear instructions were provided to students to minimize external influences on their responses. The assessments were supervised by trained research assistants and subject teachers to maintain consistency in administration and reduce variability in test-taking conditions.

Following the completion of the post-test, student responses were compiled, coded, and organized for statistical analysis. The data were cross-checked for completeness and accuracy before proceeding with further analysis. The structured data collection approach ensured that variations in student performance were reliably captured, allowing for a robust comparison of the two instructional strategies. By implementing a rigorous data collection process, this study ensured the credibility of its findings and provided a strong empirical foundation for evaluating the effectiveness of Jigsaw cooperative learning in geometry education.

ANALYSIS AND RESULTS

Data Analysis

Table 2: Descriptive Statistics on the Pre-test and Post-test for the Groups

Descriptive Variable	**Pre-test**		**Post-test**	
	School A	**School B**	**Traditional**	**Jigsaw method**
Minimum	4	4	3	7
Maximum	18	21	21	24
Mean	10.0	13.13	10.97	14.81
Std. Deviation	3.99	4.40	4.19	4.38
Skewness	0.341	-0.287	0.312	-0.024
Kurtosis	-0.761	-0.857	-0.68	-1.038

Table 1 presents the descriptive statistics for the pre-test and post-test scores across different groups. The pre-test scores compare the performance of students from School A and School B, while the post-test scores correspond to students taught using either the Traditional or Jigsaw method. For the pre-test, scores in School A ranged from 4 to 18, with a mean score of 10.0 and a standard deviation of 3.99. In contrast, School B had a wider range of 4 to 21, a higher mean of 13.13, and a standard deviation of

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4.40. The skewness values indicate that School A's distribution was slightly positively skewed (0.341), meaning more students scored on the lower end, while School B's distribution was slightly negatively skewed (-0.287), suggesting a slight concentration of scores on the higher end. The negative kurtosis values for both groups (-0.761 for School A and -0.857 for School B) suggest a relatively flat distribution, indicating fewer extreme values. For the post-test, students in the Traditional method group scored between 3 and 21, with a mean of 10.97 and a standard deviation of 4.19. The Jigsaw method group had a higher score range of 7 to 24, a higher mean of 14.81, and a standard deviation of 4.38. Both groups showed negative skewness, with values of 0.312 for the Traditional method and -0.024 for the Jigsaw method, indicating that more students scored on the higher end. The negative kurtosis values (-0.68 and -1.038, respectively) suggest a broad, even distribution of scores without significant clustering at the extremes. Overall, the data suggest that students taught using the Jigsaw method outperformed those taught using the Traditional method, as evidenced by higher post-test mean scores and a shift in distribution towards higher performance.

Normality Assessment for the Pre-Test and Post-Test by Groups

To assess the normality of the test scores across the groups, a Kolmogorov-Smirnov test was conducted, and the results are displayed in **Table 3**. This test is used to determine whether the distribution of scores in each group significantly deviates from a normal distribution. The null hypothesis for the Kolmogorov-Smirnov test posits that the sample comes from a normal distribution, while the alternative hypothesis suggests that the data does not follow a normal distribution. The results of the test are shown in the table, including the **Kolmogorov-Smirnov statistic (Statistic)**, the **degrees of freedom (df)**, and the **P value** for each group.

Table 3: Normality Test for Each Group

Tests	Group	Kolmogorov-Smirnov		
		Statistic	df	P value
Pre-Test	School A	.114	101	.003
	School B	.094	95	.038
Post-Test	Traditional	.106	101	.007
	Jigsaw method	.108	95	.008

a. Lilliefors Significance Correction

For the Pre-test, the P-values for School A and School B were .003 and .038, respectively, all of which are less than the common significance level of 0.05. This means we reject the null hypothesis for all three groups, suggesting that the pre-test scores are not normally distributed in any of the groups. For the Post-test, the P-values for the Traditional group and Jigsaw method group were .007 and .008, respectively. Again, all of these values are below 0.05, leading to the rejection of the null hypothesis for all post-test groups. This indicates that the post-test scores are also not normally distributed. Since the P-values are all less than 0.05, we reject the null hypothesis for all groups in both the pre-test and post-test, concluding that the test scores are not normally distributed in any of the groups.

The Impact of Utilizing the Jigsaw Cooperative Learning Technique Alone on Students' Geometry Performance in Circle Theorem.

The results in Table 4.3 and Table 4.4 indicate that the use of non-parametric statistical tests, such as the Mann-Whitney U test, is appropriate for this dataset due to the violation of parametric methods. Overall, these findings underscore the variability in students' performance across both groups and emphasize the need for robust analytical approaches to accurately assess the impact of the Jigsaw

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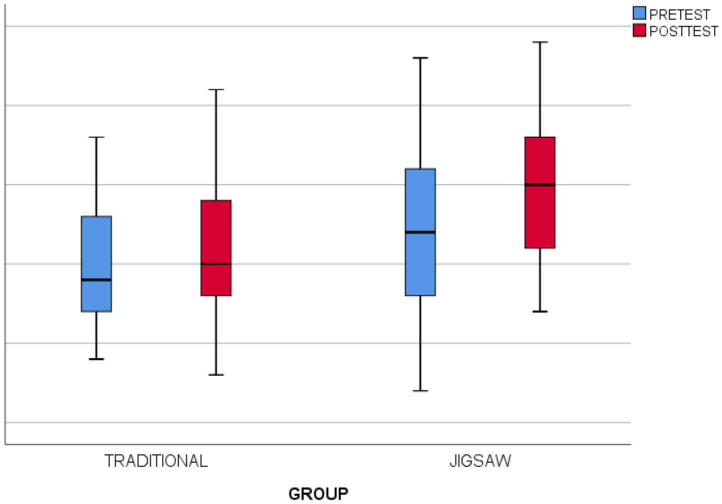
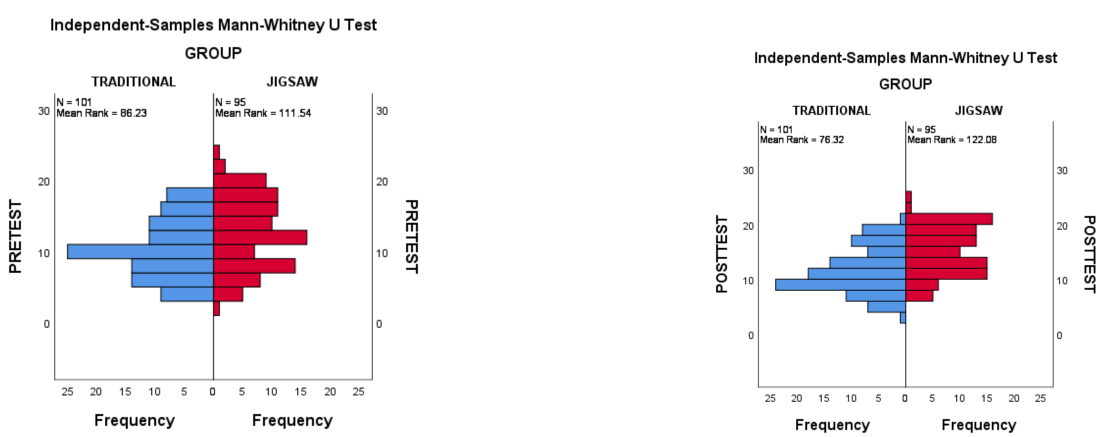
cooperative learning technique on students' geometry achievement in circle theorems.

Figure 1: A Box-plot Showing Distribution of Students' Achievement Across Groups (Traditional and Jigsaw Cooperative Learning Model)



The provided box-plot in Figure 1 illustrates the pre- and post-test scores for two groups: Traditional and Jigsaw methods. The boxplots reveal that both groups exhibited an increase in scores from the pre-test to the post-test. However, the Jigsaw group demonstrated a more substantial improvement, with a higher median and a wider range in their post-test scores compared to the Traditional group. This suggests that the Jigsaw method may be more effective in enhancing learning outcomes than the traditional method. While the Traditional group also experienced an increase in scores, the magnitude of the improvement was less pronounced. This finding supports the notion that the Jigsaw method may be a more engaging and effective approach to learning, as it encourages active participation, collaboration, and a deeper understanding of the material.

Figure 2: Impact of Teaching Method on Student Achievements (Mann Whitney U Test)



The histograms in Figure 2 depicts the distribution of pre-and post-test scores for the Traditional and Jigsaw groups. The pre-test scores for both groups appear to be relatively similar, with a slight skew

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towards lower scores. However, the post-test scores reveal a notable difference between the two groups. The Traditional group's post-test scores exhibit a wider spread and a higher frequency of lower scores compared to the Jigsaw group. In contrast, the Jigsaw group's post-test scores demonstrate a narrower distribution with a higher frequency of higher scores. This suggests that the Jigsaw method may have a more consistent and positive impact on learning outcomes compared to the traditional method. While the histograms provide a visual representation of the data, further statistical analysis is necessary to confirm these observations and draw more definitive conclusions.

Table 4: Independent-Samples Mann-Whitney U Test for the Various Stages Across Groups (TRADITIONAL & JIGSAW)

STAGE	SAMPLE SIZE	Mann-Whitney U	Wilcoxon W	Test Statistic	Standard Error	Standardized Test Statistic	Asymptotic Sig.(2-sided test)	Effect size
PRETEST	196	6036.50	10596.50	6036.50	396.074	3.128	0.002	0.23
POSTTEST	196	7038.00	11598.00	7038.00	396.014	5.658	< 0.001	0.48

The results of the Independent-Samples Mann-Whitney U Test for both the pretest and post-test scores indicate statistically significant differences between the groups. For the pretest, the Mann-Whitney U value is 6036.50 (Z = 3.128, p = 0.002), suggesting a significant difference in baseline score distributions between the groups. The corresponding effect size is 0.23, which falls within the small to medium range based on conventional benchmarks. For the posttest, the Mann-Whitney U value is 7038.00 (Z = 5.658, p < 0.001), again indicating a statistically significant difference in score distributions following the instructional intervention. The effect size is 0.48, which is considered moderate, reflecting a more substantial impact of the intervention on academic performance. These findings underscore that the instructional approaches (Traditional vs. Animation) led to meaningful improvements in performance, with the Animation-based method producing notably greater gains in the post-test phase. The larger effect size post-intervention suggests the instructional technique had a more pronounced effect on student outcomes after exposure.

DISCUSSION

This study examined the effectiveness of the Jigsaw cooperative learning technique in enhancing students' comprehension of circle theorems, a topic in geometry that requires advanced abstract reasoning and spatial visualization. The findings demonstrated both statistically and educationally significant gains for students taught using the Jigsaw approach. Results from the Mann-Whitney U test indicated significant group differences at the pre-test stage (*U = 6036.50, Z = 3.128, p = 0.002, r = 0.23*) and a more pronounced effect at the post-test (*U = 7038.00, Z = 5.658, p < 0.001, r = 0.48*). The post-test effect size, categorized as moderate, underscores the substantive impact of the Jigsaw method in promoting a deeper understanding of complex geometric concepts.

The **significant improvement observed in the Jigsaw group** can be attributed to the cooperative learning environment that it fosters. Unlike the teacher-centred traditional approach, which often results in passive learning, the Jigsaw method encourages **active student engagement**. In this approach, students are assigned specific parts of the material to master, then regroup to combine their knowledge and construct the full conceptual framework. This collaborative process not only enhances individual comprehension but also **promotes peer teaching**, a mechanism known to improve retention and metacognitive awareness. One of the key strengths of the Jigsaw model lies in its capacity to support learning in **cognitively demanding disciplines like geometry**. Abstract

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constructs such as circle theorems are often challenging for students taught via conventional lecture formats. The Jigsaw method, by distributing responsibility and promoting interdependence, **reduces the cognitive load** for each individual through what cognitive scientists call **distributed cognition**. Students pool their cognitive resources to solve problems and explain concepts, thereby scaffolding each other's learning.

This aligns with **Vygotsky's social constructivist theory**, which posits that learning is fundamentally social and that development is mediated through interaction with more knowledgeable peers. In Jigsaw settings, the social dynamic fosters epistemic agency, enabling students to **co-construct knowledge**, engage in deeper conceptual discussions, and sharpen their higher-order thinking skills (Vygotsky, 1978).

These findings also align with a growing empirical consensus in the literature. For example, **Garcia (2022)** reported significant academic and cognitive gains in a Jigsaw-based online instruction setting, while **Hidayati (2022)** found that Jigsaw instruction improved mastery of the Pythagorean Theorem, with 87.5% of students achieving success by the third learning cycle. Moreover, **Suglo (2024)** and **Enoch (2023)** demonstrated that applying relevant geometric theorems—key to success in circle geometry—significantly correlates with improved academic performance, particularly when supported by conceptual teaching approaches. Beyond performance gains, the Jigsaw model also enhances **student motivation and accountability**. Cooperative learning fosters intrinsic motivation because students become personally invested in the group's success. This increased sense of responsibility, paired with the requirement to teach others, promotes sustained engagement—an outcome supported by this study's observations.

However, the effectiveness of the Jigsaw method hinges on **careful planning and facilitation**. Teachers must be adept at orchestrating group dynamics, ensuring equitable participation, and managing time constraints. Dominant voices must be moderated, and quieter students encouraged to contribute, lest the cooperative advantage be undermined by uneven participation. These challenges call for **targeted teacher training and curricular flexibility**. Looking ahead, **future research** should investigate the longitudinal impact of Jigsaw learning on retention, metacognitive development, and students' mathematical identity. Exploring its application across other domains (e.g., algebra, statistics) and educational levels will help assess its generalizability. Investigations into neurocognitive responses or multimodal learning analytics could yield deeper insights into how peer interaction transforms learning processes.

CONCLUSION AND RECOMMENDATIONS

This study provides compelling evidence of the significant impact of the Jigsaw cooperative learning technique on students' geometry performance, particularly in the context of circle theorems. The findings suggest that adopting cooperative learning strategies can address the limitations of traditional teacher-centred instructional methods and improve student engagement, comprehension, and retention of geometric concepts. The results align with constructivist learning theories, reinforcing the idea that active student participation and peer collaboration contribute to higher-order thinking and problem-solving abilities.

Expanding the scope beyond immediate academic performance, the study highlights the potential long-term benefits of the Jigsaw method in fostering essential skills such as collaborative problem-solving, communication, and independent critical thinking. These skills are crucial for students' success beyond mathematics classrooms, influencing their ability to apply logical reasoning in real-world scenarios. As education increasingly integrates technology-enhanced learning, incorporating animations and interactive visualizations into the Jigsaw model could further enhance students' understanding of complex

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geometric principles. Future research should investigate how multimedia elements, such as dynamic visual representations of circle theorems, influence cognitive load and spatial reasoning when combined with cooperative learning strategies.

The findings of this study have significant practical implications for teachers, curriculum designers, and policymakers. Educators can implement the Jigsaw method by structuring lessons around small, interdependent learning groups, where students become "experts" on different parts of a topic before teaching their peers. This approach not only enhances subject comprehension but also promotes student accountability and engagement, fostering a more interactive learning environment. Integrating digital tools, animations, and interactive simulations into the Jigsaw method could further support students' conceptual understanding of geometry, particularly for visually demanding topics like circle theorems.

Moreover, the role of teachers in implementing the Jigsaw model is crucial. Effective facilitation is necessary to ensure equal participation among students, prevent dominant individuals from taking over discussions, and support struggling learners. Teacher training programs should emphasize the pedagogical benefits of cooperative learning, offering practical workshops on how to structure Jigsaw activities, assess student contributions, and incorporate technology-enhanced learning strategies. Schools should also provide educators with access to digital learning resources, including animated instructional materials and geometry visualization tools, to maximize the effectiveness of the Jigsaw approach. To expand on the findings of this study, further research should focus on the long-term impact of cooperative learning by investigating whether the benefits of the Jigsaw method extend beyond immediate academic gains. Studies should examine how it influences students' retention of geometric concepts over time and their performance in subsequent mathematical topics.

Research should also explore how integrating animations, interactive geometry software, and augmented reality enhances student engagement and understanding in cooperative learning settings. Given the increasing role of digital tools in education, this aspect of cooperative learning is particularly important. While this study focused on geometry, further research should assess whether the Jigsaw method can be effectively applied to other mathematical areas, such as algebra, calculus, and statistics. This would provide insights into its broader applicability across different branches of mathematics. Additionally, research should examine how different levels of teacher preparation and instructional strategies impact the effectiveness of the Jigsaw method. Studies should evaluate how teachers perceive and implement cooperative learning models in diverse classroom settings and identify best practices for integrating these methods into various educational systems. Comparing the Jigsaw method with other cooperative learning models, such as Team-Based Learning, Problem-Based Learning, and Peer Tutoring, would provide valuable insights into the most effective instructional strategies for different student populations and mathematical concepts. The Jigsaw cooperative learning method offers a transformative approach to teaching geometry, fostering active student participation, deeper conceptual understanding, and stronger collaborative skills.

The study highlights its potential for long-term academic benefits, particularly when combined with technological advancements such as animations and interactive learning environments. Educators, policymakers, and curriculum designers should consider integrating structured cooperative learning models into mathematics instruction to create more inclusive, engaging, and effective learning experiences. However, successful implementation requires teacher training, technological support, and ongoing research to refine best practices and maximize the method's effectiveness in diverse educational settings.

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