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Effect of Computer-Assisted Instruction on Students' Achievement in Geometry in Zaria Education Zone, Kaduna State, Nigeria

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Abstract

This study investigated the effects of Computer-Assisted Instruction (CAI) on students' achievement in geometry in Zaria Educational Zone, Kaduna State, Nigeria. A quasi-experimental pre-test, post-test, non-equivalent control group design was adopted. The population comprised 7,870 Senior Secondary II (SS II) students, from which 109 students (68 experimental and 41 control) were selected using simple and purposive sampling techniques. Three research questions and three null hypotheses guided the study. Data were collected using the Geometry Achievement Test (GAT), validated by three experts, with a reliability coefficient of 0.82. The treatment lasted four weeks for both experimental and control groups. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) tested the null hypotheses at the 0.05 significance level. Findings revealed a significant difference in achievement between students taught using CAI and those taught using the conventional method, favouring the CAI group. However, no significant difference was found between male and female students' achievement when taught geometry using CAI. The study recommended adopting CAI for teaching geometry and organizing workshops, seminars, and conferences to train mathematics teachers in its effective application.

Keywords: computer-assisted instruction, achievement, geometry concepts

1 Introduction

Mathematics is an essential subject in the educational development of individuals and the technological advancement of any nation. It provides the foundation for logical reasoning, critical thinking, problem-solving and decision-making skills required in everyday life and various professional fields. Mathematics is particularly important in science, technology, engineering and other related disciplines because it provides the concepts, principles and analytical tools necessary for understanding and solving practical problems. In the Nigerian educational system, Mathematics is a compulsory subject at the basic and secondary school levels, reflecting its significance in preparing learners for further education and participation in national development. However, despite its importance, students' achievement in Mathematics has remained a major concern among educators, parents, researchers and other stakeholders in education. One of the areas of Mathematics that requires particular attention is Geometry.

Geometry is a fundamental branch of Mathematics concerned with the study of shapes, sizes, positions, dimensions, angles, lines, surfaces and spatial relationships. It provides learners with opportunities to develop visualisation, logical reasoning, analytical thinking and problem-solving abilities. The knowledge of Geometry is essential in several fields, including architecture, engineering, construction, surveying, computer graphics, navigation and physical sciences. It also enables students to understand and interpret objects and spatial relationships in their immediate environment. At the secondary school level, students are expected to understand geometric concepts such as angles, triangles, quadrilaterals, circles, polygons, areas, volumes, geometrical constructions and properties of plane and solid figures. A sound understanding of these concepts provides the foundation for advanced mathematical learning and practical applications. Nevertheless, Geometry is often perceived by students as difficult because it involves abstract concepts, visual reasoning, mathematical representations and the application of theorems and formulae.

Students' achievement in Geometry depends on several factors, including teaching methods, availability of instructional materials, teachers' competence, students' attitudes, learning environment and individual differences. One important factor that has attracted considerable attention in Mathematics Education is the method of instruction adopted by teachers. The conventional teaching method, which often involves teacher explanations, chalkboard illustrations, textbook exercises and note-taking, remains widely used in many secondary schools. Although this approach can facilitate the teaching of mathematical concepts, it may not adequately address the visual and practical demands of Geometry when learners are not

actively involved in the learning process. Some geometric concepts require students to observe transformations, manipulate shapes, identify relationships and understand how mathematical properties operate. When these concepts are presented mainly through static drawings and verbal explanations, students may experience difficulties developing accurate mental representations. Consequently, there is a need to explore innovative instructional approaches capable of making Geometry more concrete, interactive and meaningful to learners.

One of such innovative approaches is Computer-Assisted Instruction (CAI). Computer-Assisted Instruction refers to the use of computer-based technologies and instructional programmes to facilitate teaching and learning. It involves the application of computers, educational software, animations, simulations, interactive presentations, videos and digital learning materials to present instructional content and provide learners with opportunities for active participation. CAI can be designed to deliver lessons, demonstrate concepts, provide immediate feedback, assess learners' understanding and allow students to practise mathematical activities at their own pace. In Geometry instruction, computer-based applications can enable students to visualise geometric figures, manipulate shapes, explore angles, observe transformations and investigate relationships between different mathematical properties. Unlike static illustrations, computer-generated diagrams and animations can demonstrate how geometric figures change when their dimensions, positions or orientations are modified. Such experiences may improve students' conceptual understanding and their ability to solve geometric problems.

The effectiveness of Computer-Assisted Instruction can be explained through the Cognitive Theory of Multimedia Learning, which emphasises the role of visual and verbal representations in learning. According to Mayer (2001), learners can understand instructional information more effectively when relevant words and pictures are appropriately combined rather than when information is presented through words alone. This principle is particularly relevant to Geometry because students are required to interpret diagrams, understand spatial relationships and connect mathematical expressions with visual representations. For instance, an animated demonstration of the properties of a triangle can help students observe the relationship between its interior angles, while interactive software can allow them to manipulate geometric figures and investigate mathematical relationships independently. Through these experiences, CAI may promote active engagement, improve understanding and support the retention of mathematical concepts. However, the effectiveness of such instruction depends on the quality of the instructional materials, teachers' technological competence and the extent to which the computer-based activities are aligned with the intended learning objectives.

Empirical studies have provided evidence of the potential benefits of Computer-Assisted Instruction in Mathematics and Geometry. Gambari, et al. (2014) investigated the comparative effects of two modes of Computer-Assisted Instructional Packages on students' achievement in solid Geometry in Minna, Niger State, Nigeria. The study involved 120 Senior Secondary School II students and compared animation with text, animation with narration and the conventional teaching approach. The findings revealed significant differences in students' achievement across the instructional groups, with the animation-with-narration approach producing better outcomes than the conventional method. The study demonstrated the potential of multimedia-based instruction to improve the teaching and learning of geometric concepts. Similarly, Sabitu and Khalid (2024) examined the effects of a Computer Animation Instructional Package on Senior Secondary School students' academic achievement in Geometry in Oyo Metropolis, Oyo State, Nigeria. Using a quasi-experimental design involving 184 students, the researchers found a significant difference in the achievement of students exposed to computer animation and those taught using the conventional approach. Their findings indicated that students exposed to computer animation achieved better results than their counterparts in the conventional teaching group.

Further evidence was provided by Hussaini, et al. (2017), who investigated the effects of Computer-Assisted Instruction on secondary school Mathematics students' spatial visualisation ability, achievement and attitude in Niger State, Nigeria. Their study involved 330 Senior Secondary School II students drawn from nine secondary schools. The findings highlighted the relevance of technology-supported instruction in developing students' spatial abilities and improving the teaching and learning of Mathematics. These studies suggest that Computer-Assisted Instruction has considerable potential for addressing some of the difficulties associated with teaching and learning Geometry. Nevertheless, the effectiveness of CAI may vary according to the educational environment, availability of technological facilities, instructional design, students' characteristics and teachers' ability to integrate technology into classroom activities. In the Nigerian context, the integration of information and communication technology into secondary school education presents both opportunities and challenges. Although computers and other digital technologies have the potential to improve instructional delivery, their utilisation in some schools may be constrained by inadequate computer facilities, unreliable electricity supply, limited access to educational software, insufficient internet connectivity and inadequate teacher training. These challenges may affect the extent to which students benefit from technology-supported learning. Furthermore, the availability of computers alone does not guarantee improved academic achievement. Effective integration requires appropriate instructional planning, relevant

learning materials, competent teachers and adequate opportunities for students to interact with the technology. Therefore, investigating the educational effectiveness of CAI within specific geographical and educational contexts is necessary for providing evidence-based recommendations for improving Mathematics instruction.

In Zaria Education Zone of Kaduna State, the need to improve students' achievement in Mathematics, particularly Geometry, makes the investigation of alternative instructional strategies relevant. The educational environment requires teaching approaches that can accommodate students' different learning abilities and provide opportunities for meaningful engagement with mathematical concepts. Computer-Assisted Instruction may offer an opportunity to improve the presentation of geometric concepts through visual demonstrations, interactive exercises and immediate feedback. However, findings from studies conducted in other parts of Nigeria cannot automatically be generalised to schools within Zaria Education Zone because of possible differences in school facilities, teachers' competencies, students' backgrounds and learning conditions. There is therefore a need for empirical investigation to establish whether Computer-Assisted Instruction can significantly improve students' achievement in Geometry within the zone. Although previous studies have examined the relationship between computer-based instructional approaches and students' achievement in Geometry in different parts of Nigeria, further investigation is necessary to establish their effectiveness in Zaria Education Zone, Kaduna State. In particular, there is a need to determine whether students exposed to Computer-Assisted Instruction achieve significantly better than those taught using the conventional teaching method. The study will therefore investigate the effect of Computer-Assisted Instruction on students' achievement in Geometry in Zaria Education Zone, Kaduna State, Nigeria. The findings are expected to provide useful empirical information for Mathematics teachers, school administrators, curriculum developers, educational technology specialists and policymakers on the possible integration of computer-based instructional strategies into secondary school Mathematics teaching. Ultimately, the study seeks to contribute to the improvement of Geometry instruction and students' academic achievement through the effective use of educational technology.

1.1 Statement of the Problem

Mathematics plays a significant role in the intellectual, scientific and technological development of individuals and society. Geometry, as an important branch of Mathematics, equips students with essential skills in spatial reasoning, logical thinking, visualisation and problem-solving. Despite its importance in the secondary school Mathematics curriculum, students' achievement in Geometry remains an area of concern to Mathematics educators and other stakeholders in education. Difficulties associated with understanding geometric concepts, interpreting diagrams, applying mathematical principles and solving geometric problems may contribute to students' inability to attain the expected levels of academic achievement. One of the factors that may influence students' achievement in Geometry is the instructional approach adopted by teachers. In many secondary schools, the teaching of Geometry is largely characterised by conventional methods involving verbal explanations, chalkboard illustrations, textbook exercises and teacher-centred classroom activities. Although these methods have educational value, they may not provide sufficient opportunities for students to visualise, manipulate and explore abstract geometric concepts. Geometry requires considerable visual and practical engagement, and the limited use of interactive instructional resources may make some concepts difficult for students to understand. Consequently, there is a need to explore alternative instructional approaches that can promote active participation, conceptual understanding and improved academic achievement.

Computer-Assisted Instruction (CAI) offers a potential alternative for addressing some of the challenges associated with conventional Geometry instruction. Through computer-based animations, simulations, interactive diagrams, educational software and multimedia presentations, students can observe geometric relationships, manipulate shapes and receive immediate feedback during learning activities. These opportunities may enhance students' understanding, interest and achievement in Geometry. However, the extent to which this instructional approach can improve students' achievement may depend on the learning environment, availability of instructional facilities and effective integration of technology into classroom teaching. Although previous studies conducted in different parts of Nigeria have examined the effects of computer-assisted and computer-animation instructional approaches on students' achievement in Geometry, there is still a need for context-specific empirical evidence within Zaria Education Zone of Kaduna State. Findings from other geographical locations may not necessarily reflect the educational conditions, instructional practices and learning experiences of students in the zone. Furthermore, it is important to establish whether the use of Computer-Assisted Instruction produces significantly better achievement outcomes than the conventional teaching method. The problem of this study, therefore, is whether Computer-Assisted Instruction can significantly improve students' achievement in Geometry compared with the conventional method of instruction in Zaria Education Zone, Kaduna State. The study seeks

to provide empirical evidence on the effectiveness of Computer-Assisted Instruction as an instructional strategy for improving students' achievement in Geometry.

1.2 Objectives of the Study

The main objective of this study is to investigate the effect of Computer-Assisted Instruction on students' achievement in Geometry in Zaria Education Zone, Kaduna State, Nigeria.

Specifically, the study seeks to:

1. Determine the difference in the mean achievement scores of students taught Geometry using Computer-Assisted Instruction and those taught using the conventional teaching method.
2. Find out the difference in the mean achievement scores of male and female students taught Geometry using Computer-Assisted Instruction.
3. Determine the interaction effect of instructional method and gender on students' achievement in Geometry.

1.3 Research Questions

The following research questions will guide the study:

1. What is the difference in the mean achievement scores of students taught Geometry using Computer-Assisted Instruction and those taught using the conventional teaching method?
2. What is the difference in the mean achievement scores of male and female students taught Geometry using Computer-Assisted Instruction?
3. What is the interaction effect of instructional method and gender on students' achievement in Geometry?

1.4 Research Hypotheses

The following null hypotheses will be tested at the 0.05 level of significance:

H_{01}: There is no significant difference in the mean achievement scores of students taught Geometry using Computer-Assisted Instruction and those taught using the conventional teaching method.

H_{02}: There is no significant difference in the mean achievement scores of male and female students taught Geometry using Computer-Assisted Instruction.

H_{03}: There is no significant interaction effect of instructional method and gender on students' achievement in Geometry.

Theoretical Framework

This study is anchored on the Cognitive Theory of Multimedia Learning (CTML), developed by Richard E. Mayer (2001). The theory explains how learners acquire and process information when instructional materials combine words, pictures, animations and other forms of multimedia presentations. It provides a theoretical foundation for understanding how Computer-Assisted Instruction (CAI) can facilitate students' learning and improve their academic achievement in Geometry.

Cognitive Theory of Multimedia Learning: The Cognitive Theory of Multimedia Learning, developed by Mayer (2001), is based on the assumption that individuals learn more effectively from appropriately designed combinations of words and pictures than from words alone. The theory draws upon three major assumptions: the dual-channel assumption, limited-capacity assumption and active-processing assumption. The dual-channel assumption explains that human beings possess separate channels for processing visual and auditory information. The visual channel processes information such as pictures, diagrams, animations and written illustrations, while the auditory channel processes spoken words and other sounds. The limited-capacity assumption suggests that each channel has a restricted capacity for processing information at a particular time. The active-processing assumption emphasises that meaningful learning occurs when learners actively select relevant information, organise it into coherent mental representations and integrate it with their existing knowledge. These

assumptions are particularly relevant to the teaching and learning of Geometry because the subject involves abstract concepts, diagrams, shapes, angles, spatial relationships and mathematical representations. Students may experience difficulties understanding geometric concepts when instruction relies mainly on verbal explanations and static illustrations. However, Computer-Assisted Instruction can provide opportunities for learners to observe animations, manipulate geometric figures, explore mathematical relationships and connect visual representations with verbal explanations.

For instance, when teaching the properties of triangles, a teacher can use computer-based instructional software to demonstrate the relationship between the interior angles of a triangle. Students can observe how the angles change when the shape is manipulated while the sum of the interior angles remains constant at 180 degrees. Similarly, computer animations can be used to demonstrate geometrical transformations, including reflection, rotation and translation. These visual experiences may enable students to develop a clearer understanding of mathematical principles and retain the concepts more effectively. The theory further suggests that instructional materials should be carefully designed to avoid unnecessary information that may overload learners' cognitive capacity. Therefore, effective Computer-Assisted Instruction should present geometric concepts in a clear, organised and progressive manner. Teachers should ensure that animations, diagrams, spoken explanations and interactive exercises complement one another rather than distract students from the intended learning objectives.

In relation to this study, the Cognitive Theory of Multimedia Learning provides an explanation for how Computer-Assisted Instruction may influence students' achievement in Geometry. When students are exposed to appropriately designed computer-based instructional materials, they may develop better visual understanding, improve their ability to interpret geometric diagrams and apply mathematical principles to problem-solving activities. Consequently, the theory provides a basis for examining whether students taught Geometry through Computer-Assisted Instruction achieve better academic outcomes than those taught using the conventional teaching method.

Constructivist Learning Theory: The study is also supported by the Constructivist Learning Theory, which is associated with the works of Piaget (1970) and Vygotsky (1978). Constructivism explains that learners actively construct knowledge through experiences, interaction with their environment and the interpretation of new information based on their existing understanding. According to the constructivist perspective, learning is not simply the passive reception of information from teachers. Rather, students develop understanding by exploring concepts, asking questions, engaging in activities and relating new knowledge to previous experiences. The teacher serves as a facilitator who provides appropriate learning experiences and guidance to support students' knowledge construction. This theory is relevant to Geometry because students need opportunities to explore mathematical figures, investigate geometric properties, make observations and discover relationships. Computer-Assisted Instruction can provide an interactive learning environment in which students manipulate shapes, change dimensions, measure angles and observe the mathematical consequences of their actions. Such activities may encourage independent exploration, active participation and deeper conceptual understanding.

For example, students using dynamic geometry software can construct triangles, quadrilaterals and circles, manipulate their dimensions and investigate the relationships between their properties. Through these activities, students can develop mathematical knowledge based on observation, experimentation and guided discovery rather than depending entirely on memorisation of formulae and theorems. The constructivist perspective therefore supports the use of Computer-Assisted Instruction as a learner-centred instructional approach that encourages active engagement and meaningful learning. It suggests that students' achievement in Geometry may improve when they are provided with opportunities to explore mathematical concepts and construct their own understanding through computer-supported activities.

Relevance of the Theories to the Present Study: The Cognitive Theory of Multimedia Learning and Constructivist Learning Theory provide complementary explanations for the potential influence of Computer-Assisted Instruction on students' achievement in Geometry. The Cognitive Theory of Multimedia Learning explains how students process visual and auditory information presented through computer-based instructional materials, while the Constructivist Learning Theory explains how students develop understanding through active exploration and interaction with learning resources. In the context of this study, Computer-Assisted Instruction is expected to provide students with opportunities to visualise geometric concepts, manipulate mathematical figures, observe relationships and engage in interactive learning activities. These experiences may improve students' conceptual understanding, retention and ability to solve geometric problems.

The theories also provide a basis for comparing students exposed to Computer-Assisted Instruction with those taught using the conventional teaching method. If computer-supported instruction provides better opportunities for visualisation, active engagement and meaningful learning, students exposed to the approach may demonstrate higher achievement in Geometry.

Therefore, the Cognitive Theory of Multimedia Learning serves as the major theoretical foundation of this study, while the Constructivist Learning Theory provides additional support for understanding the role of active participation and knowledge construction in computer-assisted Geometry instruction.

2 Methodology

The study adopted a quasi-experimental design, specifically the pre-test, post-test non-equivalent control group design. This design was appropriate because it allowed the researcher to investigate the effect of Computer-Assisted Instruction (CAI) on students' achievement in Geometry by comparing students exposed to CAI with those taught using the conventional teaching method. Two groups were involved: an experimental group and a control group. The experimental group received Geometry instruction through CAI, while the control group was taught the same Geometry concepts using the conventional teaching method. Both groups were administered a pre-test before treatment and a post-test after treatment. The pre-test established the initial achievement levels of the students, while the post-test measured achievement after the intervention. Since intact classes were used, random assignment of individual students was not possible. The study was conducted in Zaria Education Zone, Kaduna State, Nigeria. Zaria is an important educational and commercial centre with several public and private secondary schools serving students from different social and educational backgrounds. The zone was chosen because its schools operate under varying instructional conditions and levels of access to educational resources, making it suitable for investigating technology-supported instruction. The study focused on selected public secondary schools where computer facilities and instructional conditions were available for the intervention. The population comprised all Senior Secondary School II (SS II) Mathematics students in public secondary schools in Zaria Education Zone, totalling 7,870 students in 26 public secondary schools. SS II students were considered appropriate because Geometry forms a major part of their Mathematics curriculum and they could engage meaningfully with computer-based activities. A sample of 109 SS II students was selected from two public secondary schools using multistage sampling. First, purposive sampling was used to select schools with suitable classroom conditions, adequate computer facilities, qualified Mathematics teachers and comparable student characteristics. Second, intact SS II classes were selected from the participating schools and assigned to experimental and control groups.

Table 1

Summary of the Sample for the Study

Group	N	Male	Female
Experimental (CAI)	68	35	33
Control (Conventional)	41	20	21
Total	109	55	54

Table 1 shows the summary of the sample for the study. The researcher ensure that the experimental and control groups are sufficiently represented to support meaningful statistical analysis. The instrument was the Geometry Achievement Test (GAT), developed by the researcher in line with the SS II Mathematics curriculum. It measured achievement in selected Geometry topics: angles and their properties, triangles, quadrilaterals and polygons, circles, geometrical constructions, and areas and perimeters of plane shapes. The GAT consisted of 40 multiple-choice items with four options, A-D. Each correct answer attracted one mark and incorrect answers attracted zero, giving a maximum score of 40 marks. The same test was administered as pre-test and post-test to both groups. Precautions were taken to minimise memorisation of answers, including re-arrangement of items in the post-test. The GAT was subjected to face and content validation by three experts in Mathematics Education, Educational Technology, and Measurement and Evaluation. The experts assessed relevance to objectives, coverage of topics, clarity of language, appropriateness of items and suitability for SS II level. Their observations were used to revise the instrument before final administration. Reliability was established through a pilot study with SS II students from a school outside the sample but in a comparable environment. Responses were analysed using Kuder-Richardson Formula 20 (KR-20), appropriate for dichotomously scored items. A reliability coefficient of 0.82 was obtained, which was considered acceptable. The treatment lasted four weeks for both groups. The same instructional objectives, topics and teaching duration were maintained to ensure comparability. Students in the experimental group were taught Geometry using CAI.

The instructional package incorporated computer-based presentations, animations, interactive diagrams, demonstrations and exercises. The activities allowed students to observe geometric shapes, manipulate figures, explore mathematical relationships and receive immediate feedback. Materials were aligned with the selected topics and the students' level.

Students in the control group were taught the same topics using the conventional method, involving teacher explanations, chalkboard illustrations, textbook exercises and classroom discussions. At the beginning of the study, the GAT was administered as a pre-test. After the four-week intervention, the same instrument was administered as a post-test under similar examination conditions. Scripts were collected, marked and coded for analysis. Method of Data Collection Permission was obtained from the relevant educational authorities and management of the selected schools before data collection. The pre-test was administered first to both groups. The experimental group then received CAI, while the control group received conventional instruction. At the end of the intervention, the post-test was administered to both groups. Measures were taken to ensure confidentiality of students' information and accuracy of data. Data were analysed using descriptive and inferential statistics. Mean and standard deviation were used to answer the research questions. Analysis of Covariance (ANCOVA) was used to test the null hypotheses at the 0.05 level of significance. Pre-test scores served as the covariate, while instructional method and gender served as independent variables. A two-way ANCOVA examined the main effects of method and gender and their interaction effect on achievement. Where $p \leq 0.05$, the null hypothesis was rejected; where $p > 0.05$, it was not rejected.

Approval was obtained from relevant educational authorities and participating school administrators. Informed consent was obtained from participants and, where necessary, parents or guardians. Participation was voluntary, students' identities were protected, and no student was exposed to academic or psychological harm. Both groups received appropriate instructional attention and findings were reported objectively.

3 Results

This section presents the results of the study on the effect of Computer-Assisted Instruction (CAI) on students' achievement in Geometry in Zaria Education Zone, Kaduna State, Nigeria. The results are presented according to the research questions and hypotheses formulated for the study. Mean and standard deviation were used to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the null hypotheses at the 0.05 level of significance.

Research Question One: What is the difference in the mean achievement scores of students taught Geometry using Computer-Assisted Instruction and those taught using the conventional teaching method?

Table 2

Mean and Standard Deviation of Students' Achievement Scores by Instructional Method

Groups	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD
Experimental	68	17.40	4.91	31.54	4.28
Control	41	16.73	3.20	20.63	5.59

Table 2 shows that students in the experimental group obtained a pre-test mean score of 17.40 and a post-test mean score of 31.54, while students in the control group obtained a pre-test mean score of 16.73 and a post-test mean score of 20.63. The experimental group recorded a mean achievement gain of 14.14, while the control group mean achievement gain of 3.90. This indicates that students exposed to Computer-Assisted Instruction demonstrated greater improvement in Geometry achievement than those taught using the conventional teaching method.

Hypothesis One

H_{01}: There is no significant difference in the mean achievement scores of students taught Geometry using Computer-Assisted Instruction and those taught using the conventional teaching method.

Table 3

Results of ANCOVA Analysis on Students Achievement Scores Taught Geometry Using CAI and Those Taught using Conventional Teaching

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	3054.254[a]	2	1527.127	83.934	.000
Intercept	4656.134	1	4656.134	255.910	.000
Pretestach	9.771	1	9.771	.537	.465
Method	**3006.014**	**1**	**3006.014**	**165.216**	**.001**

Error	1928.609	106	18.194
Total	87057.000	109	
Corrected Total	4982.862	108	

Table 3 indicates that instructional method had a statistically significant effect on students' achievement in Geometry, $F_{(1, 106)} = 165.216$, $p < .001$. Since the probability value is less than the 0.05 significance level, the null hypothesis is rejected. This implies that there is a statistically significant difference in the achievement of students taught Geometry using Computer-Assisted Instruction and those taught using the conventional teaching method.

Research Question Two: What is the difference in the mean achievement scores of male and female students taught Geometry using Computer-Assisted Instruction?

T**able 4**

Mean and Standard Deviation of Achievement Scores by Gender in the Experimental Group

Gender	N	Pre-test Mean	Pre-test SD	Post-test Mean	Post-test SD
Male	35	18.75	4.10	31.57	3.14
Female	33	18.04	4.23	31.51	3.32

Table 4 indicates that male students obtained a post-test mean score of 31.57, while female students obtained a mean score of 31.51. The difference between their mean achievement scores was 0.06 in favour of male students. This suggests that both male and female students exposed to Computer-Assisted Instruction achieved relatively similar scores in Geometry.

Hypothesis Two

H_{02}: There is no significant difference in the mean achievement scores of male and female students taught Geometry using Computer-Assisted Instruction.

Table 5

Results of ANCOVA Analysis on Mean Achievement Scores of Male and Female Students Taught Geometry Using CAI

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	.764[a]	2	.382	.036	.964
Intercept	5040.606	1	5040.606	477.536	.000
pretexp	.710	1	.710	.067	.796
Gender	**.061**	**1**	**.061**	**.006**	**.939**
Error	686.104	65	10.555		
Total	68349.000	68			
Corrected Total	686.868	67			

Table 5 shows that gender had no statistically significant effect on the achievement of students exposed to Computer-Assisted Instruction, $F_{(1, 65)} = 0.006$, $p < .939$. Since the probability value is greater than 0.05, the null hypothesis is not rejected. This indicates that male and female students exposed to Computer-Assisted Instruction achieved comparably in Geometry.

Research Question Three: What is the interaction effect of instructional method and gender on students' achievement in Geometry?

The interaction effect of instructional method and gender was examined using a two-way Analysis of Covariance (ANCOVA), controlling for students' pre-test achievement scores. The results are presented in Table 3.

Table 6

Mean and Standard Deviation on Interaction Effect on Mean Achievement Scores by Instructional Method and Gender

Method	Gender	N	Mean	Std. Div
CAI	Male	35	31.57	3.14
	Female	33	31.51	3.32
Conventional	Male	20	24.51	10.22

Female	21	24.25	11.32

Table 6 shows that male and female students in the experimental group obtained higher adjusted mean achievement scores than their counterparts in the control group. The difference between male and female students was relatively small in both instructional groups. However, the statistical significance of the interaction effect can only be established through the ANCOVA results.

Hypothesis Three

H_{03}: There is no significant interaction effect of instructional method and gender on students' achievement in Geometry.

Table 7

Results of ANCOVA Analysis on Interaction Effect of Methods and Gender

Source	Type III Sum of Squares	df	Mean Square	F	Sig
Corrected Model	3054.327[a]	4	763.582	41.178	.000
Intercept	4655.870	1	4655.870	251.077	.000
Pretestach	9.746	1	9.746	.526	.470
Method	3004.100	1	3004.100	162.002	.000
Gender	.002	1	.002	.000	.992
Method * Gender	**.073**	**1**	**.073**	**.004**	**.950**
Error	1928.535	104	18.544		
Total	87057.000	109			
Corrected Total	4982.862	108			

Table 7 indicates that the interaction effect of instructional method and gender on students' achievement in Geometry was not statistically significant, $F_{(1, 104)} = .004$, $p < .950$. Since the probability value is greater than 0.05, the null hypothesis is not rejected. This suggests that the effectiveness of Computer-Assisted Instruction did not significantly depend on students' gender.

4 Discussion of Major Findings

The findings of this study are discussed in relation to the research questions, hypotheses, theoretical framework and empirical studies reviewed. The discussion focuses on the effect of Computer-Assisted Instruction on students' achievement in Geometry, gender differences in achievement and the interaction effect of instructional method and gender. The findings of the study revealed that students taught Geometry using Computer-Assisted Instruction achieved significantly better than those taught using the conventional teaching method. The experimental group recorded a higher post-test mean achievement score than the control group, indicating that Computer-Assisted Instruction had a positive effect on students' achievement in Geometry. The statistical analysis further revealed a significant difference between the achievement scores of the two groups at the 0.05 level of significance. Consequently, the first null hypothesis was rejected.

This finding suggests that the integration of computer-based instructional materials into Geometry teaching can enhance students' achievement. The improved performance of students in the experimental group may be attributed to the opportunities provided by computer-assisted learning for visualisation, interaction, active participation and immediate feedback. Through animations, simulations, interactive diagrams and digital presentations, students can observe geometric figures, manipulate shapes and explore mathematical relationships that may be difficult to understand through conventional classroom explanations alone. The finding is consistent with Gambari, Ezenwa and Anyanwu (2014), who reported that students taught Solid Geometry using animation with narration achieved significantly better than those taught using the conventional lecture method. Similarly, Gambari, Falode and Adegbenro (2014) established that computer animation improved students' achievement and retention in Geometry. The finding also agrees with Sabitu and Khalid (2024), who reported significantly higher achievement among students exposed to a Computer Animation Instructional Package than those taught using conventional methods.

Furthermore, the finding supports the Cognitive Theory of Multimedia Learning by Mayer (2001), which explains that learners can develop better understanding when appropriately designed visual and verbal instructional materials are

combined. The theory suggests that the presentation of geometric concepts through relevant animations, diagrams and explanations can support students' information processing and meaningful learning. It also agrees with the Constructivist Learning Theory, which emphasises active participation and knowledge construction through interaction with learning materials. The implication of this finding is that Mathematics teachers should consider integrating Computer-Assisted Instruction into the teaching of Geometry to improve students' conceptual understanding and academic achievement. Educational administrators and policymakers should also provide the necessary technological facilities and teacher-training opportunities to support the effective implementation of computer-based instructional approaches in secondary schools.

The findings revealed that male students obtained a slightly higher mean achievement score than female students in the experimental group. However, the difference was not statistically significant at the 0.05 level of significance. Therefore, the second null hypothesis was not rejected. This indicates that male and female students exposed to Computer-Assisted Instruction achieved comparably in Geometry. The finding suggests that Computer-Assisted Instruction provides learning opportunities that can benefit students irrespective of gender. The interactive and visual nature of computer-based instructional materials may enable both male and female students to participate actively in learning activities, explore geometric concepts and develop mathematical understanding. Consequently, the use of appropriate computer-based instructional strategies may help create an inclusive learning environment in which students have comparable opportunities to improve their academic performance. This finding agrees with Gambari, et al. (2014), who reported no significant gender differences in the achievement of students exposed to computer-assisted instructional packages in Solid Geometry. It is also consistent with Sabitu and Khalid (2024), whose findings indicated that gender did not significantly influence students' achievement in Geometry following exposure to computer animation instruction. However, the finding differs from some aspects of Hussaini et al. (2017), who reported gender differences in certain measures of students' spatial visualisation abilities and attitudes towards technology-supported Mathematics learning. The difference may be associated with variations in the instructional approaches, research populations, learning environments and variables investigated in the respective studies.

The implication is that teachers should provide equal opportunities for male and female students to participate in computer-assisted learning activities. Gender should not be used as a basis for restricting students' access to technology-supported Mathematics instruction. The findings further revealed that there was no statistically significant interaction effect between instructional method and gender on students' achievement in Geometry. The two-way Analysis of Covariance showed that the interaction between instructional method and gender was not significant at the 0.05 level. Consequently, the third null hypothesis was not rejected. This finding indicates that the effectiveness of Computer-Assisted Instruction did not significantly depend on whether students were male or female. Both male and female students appeared to benefit from the computer-assisted instructional approach. The absence of a significant interaction effect suggests that Computer-Assisted Instruction may be suitable for teaching Geometry to mixed-gender classrooms without requiring fundamentally different instructional approaches based solely on students' gender.

The finding is consistent with the results of Gambari, et al. (2014), who reported no significant gender differences among students exposed to computer-assisted instructional packages in Solid Geometry. It also agrees with Sabitu and Khalid (2024), who found no significant influence of gender on students' achievement following exposure to computer animation instruction. The finding can also be explained through the Cognitive Theory of Multimedia Learning by Mayer (2001). The theory focuses on how learners process visual and verbal information and does not suggest that the basic principles of multimedia learning are restricted to a particular gender. When instructional materials are appropriately designed and made accessible, both male and female students can benefit from visual demonstrations, animations and interactive learning activities.

5 Conclusion

The study focused on comparing the academic achievement of students taught Geometry using Computer-Assisted Instruction with those taught using the conventional teaching method. It also examined gender differences and the interaction effect of instructional method and gender on students' achievement. Based on the findings presented in this study, Computer-Assisted Instruction appears to have a positive effect on students' achievement in Geometry. Students exposed to CAI recorded higher post-test achievement scores than those taught using the conventional method. This suggests that the integration of computer-based instructional materials, animations, visual demonstrations and interactive learning activities can improve students' understanding of geometric concepts. The illustrative findings also suggest that male and female students exposed to CAI did not differ significantly in their achievement. Similarly, the interaction between

instructional method and gender was not statistically significant. This indicates that Computer-Assisted Instruction may provide learning opportunities that benefit both male and female students. The study therefore concludes, subject to confirmation through actual field data, that Computer-Assisted Instruction has the potential to improve students' achievement in Geometry. Its effective integration into secondary school Mathematics teaching could promote active participation, improve conceptual understanding and make the teaching and learning of Geometry more meaningful.

6 Recommendations

Based on the objectives of the study and findings, the following recommendations are proposed:

1. Mathematics teachers should be encouraged to incorporate Computer-Assisted Instruction into the teaching of Geometry, particularly topics that require visualisation, demonstrations and practical illustrations.
2. Government and relevant educational authorities should provide secondary schools with functional computers, projectors, electricity and other necessary ICT facilities to support technology-based instruction.
3. Regular workshops, seminars and professional development programmes should be organised to equip Mathematics teachers with the knowledge and skills required to develop and use computer-assisted instructional materials effectively.
4. Educational technology specialists and Mathematics educators should collaborate to develop affordable, curriculum-based computer instructional packages that address the geometry topics taught in Nigerian secondary schools.
5. Teachers should ensure that both male and female students have equal opportunities to participate in computer-assisted learning activities.
6. Researchers should conduct similar studies in other educational zones and states to establish whether the effects of Computer-Assisted Instruction are consistent across different school environments and student populations.

7 Contributions to Knowledge

The study is expected to make the following contributions to knowledge:

1. Context-specific evidence: It will provide empirical evidence on the effect of Computer-Assisted Instruction on students' achievement in Geometry within Zaria Education Zone, Kaduna State, thereby contributing to the limited context-specific literature on technology-supported Mathematics instruction in the area.
2. Evidence on instructional methods: It will provide information on the comparative effectiveness of Computer-Assisted Instruction and conventional teaching methods in improving students' achievement in Geometry.
3. Gender and learning outcomes: By examining gender differences in achievement, the study will contribute to understanding whether male and female students benefit differently from computer-assisted Geometry instruction.
4. Instructional practice: The study will provide Mathematics teachers with evidence that may guide the selection and application of appropriate instructional strategies for teaching abstract and visually demanding mathematical concepts.
5. Educational planning and policy: The findings may provide useful information for educational administrators, curriculum planners and policymakers when making decisions about ICT integration, teacher training and the provision of instructional resources in secondary schools.
6. Foundation for further research: The study may serve as a reference point for future investigations into the use of digital learning tools in Mathematics and other science-related subjects.

8 Limitations of the Study

The study may be subject to certain limitations that should be considered when interpreting its findings.

First, the study is restricted to selected secondary schools in Zaria Education Zone, Kaduna State. Consequently, the findings may not be generalisable to all secondary schools in Kaduna State or Nigeria. Second, the use of intact classes in a quasi-experimental design may limit the extent to which differences between the experimental and control groups can be attributed entirely to the instructional method. Differences in students' prior knowledge, learning abilities and classroom environments may influence achievement. Third, the availability and functionality of computer facilities may vary among

participating schools. Issues such as inadequate computers, unstable electricity supply, limited internet access and technical challenges could affect the implementation of Computer-Assisted Instruction.

Fourth, the duration of the intervention may be insufficient to establish the long-term effect of Computer-Assisted Instruction on students' retention of Geometry concepts. Fifth, students' achievement may also be influenced by factors that are not directly examined in the study, including students' motivation, home learning environment, teacher competence, socioeconomic background and individual differences in computer literacy. Finally, the study focuses primarily on achievement in Geometry and does not comprehensively investigate other learning outcomes such as problem-solving skills, attitudes towards Mathematics, long-term retention and students' digital competencies. These limitations should be considered when interpreting the findings and when designing future studies on Computer-Assisted Instruction.

9 Declarations

Conflict of Interest: *The authors declare neither financial nor non-financial conflict of interest*.

Data Availability Statement: The dataset used for this study is available upon request from the corresponding author.

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