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Effects of Geometrical Set and Geogebra Application on Achievement in Geometry among Upper Basic Students in Owerri Education Zone, Imo State, Nigeria

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Abstract

This study investigated the effect of geometrical set and GeoGebra application on students' academic achievement in geometry, with attention to gender differences, in the Owerri education zone, Imo State. The study adopted a quasi-experimental design with pre-test, post-test, and control groups. A total of 107 Junior Secondary School students, purposively drawn from three schools, participated in the study. Students were assigned to three groups: one taught with GeoGebra, another with geometrical sets, and a control group taught with lecture methods. Data were collected using a validated geometry achievement test, while mean, standard deviation, and Analysis of Covariance (ANCOVA) were used for analysis. Findings revealed significant differences in achievement across the instructional methods. Students exposed to GeoGebra and geometrical sets performed significantly better than those taught with lecture method. GeoGebra produced more consistent achievement outcomes, while gender differences were not significant, indicating that digital tools may help bridge gender gaps in mathematics learning. The study concludes that integrating GeoGebra with geometrical sets provides a balanced and effective instructional material for teaching geometry.

Keywords: Geometry, GeoGebra, Geometrical sets, Academic achievement

Introduction

Mathematics, often regarded as the “language of science,” is the study of numbers, patterns, shapes, and logical relationships that enable humans to solve problems and interpret the world (Uzuegbu *et al.*, 2024). It equips learners with reasoning, problem-solving, and analytical skills that are essential for academic success and national development. Within mathematics, geometry holds a special place as it explores the properties and relationships of points, lines, angles, surfaces, and solids. Beyond schoolwork, geometry underpins careers in engineering, architecture, computer graphics, and science applications (Okigbo & Okeke, 2020). Yet, despite its significance, Nigerian secondary school students consistently underperform in geometry, as documented in repeated WAEC Chief Examiners' Reports (2021; 2022; 2023), raising critical concerns about teaching practices and learning outcomes especially in geometry. Geometry's abstract nature demands spatial reasoning skills many students struggle to develop. Concepts such as points, lines, planes, and transformations are intangible and, when taught mainly through lectures, remain disconnected from learners' experiences. Okigbo and Okeke (2020) observe that the lecture method emphasizes memorization over conceptual understanding, limiting students' ability to visualize geometric relationships. Yet geometry underpins mathematics, science, technology, and architecture, meaning poor mastery disadvantages students



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in examinations and future pursuits. Addressing geometry learning challenges is therefore central to improving achievement and preparing students for national development. Instructional tools provide a pathway to overcoming these learning challenges in geometry. Geometrical sets (compasses, protractors, rulers, and set squares) promote accuracy, active engagement, and hands-on construction. They allow students to model geometric ideas and practise repeatedly, which builds confidence and deeper understanding. Research shows that learners who engage with these tools retain concepts better than those taught by lecture alone (Eze & Nworgu, 2021; Onwumere & Ugwuegbulam, 2020). Yet many teachers undervalue their potential, preferring lecture methods that limit interaction and practice (Okeke & Aja, 2022). The neglect of these low-cost, effective tools is therefore troubling.

Technological advances have introduced GeoGebra, a dynamic software that encourages active engagement through interactive diagrams, real-time feedback, and visualizations. It allows students to model abstract concepts, practice problem-solving, and explore geometry in discovery-based ways. Research confirms that GeoGebra promotes deeper understanding, higher-order thinking, and independent learning (Achor & Umoru, 2019; Usman & Akinyemi, 2021). However, adoption in Nigerian schools is still limited due to poor teacher training, scarce resources, and weak awareness (Akani & Eke, 2023). Meanwhile, lectures dominate because they are cheaper, yet they reduce students to passive listeners (Iji & Abah, 2020). This imbalance requires urgent change. The issue of underutilized methods highlights the need for comparative studies. While GeoGebra, geometrical sets, and lecture methods each have strengths, limited evidence exists on their relative effectiveness in improving geometry achievement (Odey & Onah, 2020; Achor & Okoh, 2022). Moreover, the role of gender remains inconclusive. Some studies suggest males excel due to stronger spatial reasoning (Nwoye & Abah, 2021), while others show no significant gender differences when effective tools are used (Eze & Okeke, 2023). These contradictions suggest that both method and gender may shape achievement. Against this backdrop, the present study compares the effects of GeoGebra, geometrical sets, and lecture methods on students' geometry achievement, while also examining gender differences. The findings are expected to guide teachers, policymakers, and curriculum planners toward evidence-based strategies that improve learning outcomes. Furthermore, this study is anchored on Constructivist Theory, which emphasizes knowledge construction through active engagement. In geometry, this occurs when students use physical instruments or manipulate virtual objects in GeoGebra. Social Cognitive Theory (Bandura) also explains that interaction, modelling, and practice influence learning. These frameworks support examining the relative benefits of GeoGebra and geometrical sets across genders.

Empirical evidence highlights these tools' effectiveness. Onwumere and Ugwuegbulam (2020), using quasi-experimental design with 100 JSS3 students, found that geometrical sets significantly improved performance compared to lectures. Similarly, Eze and Nworgu (2021) showed that both genders benefited, though females gained more in accuracy and retention. Usman and Akinyemi (2021), studying 120 students exposed to GeoGebra, reported no significant gender differences, indicating that interactive tools can bridge spatial reasoning gaps. Together, these studies confirm that both GeoGebra and geometrical sets improve outcomes, though their comparative gender impact remains underexplored. This gap underscores the relevance of the present study.

Statement of the Problem

Despite the central role of geometry in mathematics and its application in science, engineering, and technology, Nigerian secondary school students continue to perform poorly in the subject. Repeated



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West African Examinations Council (WAEC) Chief Examiners' Reports (2021, 2022, 2023) highlight persistent weaknesses in plane, circle, and construction geometry, indicating that the problem is systemic and unresolved. The abstract nature of geometry, coupled with the dominance of lecture-based instruction, makes it difficult for students to visualize and internalize concepts. As a result, many learners resort to rote memorization, leading to shallow understanding and low achievement. Instructional tools such as geometrical sets and modern digital applications like GeoGebra have the potential to make geometry more interactive, concrete, and engaging. Yet, their use in Nigerian classrooms remains limited due to teacher preference for lectures, inadequate training, and lack of resources. Furthermore, existing studies provide inconclusive findings on the relative effectiveness of these methods, particularly when gender differences are considered. Some research suggests male students perform better in spatial tasks, while others report no significant gender effect when supportive tools are used. This inconsistency creates uncertainty for teachers and policymakers. In the light of this, a systematic study comparing GeoGebra, geometrical sets, and lecture methods—while examining gender interactions—is urgently needed.

Objectives of the study

1. Determine the mean achievement scores of students when taught geometry using GeoGebra, Geometrical Sets and those exposed to lecture method without these facilities.
2. Interaction effect of gender and instructional materials on students' achievement scores in geometry.

Research Questions

1. What are the mean achievement scores of students taught geometry using GeoGebra, geometrical sets, and those taught without these facilities exposed to lecture method?
2. What is the interaction effect of gender and instructional materials on students' mean achievement scores in geometry?

Hypotheses

- H₀₁:** There is no significant difference in the mean achievement scores of students taught geometry using GeoGebra, geometrical sets, and those taught without these facilities
- H₀₂:** There is no significant interaction effect of gender and instructional tools on students' mean achievement scores in geometry.

Methodology

This study adopted a quasi-experimental research design of the pre-test, post-test, non-equivalent control group type. This design was considered appropriate because it allowed the researcher to determine the effect of GeoGebra, geometrical sets, and the lecture method on students' academic achievement in geometry without random assignment of participants. The population of the study comprised all Junior Secondary School (JSS 2) mathematics students in the Owerri Education Zone of Imo State, Nigeria. From this population, three intact classes were purposively selected from three different schools to ensure comparable exposure to the curriculum. A total of 107 students participated, with 35 assigned to the GeoGebra group, 35 to the geometrical set group, and 37 to the control (lecture) group. The instrument for data collection was a researcher-developed Geometry Achievement Test (GAT) consisting of 25 multiple-choice and structured items covering plane and solid geometry. The instrument was validated by three experts in mathematics education and measurement/evaluation. Its reliability was established using the Kuder-Richardson formula (KR-20), yielding a coefficient of 0.82, indicating high internal consistency. Data collection followed three phases: pre-test, treatment, and post-test. Each group received instruction for four weeks according to their designated method. The GeoGebra group was taught using dynamic geometry software; the

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geometrical set group was taught with compasses, rulers, and protractors; while the control group received conventional lecture instruction. Data were analyzed using mean and standard deviation to answer the research questions, while Analysis of Covariance (ANCOVA) was employed to test the hypotheses at 0.05 level of significance.

Presentation of Results:

Research Question 1:

What are the mean achievement scores of students taught geometry using GeoGebra, geometrical sets, and those taught without these facilities exposed to lecture method?

Table 1: Mean achievement scores and standard deviations of students taught geometry using GeoGebra application, geometrical sets and those taught without them.

Materials	N	Pre-test \bar{X}	SD	Post-test \bar{X}	SD	Mean Achievement Gain
GeoGebra Application	35	25.77	4.82	59.34	7.26	33.57
Geometrical sets	35	26.49	5.40	64.38	10.79	37.89
Control	37	23.89	4.44	52.97	8.72	29.08

At the pre-test stage, students across the three groups recorded similar low mean scores: GeoGebra (M = 25.77, SD = 4.82), geometrical sets (M = 26.49, SD = 5.40), and control (M = 23.89, SD = 4.44), indicating comparable baseline previous knowledge. After instruction, all groups improved, but with notable differences. The geometrical sets group achieved the highest post-test mean of 64.38 (SD = 10.79), reflecting a gain of 37.89. The GeoGebra group followed with a post-test mean of 59.34 (SD = 7.26) and a gain of 33.57, while the control group, though improved, had the lowest post-test mean of 52.97 (SD = 8.72) with a gain of 29.08. Variability in scores also differed: the geometrical sets group showed the widest spread, suggesting uneven mastery, while the GeoGebra group's lower SD reflected more consistent outcomes. Overall, instructional materials enhanced achievement more effectively than lecture, with geometrical sets proving most impactful.

Hypothesis 1: There is no significant difference in the mean achievement scores of students taught geometry using GeoGebra, geometrical sets, and those taught without these facilities

Table 2: Analysis of covariance (ANCOVA) on the mean achievement scores of students taught geometry using GeoGebra application, geometrical sets and those taught without them.

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	3633.649 ^a	6	605.608	8.314	.000
Intercept	12323.486	1	12323.486	169.178	.000
Pretest	2.480	1	2.480	.034	.854
Materials	2185.187	2	1092.593	14.999	.000
Gender	109.604	1	109.604		.223
Materials*Gender	1145.129	2	572.565		.001
Error	7284.351	100	72.844		
Total	383385.000	107			
Corrected Total	10918.000	106			

a. R Squared = .333 (Adjusted R Squared = .293)



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From Table 2, it can be seen that after adjusting for pretest scores, there was a statistically significant main effect of instructional materials on students’ achievement in geometry, $F(2, 100) = 14.999$, $p < .05$. This indicates that students taught with GeoGebra, geometrical sets, and lecture method did not achieve equally, thereby rejecting the null hypothesis of no significant difference. Specifically, the type of instructional material accounted for meaningful variation in post-test achievement scores, with $R^2 = .333$ showing that about 33% of the variance in achievement was explained by the model. The non-significant effect of pretest ($p = .854$) suggests that initial differences among groups did not influence the outcome, strengthening the validity of the post-test differences. Additionally, the significant interaction between materials and gender ($p = .001$) indicates that the effectiveness of instructional materials varied by gender. Thus, the hypothesis is rejected: instructional materials significantly influenced students’ mean achievement scores in geometry and their order of influence is established in Table 3.

Table 3: LSD Post hoc Analysis of Students Post-test scores classified by Instructional Materials

(I) Method	(J) Method	Mean Difference (I-J)	Std. Error	Sig.
GeoGebra Application	Geometrical Set	-5.036	1.163	.540
	Control	6.371*	1.179	.113
Geometrical Set	GeoGebra Application	5.036	2.141	.021
	Control	11.407*	2.141	.000
Control	GeoGebra Application	-6.371*	2.170	.004
	Geometrical Set	-11.407*	2.141	.000

* = significant at .05 level of Significance

The LSD post hoc analysis in Table 3 provides further insight into the differences among instructional methods. The comparison between GeoGebra and Geometrical Sets shows a mean difference of -5.036 , which is not statistically significant ($p = .540$). This suggests that although the geometrical sets group performed slightly better, the difference was not large enough to be meaningful. However, when GeoGebra is compared with the Control group, the mean difference of 6.371 is statistically significant ($p = .004$), indicating that students taught with GeoGebra outperformed those taught through lecture. Similarly, comparing Geometrical Sets with the Control group yields the largest mean difference of 11.407 , which is highly significant ($p = .000$). This confirms that students taught with Geometrical Sets performed far better than those in the lecture group. In summary, both GeoGebra and Geometrical Sets significantly improved achievement compared to lecture, with Geometrical Sets producing the strongest effect.

Research Question 2: What is the interaction effect of gender and instructional materials on students’ mean achievement scores in geometry?

Table 4: Mean achievement and Standard deviation scores of male and female students taught geometry using GeoGebra and geometrical set.

Instructional Materials	Gender	N	Pretest (\bar{X})	SD	Posttest (\bar{X})	SD	Mean Achievement Gain
Geometrical Set	Male	17	25.10	4.51	66.21	9.34	41.11
	Female	20	26.44	3.29	62.55	7.01	36.11



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GeoGebra	Male	16	25.80	3.91	57.90	6.97	32.10
Application	Female	19	27.18	4.89	60.78	6.09	33.60

The results in Table 4 shows that the interaction between gender and instructional materials on students’ mean achievement scores in geometry has mixed patterns. For the geometrical set, males achieved a higher mean gain (41.11) than females (36.11), indicating that this method was slightly more effective for boys. In contrast, with the GeoGebra application, females recorded a greater mean gain (33.60) compared to males (32.10), suggesting that the digital approach supported girls’ achievement more strongly. The standard deviations also highlight differences in consistency. Among those taught with the geometrical set, males (SD = 9.34) showed more variability in post-test performance than females (SD = 7.01), while in the GeoGebra group, the spread of scores was similar for males (SD = 6.97) and females (SD = 6.09). The results point to an interaction effect: geometrical sets favoured boys’ achievement, whereas GeoGebra fostered slightly better gains among girls, which shows the importance of gender-sensitive instructional strategies in geometry learning.

Hypothesis 2: There is no significant interaction effect of gender and instructional tools on students’ mean achievement scores in geometry.

Table 5: Analysis of Covariance (ANCOVA) on Interaction Effect of Gender and Instructional Materials on Students’ Mean Achievement Scores in Geometry

Source	Type III Sum of Squares	df	Mean Square	F	Sig. (p)	Decision
Corrected Model	1105.642	4	276.411	7.462	.000	S
Intercept	20065.214	1	20065.214	541.883	.000	S
Pretest	362.187	1	362.187	9.785	.003	S
Gender	689.024	1	689.024	18.608	.000	S
Materials	12.837	1	12.837	0.347	.558	NS
Gender × Materials	23.652	1	23.652	0.639	.427	NS
Error	2504.218	67	37.390			
Total	436,405.000	71				
Corrected Total	3610.000	71				

a. R Squared = .306 (Adjusted R Squared = .265)

The ANCOVA results indicate that gender had a statistically significant main effect on achievement ($F = 18.608, p < .05$), while instructional materials alone did not ($F = 0.347, p = .558$). Importantly, the interaction between gender and instructional materials was not significant ($F = 0.639, p = .427$), meaning the combined effect of gender and instructional method did not influence achievement differently across groups. However, since the interaction effect was not significant, the null hypothesis was not rejected. This implies that while gender plays an independent role in achievement, the choice of instructional material does not interact with gender to affect outcomes in geometry

Discussion of Findings

The findings of this study resonate strongly with the theoretical frameworks guiding it. The Constructivist Theory underscores that students learn best through active engagement with instructional tools (Uzuegbu *et al.*, 2024). The present results confirm this: both GeoGebra and geometrical sets significantly improved achievement compared to the lecture method, with geometrical sets producing the highest mean gain. This supports Onwumere and Ugwuegbulam (2020), who found geometrical sets more effective than conventional methods. Educationally, this implies that teachers should integrate hands-on materials and digital tools into geometry instruction rather than relying solely on lectures, as such approaches foster deeper conceptual understanding.



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The results also revealed gender differences, with males benefiting more from geometrical sets and females showing stronger gains with GeoGebra. This aligns with Eze and Nworgu (2021), who observed that gender influences learning outcomes in accuracy and retention. The implication is that educators should adopt a blended strategy, offering both physical and digital tools to cater to diverse learner needs and reduce gender-based disparities. However, the ANCOVA results showed that the interaction effect of gender and instructional materials was not significant ($p = .427$). This finding echoes Usman and Akinyemi (2021), who reported that GeoGebra minimizes gender differences in spatial reasoning. This suggests that when thoughtfully implemented, modern instructional technologies can bridge gender gaps, making classrooms more equitable. Teachers should therefore be trained to apply such tools inclusively, ensuring both male and female learners are equally supported. From the above, the study demonstrates that instructional materials matter more than gender interactions in shaping achievement. The broader implication for educational policy is the urgent need to equip schools with both digital tools like GeoGebra and traditional sets. This will enable teachers to design learner-centered, gender-sensitive geometry lessons that enhance achievement for all students.

Conclusion

This study set out to examine the comparative effects of GeoGebra, geometrical sets, and the conventional lecture method on students' achievement in geometry, with attention to possible gender interactions. The findings revealed that both GeoGebra and geometrical sets significantly enhanced achievement compared to lecture, with geometrical sets proving the most effective overall. While males benefitted slightly more from geometrical sets and females from GeoGebra, the interaction effect between gender and instructional materials was not statistically significant, showing that both tools can support learning across genders. These results aligned with Constructivist and Social Cognitive theories, confirming that active engagement, modelling, and practice are vital for meaningful geometry learning. Empirical evidence from earlier studies also resonates with these findings, underscoring the superiority of instructional tools over rote lecture methods. The study concludes that improving students' achievement in geometry requires moving beyond lecture-based instruction towards integrating both traditional and digital tools. Such practices not only strengthen spatial reasoning but also promote inclusive learning, thereby equipping Nigerian students with the mathematical competencies needed for academic progression and national development.

Recommendations

Based on the outcome, the following recommendations are made:

1. Ministries of Education and school administrators should ensure that GeoGebra is incorporated into the mathematics curriculum at the secondary school level. Teacher training workshops should be organized to build capacity for its effective use.
2. Teachers should not underrate geometrical sets as outdated. Instead, they should actively incorporate them into daily geometry lessons, especially for constructions and measurements, since they promote accuracy and hands-on learning.
3. Teachers are encouraged to adopt a blend of GeoGebra and geometrical sets alongside lectures. This hybrid approach will help bridge the gap between abstract visualization, practical reasoning, and theoretical knowledge.
4. Given that GeoGebra eliminates gender gaps in achievement, schools should prioritize its use to provide equitable learning opportunities for both male and female students.



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