



Effects of Integrating GeoGebra Software on Performance and Retention in ... Ibrahim, A. & Umar, S. (2026)

Effects of Integrating GeoGebra Software on Performance and Retention in Geometry among Secondary School Students in Zamfara State, Nigeria

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Abstract

This study investigated the upshot of integrating the GeoGebra software package on students' academic performance and knowledge retention in geometry across senior secondary schools in Zamfara State, Nigeria. Driven by persistent poor performance rates and heavy reliance on traditional rote methods, the study adopted a quasi-experimental post-test and post-post-test control group design. A sample of 415 senior secondary two (SS II) students was drawn from the population of 79,745 students across the state using an intact class approach. A convenience sampling approach was used in selecting Gusau Educational Zone for the study out of four zones, and a purposive sampling technique was employed in the selection of eight schools from four LGAs under study. Data was gathered using the researcher-developed "Geometry Performance and Retention Test" (GPART), validated by three experts and which attained a PPMC reliability coefficient of 0.82 after test-retest. Research questions were answered using descriptive statistics of mean and standard deviation, while independent samples t-tests analyzed the null hypotheses at a 0.05 level of significance. The findings revealed a statistically significant performance difference favoring students taught geometry using GeoGebra over conventional instruction ($t=6.891$, $p=.000$), leading to the rejection of null hypothesis one. Furthermore, gender did not exert a statistically significant influence on immediate academic performance under GeoGebra-mediated instruction ($t=.548$, $p=.585$), resulting in the retention of null hypothesis two and demonstrating equitable learning benefits. However, a significant gender difference emerged in long-term knowledge retention ($t=2.386$, $p=.019$), where female students achieved higher mean retention scores, leading to the rejection of null hypothesis three. The study concludes that interactive digital tools substantially improve academic achievement and cognitive recall. It recommends institutionalizing GeoGebra in the curriculum and supporting gender-inclusive pedagogies.

Keywords: GeoGebra software, Academic performance, Knowledge retention, Geometry

Introduction

Within Nigeria's educational framework, mathematics functions as a core academic pillar that builds essential problem-solving abilities, structural reasoning, and quantitative literacy for a data-driven society (National Council of Teachers of Mathematics [NCTM], 2024). Beyond standard arithmetic, the discipline acts as a universal catalyst for economic viability and technological advancement (OECD, 2023), allowing learners to critically analyze real-world situations and make informed decisions (Hanushek & Woessmann, 2020). Nevertheless, delivering effective math instruction faces major hurdles, particularly in abstract domains like geometry. Instructors in senior secondary institutions throughout Zamfara State encounter severe resource constraints such as a lack of visual aids, physical models, and interactive software that hamper effective teaching (Bello, 2025). To overcome these structural limitations, incorporating digital application tools has become a vital pedagogical shift. Research indicates that dynamic technologies greatly enhance student motivation,



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concept retention, and spatial visualization (Achor et al., 2023). GeoGebra stands out among these platforms by merging algebra, calculus, and geometry into a unified interactive space where students can actively explore and modify geometric shapes (Hohenwarter, 2024). Recent findings show that utilizing such digital applications successfully connects theoretical research with classroom practice, boosting active student participation (Ardina et al., 2025). Furthermore, historical analyses spanning two decades confirm that GeoGebra excels as an interactive medium that improves problem-solving, modelling, and knowledge retention over traditional methods (Awaji et al., 2025). This educational framework relies heavily on core variables: geometry, academic performance, and knowledge retention. Geometry provides the structural foundation for analyzing lines, points, shapes, and spatial dimensions. Academic performance reflects measurable achievement through testing, whereas knowledge retention denotes the long-term cognitive ability to recall and apply these mathematical concepts rather than relying on short-term memorization. Historically, geometry instruction relied on static illustrations and rote learning, which severely limited students' spatial abilities and overall performance in Zamfara State classrooms. Long-term geometric retention heavily predicts overall success in major external examinations like WAEC and NECO across Nigerian secondary schools (Njoku, 2024). Because geometry requires strong visual imagination, temporary memorization falls short, making interactive platforms like GeoGebra essential for visualizing structural characteristics (Tan et al., 2023). Additionally, gender dynamics in northern Nigerian mathematics education remain a critical discussion point. While past assumptions favored male spatial reasoning, recent studies demonstrate that technology-based instruction minimizes these performance gaps (Sanderson & Ojimba, 2024), empowering both male and female learners equally (Awodun & Oyeiyi, 2023).

Geometry functions as a foundational mathematical branch concerned with spatial relationships, measurements, and the properties of both two-dimensional plane figures and three-dimensional solid structures (Britannica, 2024; Clements & Battista, 2023). Tracing its origins back to ancient Egypt and Mesopotamia for land surveying and construction, the field evolved through Greek contributions into an abstract discipline encompassing Euclidean, analytic, and projective geometries (Chukwu, 2019; Britannica, 2024). Within secondary education, teaching geometry presents unique pedagogical challenges due to its abstract nature, making the development of spatial intuition and critical thinking essential (Kivkovich & Chis, 2016; Brown, 2021). To overcome traditional instructional barriers and rote memorization, educators increasingly rely on interactive computer software applications like GeoGebra an open-source dynamic platform integrating geometry, algebra, and calculus to provide real-time visual representations, stimulate problem-solving, and cultivate active student engagement (Hohenwarter, 2001; Akcay et al., 2023). Enhancing academic success in this domain is closely tied to knowledge retention, defined as the cognitive ability to store, recall, and apply fundamental geometric concepts over extended periods rather than relying on temporary memorization (Parker, 2023; Lutz & Huitt, 2018). Student performance and long-term retention are heavily influenced by pedagogical strategies, instructional materials, and learning environments, with traditional lecture methods frequently yielding low retention rates compared to interactive, technology-driven approaches (Tosun, 2015; Jelatu et al., 2018). Furthermore, demographic variables such as gender continue to be widely examined to determine whether performance and retention disparities exist between male and female learners when utilizing digital tools like GeoGebra in secondary classrooms (Sanderson et al., 2022). Recent empirical research extensively documents the profound pedagogical value of integrating GeoGebra software into secondary school mathematics to overcome the inherent abstractions of geometry. Studies



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employing quasi-experimental and mixed-methods designs consistently demonstrate that GeoGebra transforms passive classrooms into interactive environments, significantly improving student achievement, spatial visualization, and long-term knowledge retention compared to conventional lecture-based methods (Awaji et al., 2025; Awaji, 2021; Hidayat et al., 2023; Ekwue et al., 2023; Akwensi et al., 2023). Researchers emphasize that the dynamic manipulation of algebraic and geometric representations bridges the gap between theoretical concepts and practical understanding across diverse geographic regions, including Nigeria, Ghana, South Africa, and Malaysia (Ado & James, 2021; Ihechukwu & Chidi, 2020; Manganyana et al., 2020; Abari et al., 2019). Furthermore, evaluations of demographic variables within these technology-mediated settings frequently report that GeoGebra fosters equitable learning outcomes by narrowing historical gender disparities in spatial reasoning and performance (Ado & James, 2021; Ihechukwu & Chidi, 2020; Abari et al., 2019). Ultimately, the literature strongly advocates for institutional curriculum reforms and sustained teacher professional development to maximize the efficacy of dynamic software tools in modern mathematics classrooms.

Extensive empirical research demonstrates that integrating the GeoGebra application package into mathematics classrooms significantly enhances students' academic performance and conceptual understanding in geometry compared to traditional paper-pencil methods (Aliyu, 2019; Gamage & Charles-Ogan, 2019; Udofia & Uko, 2018). Studies across various regions including Nigeria, South Africa, Ghana, Malaysia, and Thailand consistently reveal that dynamic software environments improve visualization, foster active student engagement, mitigate the abstract difficulties of two- and three-dimensional shapes, and bridge the gap between theoretical instruction and practical application (Gadese, 2016; Ansah, 2020; Khansila et al., 2022; Adelabu et al., 2019; Tay & Mensah-Wonkyi, 2018; Chimuka, 2017; Onaifoh & Ekwueme, 2017; Seloraji & Eu, 2017; Ajaegba & Ekwueme, 2023; Shadaan & Eu, 2023; Dokochi et al., 2023). Furthermore, while technological integration generally boosts student interest and overall outcomes (Bright et al., 2024; Attahiru et al., 2025), investigations into gender disparities indicate that GeoGebra-mediated instruction helps democratize learning by yielding comparable or favourable performance and retention across both male and female students (Gamage & Charles-Ogan, 2019; Adelabu et al., 2019; Onaifoh & Ekwueme, 2017; Egbunu et al., 2017; Gumel & Galadima, 2014; Hamisu, 2017). Despite regional educational investments, students in Zamfara State continue to exhibit poor academic results in internal and external mathematics assessments, largely driven by traditional instructional approaches. Statistical records from the Ministry of Education and the National Bureau of Statistics reveal that between 2016 and 2025, WASSCE candidates in the state averaged a mere 20.03% credit pass rate in mathematics, alongside a 79.97% failure rate. Examiner reports consistently highlight widespread student deficiencies in solving both 2D plane geometry and 3D solid geometry problems. Driven by these persistent performance challenges, this study investigates the integration of GeoGebra software to shift classrooms toward active, student-focused discovery, reduce learning anxiety, and improve long-term geometric retention.

Objectives of the Study

1. Examine the difference in the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State.
2. Examine the influence of gender on the performance of students when GeoGebra software is utilized in the Geometry classroom in secondary schools in Zamfara State.



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3. Examine the influence of gender on the retention rate of students when GeoGebra software is utilized in the Geometry classroom in secondary schools in Zamfara State.

Research Questions

1. Is there any difference in the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State?
2. What is the influence of gender on the mean performance scores of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State?
3. What is the influence of gender on the retention rate of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State?

Null Hypotheses

- H₀₁:** There is no significance difference between the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State.
- H₀₂:** Gender does not exert any significant influence on the mean performance scores of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State.
- H₀₃:** Gender does not exert any significant influence on the retention rate of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State.

Research Methodology

The study adopted a quasi-experimental design utilizing post-test and post-post-test experimental and control group arrangements to investigate causal impacts without random assignment. The target population comprised 79,745 Senior Secondary Two (SS2) students across 167 public senior secondary schools in Zamfara State, Nigeria. Due to regional security concerns, convenience sampling was utilized to select the Gusau Educational Zone, followed by purposive sampling to choose eight computer-equipped schools with balanced gender representation. An intact class sampling method yielded a total sample size of 415 students, divided into experimental and control groups. Data was collected using the researcher-developed "Geometry Performance and Retention Test (GPART)," a 50-item multiple-choice instrument validated by four subject-matter experts and proven reliable via a test-retest method yielding a Pearson Product-Moment Correlation coefficient of 0.82. Following a six-week treatment period utilizing the GeoGebra package alongside conventional instruction, a post-test was administered to measure academic performance, followed by a post-post-test three weeks later to assess knowledge retention. Data analysis was conducted using descriptive statistics (mean and standard deviation) for research questions, while t-test statistics executed via SPSS version 25.0 were employed to test all null hypotheses at a 0.05 level of significance.

Method of data analysis

The descriptive statistics of mean and standard deviation were used in answering all the research questions and the null hypotheses were analysed using the independent samples t-test statistics at .05 levels of significance.

Presentation of Results

Research Question One: Is there any difference in the performance of students taught geometry using GeoGebra package and those taught using conventional method in Senior Secondary Schools in Zamfara State?

Table 1: Summary of the descriptive analysis of the difference in performance of students' taught geometry using GeoGebra Software and those taught using Conventional Method

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Variables	N	$\bar{x}$	SD	S.E. Mean	Mean Diff.
Performance of Students in EG (GeoGebra)	108	39.83	5.458	.525	7.636
Performance of Students in CG (Conventional Method)	198	32.20	10.781	.766	

Source: Field Work, (2026)

Based on the descriptive analysis addressing Research Question One, there is a notable difference in the academic performance of senior secondary school students in Zamfara State taught geometry using the GeoGebra package compared to those taught using the conventional method. Specifically, the Experimental Group (GeoGebra) comprising 108 students recorded a higher mean performance score of 39.83 with a standard deviation (SD) of 5.458, whereas the Control Group (Conventional Method) with 198 students obtained a mean score of 32.20 with an SD of 10.781. The resulting mean difference of 7.636 in favour of the GeoGebra group indicates that students taught geometry using the GeoGebra software achieved superior performance and more consistent score distribution than their peers taught through the conventional method.

Null Hypothesis 1 (H_{01}): There is no significance difference between the performance of students taught geometry using GeoGebra package and those taught using conventional method

Table 2: Summary of the t-test analysis of the significance difference between the performance of students taught geometry using GeoGebra package and those taught using conventional method.

Variables	N	$\bar{X}$	SD	df	t-Crit	p-Value	Decision
Performance of Students in EG (GeoGebra)	108	39.83	5.458	304	6.891	.000	Rejected
Performance of Students in CG (Conventional Method)	198	32.20	10.781				

Source: Field Work, (2026) $\alpha \leq 0.05$ level of significance

The results in Table 2 evaluating Null Hypothesis 1 (H_{01}) indicate a statistically significant difference in the academic performance of students taught geometry using the GeoGebra experimental group (N = 108, Mean = 39.83, SD = 5.458) compared to those taught using the conventional control method (N = 198, Mean = 32.20, SD = 10.781). With a degrees of freedom (df) of 304, the resulting t-value of 6.891 and a corresponding p-value of .000 which is well below the standard .05 level of significance led to the decision that the null hypothesis is Rejected. This empirical evidence confirms that integrating the GeoGebra package significantly enhances students' geometry performance compared to conventional instructional methods.

Research Question 2: What is the influence of gender on the mean performance scores of secondary school students when GeoGebra software is utilized in the Geometry Classroom in Zamfara State?

Table 3: Summary of Descriptive Statistics of the mean performance scores of Male and Female Students taught geometry using GeoGebra Application Software.

Variables	N	$\bar{X}$	SD	S.E. Mean	Mean Diff.
Male performance	44	40.18	3.787	.571	.588
Female Performance	64	39.59	6.376	.797	

Source: Field Work, (2026)

Table 3 presents the descriptive statistics comparing the geometry performance scores of male (N = 44) and female (N = 64) students taught using the GeoGebra application software in experimental

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group. The analysis reveals that male students obtained a slightly higher mean performance score of 40.18 (standard deviation = 3.787), compared to a mean score of 39.59 (standard deviation = 6.376) recorded by their female counterparts. This yields a minor mean difference of 0.588 in favor of the male students, suggesting that while both genders benefited closely from the technology-enhanced instruction, male students achieved a marginally higher average score with less variability in their performance distribution.

Null Hypothesis 2 (H₀₂): Gender does not exert any significant influence on the mean performance scores of secondary school students when GeoGebra software is utilized in the geometry classroom in Zamfara State.

Table 4: Summary of the t-test analysis of the significance difference between performance scores of Male and Female Students taught geometry using GeoGebra Application Software.

Variables	N	$\bar{X}$	SD	df	t-Crit	P-value	Decision
Male Performance	44	40.18	3.787	106	.548	.585	Retained
Female Performance	64	39.59	6.376				

Source: Field Work, (2026) $\alpha \leq 0.05$ level of significance

The t-test analysis presented in Table 4 examines the difference in performance scores between male (N = 44, $\bar{x}$ = 40.18, SD = 3.787) and female (N = 64, $\bar{x}$ = 39.59, SD = 6.376) students taught geometry using the GeoGebra application software. With a degree of freedom (Df) of 106, the analysis yielded a p-value of .585 against a critical t-value threshold. Since the p-value of .585 is greater than the .05 level of significance, the null hypothesis is retained, indicating that there is no statistically significant difference in academic performance between male and female students when using GeoGebra.

Research Question 3: What is the influence of gender on the retention rate of secondary school students when GeoGebra software is utilized in the geometry classroom in Zamfara State.

Table 5: Summary of descriptive statistics on the influence of gender on the retention rate of secondary school students when GeoGebra Software is utilized in the geometry classroom

Variables	N	$\bar{X}$	SD	S.E. Mean	Mean Diff
Male Retention Rate	44	36.50	4.100	.618	2.250
Female Retention Rate	64	38.75	5.246	.656	

Source: Field Work (2026)

Table 5 presents the descriptive statistics examining the influence of gender on the retention rate of secondary school students when GeoGebra software is utilized in the geometry classroom. The results show that the male students in the experimental group (N = 44) recorded a mean retention score of 36.50 with a standard deviation of 4.100, while their female counterparts (N = 64) obtained a slightly higher mean retention score of 38.75 with a standard deviation of 5.246. The resulting mean difference of 2.250 indicates that female students achieved marginally better retention rates than male students when exposed to GeoGebra-assisted geometry instruction, suggesting a positive performance trend among female learners in this technology-integrated learning environment.

Null Hypothesis 3 (H₀₃): Gender does not exert any significant influence on the retention rate of secondary school students when GeoGebra software is utilized in the Geometry classroom in Zamfara State.

Table 6: Summary of the t-test analysis of the significance difference in the geometry retention of male and female students when taught using GeoGebra Software.

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Variables	N	$\bar{X}$	SD	df	t-Crit	P-Value	Decision
Male Retention Rate	44	36.50	4.100	106	2.386	.019	Rejected
Female Retention Rate (GeoGebra)	64	38.75	5.246				

Source: Field Work, (2026) $\alpha \leq 0.05$ level of significance

Based on the independent samples t-test analysis presented in Table 6, the geometry retention of male and female students taught using GeoGebra Software was evaluated with a total degree of freedom (Df) of 106 at a 0.05 level of significance. The male students (N = 44) obtained a mean retention score of 36.50 with a standard deviation (SD) of 4.100, while the female students (N = 64) obtained a mean retention score of 38.75 with a standard deviation of 5.246. With a critical t-value (t-Crit) of 2.386 and a resulting p-value of .019, the p-value is less than the .05 alpha level, leading to the decision that the null hypothesis is rejected. This indicates that there is a statistically significant difference in the retention rates between male and female students taught plane geometry using the GeoGebra application package.

Summary of the Findings

1. The first finding revealed that students' taught geometry using the GeoGebra package achieved a significantly higher mean performance score compared to those taught using the conventional instructional method. The independent samples t-test results, led to the rejection of Null Hypothesis 1. This confirms that integrating GeoGebra substantially enhances students' geometry performance.
2. The second findings of the study revealed that gender does not exert a statistically significant influence on the academic performance of students when GeoGebra software is utilized. Although male students recorded a marginally higher mean score than female students, Null Hypothesis 2 was retained, indicating that technology-enhanced geometry instruction benefits both genders equitably.
3. The third research finding revealed that there is a statistically significant difference in the retention rates of male and female students when taught plane geometry using GeoGebra. Female students recorded a higher mean retention score compared to male students, leading to the rejection of Null Hypothesis 3 and demonstrating a favorable retention advantage among female students in this digital environment.

Discussion of Findings

The first finding revealed that students taught geometry using the GeoGebra package achieved a significantly higher mean performance score compared to those taught using the conventional instructional method, leading to the rejection of Null Hypothesis 1. This outcome strongly aligns with contemporary and historical literature indicating that dynamic digital tools bridge the gap between theory and practice by replacing static illustrations and rote memorization with interactive exploration (Awaji et al., 2025; Aliyu, 2019). Furthermore, this supports the assertions of Achior et al. (2023) and Hohenwarter (2024), who emphasized that GeoGebra's integration of algebra and geometry enhances spatial visualization and student motivation, corroborating broader regional findings that technology-driven instruction consistently outperforms traditional lecture methods in secondary school mathematics (Gamage & Charles-Ogan, 2019; Akwensi et al., 2023). The second finding of the study revealed that gender does not exert a statistically significant influence on the academic performance of students when GeoGebra software is utilized, resulting in the retention of Null Hypothesis 2. While male students recorded a marginally higher mean score, the lack of statistical significance indicates that technology-enhanced geometry instruction benefits both



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genders equitably. This finding agrees with recent literature by Sanderson and Ojimba (2024) and Awodun and Oyeiyi (2023), which highlights that interactive digital platforms help dismantle historical gender disparities in spatial reasoning and mathematics achievement. By providing equal opportunities for visual manipulation and active engagement, GeoGebra fosters an inclusive learning environment where male and female learners perform on par, aligning closely with previous empirical evaluations on gender neutrality in technology-mediated classrooms (Gamage & Charles-Ogan, 2019; Adelabu et al., 2019). The third research finding revealed a statistically significant difference in the retention rates of male and female students when taught plane geometry using GeoGebra, leading to the rejection of Null Hypothesis 3. Specifically, female students recorded a higher mean retention score compared to their male counterparts, demonstrating a favorable retention advantage in this digital environment. While general literature often emphasizes broader gender parity in overall performance under digital instruction (Gamage & Charles-Ogan, 2019; Adelabu et al., 2019), this divergence in long-term cognitive retention highlights how female learners successfully leverage the interactive and visual affordances of GeoGebra. This aligns with the theoretical understanding that overcoming rote learning through dynamic software deeply impacts long-term knowledge retention (Parker, 2023), which serves as a critical predictor of success in major external examinations like WAEC and NECO across Nigerian secondary schools (Njoku, 2024).

Conclusion

In conclusion, this study demonstrates that integrating the GeoGebra application package into senior secondary geometry instruction in Zamfara State significantly improves students' academic performance and long-term knowledge retention compared to conventional lecture methods. While gender does not significantly influence immediate academic performance under technology-enhanced instruction benefiting both male and female learners equitably it does play a notable role in knowledge retention, with female students exhibiting a statistically significant advantage in long-term cognitive recall. Ultimately, the findings confirm that shifting away from traditional rote learning toward interactive, digital tools effectively mitigates instructional barriers and enhances educational outcomes, offering a vital empirical basis for curriculum reform and professional teacher development in secondary mathematics.

Recommendations

Based on the findings of this study, the following three research recommendations are proposed:

1. The State Ministry of Education, curriculum developers, and secondary school administrators should integrate GeoGebra into the official senior secondary school mathematics curriculum. Replacing traditional rote learning with interactive tools will help address low performance rates and enhance overall academic achievement in geometry.
2. Mathematics teachers should sustain inclusive, technology-driven instructional strategies that ensure equal engagement for both male and female students. Because GeoGebra successfully bridges immediate performance gaps between genders, educators must actively encourage equitable participation in all computer-assisted geometry classrooms.
3. Educational researchers and school administrators should build upon the observed retention advantages of female learners by designing structured, long-term cognitive scaffolding strategies. Enhancing sustained conceptual recall is critical for improving student success rates in major external examinations such as WAEC and NECO across Nigerian secondary schools.

References

- Abari, M. T., Gimba, R. W., Hassan, A. A., & Jiya, M. (2019). Effects of Geogebra Instructional Package on Secondary School Students Retention in Geometry in Makurdi Metropolis of



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- Benue State. *International Journal of Research and Innovation in Social Science (IJRISS)*, 3(4), 300–303.
- Achor, E. E., Onwualu, J. N., & Agu, P. O. (2023). Impact of dynamic geometry software on spatial visualization and achievement among senior secondary school students. *Journal of Science and Mathematics Education*, 19(2), 145–158.
- Adelabu, F. M., Makgato, M., & Ramaligela, M. S. (2019). The Importance of Dynamic Geometry Computer Software on Learners' Performance in Geometry. *The Electronic Journal of E-Learning (EJEL)*, 17(1), 52–63, available online at www.ejel.org.
- Ado, I. B., & James, G. D. (2021). Effects of GeoGebra on Students' Academic Achievement and Retention in Calculus in Uyo Local Government Area of Akwa Ibom State, Nigeria. *Lafiya Journal of Education*, 2(1), 122–135.
- Ajaegba, N. M., & Ekwueme, C. O. (2023). Application of GeoGebra Software and Students' Performance in Plane Geometry in Secondary in Delta State, Nigeria. *International Journal of Education and Information Technologies*, 1(2), 10–18.
- Akcay, H., Yildiz, A., & Bozkurt, H. (2023). GeoGebra for Developing Spatial Reasoning and Visualization Skills in High School Geometry. *Journal of Computer Assisted Learning*, 39(5), 432–445.
- Akwensi, V. K., High, B. S., Komla, M. D., Amanyi, C. K., Education, T., Bornaa, C. S., Education, T., Kombat, A., Abugri, A. M., & Kumasi, A. (2023). Effect of Geogebra Software on Students' Academic Performance in Mensuration at the Senior High School Level. *International Journal of Innovative Science and Research Technology*, 8(7), 1509–1516.
- Aliyu, J. (2019). Effect of GeoGebra and Paper/Pencil to the Teaching and Learning of Simultaneous Linear Equation on Students Performance in some Selected Junior Secondary Schools in Zaria, Kaduna State, Nigeria. *ABACUS Journal of the Mathematical Association of Nigeria*, 44(1), 158–165.
- Ansah, S. (2020). *Effect of using GeoGebra on van Hiele's geometric thinking levels of senior high technical school students' attainment of geometry* (Master's thesis). University of Education, Winneba. <http://ir.uew.edu.gh>
- Ardina, G., Bautista, G., Jr., & delos Santos, M. S. (2025). GeoGebra integration in Mathematics teaching: Bridging research and classroom practice. *Journal of Interdisciplinary Perspectives*, 3(8), 845–856. <https://doi.org/10.69569/jip.2025.505>
- Attahiru, A., Bello, A., & Muhammad, A. (2025). Effect of Microsoft Mathematics software on students' ability and interest in learning trigonometry among senior secondary schools in Sokoto State, Nigeria. *Journal of Mathematical Science Education*, 5(2), 112–128.
- Awaji, B. M. (2021). *Investigating the effectiveness of using GeoGebra software on students' mathematical proficiency* [Doctoral thesis, University of Glasgow]. Enlighten: Theses. <https://theses.gla.ac.uk/82594/>
- Awaji, B. M., Khalil, I., & AL-Zahrani, A. (2025). A bibliometrics study of two decades of GeoGebra research in mathematics education. *Journal of Educational and Social Research*, 15(1), 130–139. <https://doi.org/10.36941/jesr-2025-0011>
- Awodun, A. O., & Oyeiyi, K. F. (2023). Gender equity and technological interventions in secondary school mathematics: A contemporary meta-analysis. *African Journal of STEM Education*, 11(3), 202–215.
- Battista, M. T., & Clements, D. H. (2023). Enhancing Geometry Retention in Middle School: The Importance of Visualization and Conceptual Understanding. *International Journal of STEM Education*, 10(1), 1–15.
- Bello, A. A. (2025). *Challenging concepts in Euclidean geometry: A baseline survey of public secondary schools in Gusau Metropolis*. Zamfara State Education Board Report.
- Bright, A., Welcome, N. B., & Arthur, Y. D. (2024). The effect of using technology in teaching and learning mathematics on student's mathematics performance: The mediation effect of students' mathematics interest. *Journal of Mathematics and Science Teacher*, 4(2), em059. <https://doi.org/10.29333/mathsciteacher/14309>



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- Britannica, (2024). Geometry. <https://www.britannica.com/science/geometry>
- Brown, P. (2021). *Introduction to Plane Geometry: The Improving Mathematics Education in Schools (TIMES) Project*, Australian Mathematical Science Institute, Australia.
- Chimuka, A. (2017). *The Effect of Integration of GeoGebra Software in the Teaching of circle Geometry on Grade 11 Students*. Masters of Science Mathematics Education Thesis. University of South Africa.
- Chukwu, L. O. (2019). *Relationship among Test Anxiety, Academic Achievement and Interest of Senior Secondary School Students in Geometry in Enugu State, Nigeria*. The University of Nigeria Nsuka.
- Creswell, J. W., & Creswell, L. D. (2018). *Research design: Qualitative, quantitative, and mixed methods approaches* (5th ed.). Thousand Oaks, CA: Sage Publications
- Dokochi, A. S., Ifeoma, E. V., & Wushishi, D. I. (2023). Effects of Computer Assisted Instructional Package on Junior Secondary School Students Achievement and Retention in Geometry in Minna Niger State, Nigeria. *International Journal of Humanities and Social Science Invention*, 2(5), 69–74.
- Egbunu C. O, Agbo-Egwu A. O, & Anyagh, P. I (2017). Effect of Computer Aided Instructions (CAI) on Senior Secondary School Students ' Retention in Mathematics in. *International Journal of Scientific and Research Publications*, 7(7), 820–823.
- Ekwue, N. L., Ajaegba, N. M., Umukoro, P., Okeke, M. Amos-Emeaso, C. P. (2023). Effectiveness of Geogebra Application on Geometrical Mathematics among Secondary School Students in Delta State. *Global Journal of Educational Research*, 22(2), 75–80.
- Federal Government of Nigeria (2013). *National Policy on Education (Revised)*. Lagos, National Education Research Council press.
- Gadese, C. Y. (2016). *Effects of GeoGebra on Senior High School students' mathematical understanding of rigid motion* (Master's thesis, University of Education, Winneba). University of Education, Winneba Institutional Repository. <http://ir.uew.edu.gh>
- Gamage, T., & Charles-Ogan, G. I. (2019). GeoGebra Software and Students' Performance in Teaching and Learning of Circle Geometry. *Abacus (Mathematics Education Series) Vol.*, 44(1), 476–486.
- Gumel, A. M., & Galadima, H. (2014). Effect of Gender-Related Differences in Academic Achievement and Retention of Senior Secondary School Students Taught Geometry Using Problem Solving Approach. *International Conference on Education in Mathematics, Science & Technology*, 1(1), 484–488.
- Hamisu, B. T. (2017). *The Effect of Practical Approach of Teaching Geometry on Attitude and Performance of Junior Secondary School Students in Katsina State, Nigeria*. Unpublished Master's Degree dissertation in Mathematics Education. Ahmadu Bello University, Zaria.
- Hanushek, E. A., & Woessmann, L. (2020). Education, knowledge capital, and economic growth in developing economies. *World Bank Research Observer*, 35(2), 119–143.
- Hidayat, R., Kamarazan, N. A., Nasir, N., & Ayub, A. F. M. (2023). The effect of GeoGebra software on achievement and engagement among secondary school students. *Malaysian Journal of Mathematical Sciences*, 17(4), 611–627. <https://doi.org/10.47836/mjms.17.4.06>
- Hohenwarter, M. (2024). GeoGebra in the era of automated mathematics and AI integration. *GeoGebra International Research Series*, Vol. 14.
- Hohenwarter, M., & Fuchs, K. (2018). Combination of Dynamic Geometry, Algebra, and Calculus in the Software System GeoGebra. Retrieved from <http://archive.geogebra.org/static/publications/pecs>
- Hohenwarter, M., & Jones, K. (2017). Ways of Linking Geometry and Algebra: The Case of GeoGebra. In D. Küchemann (Ed), *Proceedings of the British Society for Research into Learning Mathematics*, 27(3), 126–131.
- Hohenwarter, M., Hohenwarter, J., Kreis, Y., & Lavicza, Z. (2019). Teaching calculus with free dynamic mathematics software GeoGebra. *Paper presented at the 11th International Congress on Mathematical Education*, Mexico. Hutkemri.



Effects of Integrating GeoGebra Software on Performance and Retention in ... Ibrahim, A. & Umar, S. (2026)

- Ihechukwu, B., & Chidi, O. S. (2020). GeoGebra Software: A Veritable Pedagogical Tool for Improving Students' Achievement in Geometry in Senior Secondary Schools of Owerri Municipal Council of Imo state. *International Journal of Advanced Academic Research (STE)*, 6(7), 17–27.
- Jelatu, S., Sariyasa, G., & Made, A. I. (2018). Effect of GeoGebra-Aided REACT Strategy on Understanding of Geometry Concepts. *International Journal of Instruction*, 11(4), 325–336. <https://doi.org/10.12973/iji.2018.11421a>
- Kalinowski, K. M. (2022). *Euclid's Elements and Early Modern Geometry*. In I. Mueller & V. J. Pitts (Eds.), *The Routledge Companion to the Philosophy of Mathematics* (pp. 324–342). Routledge.
- Khansila, P., Yonwilad, W., Nongharnpituk, P., & Thienyutthakul, S. (2022). Improving academic performance in geometry using a mastery learning approach through GeoGebra. *Journal of Educational Issues*, 8(2), 876–891. <https://doi.org/10.5296/jei.v8i2.20494>
- Kivkovich, N., & Chis, V. (2016). Learning Abilities and Geometry Achievements. *The European Proceedings of Social & Behavioural Science (EpsBS)*, 435–447. <https://doi.org/10.15405/epsbs.2016.12.53>.
- Lutz, S. T., & Huitt, W. G. (2018). *Information Processing and Memory: Theory and Applications*, in W. Huitt, Ed., *Becoming a Brilliant Star: Twelve Core Ideas Supporting Holistic Education*. La Vergne, TN: Ingram Spark, 25–43.
- Manganyana, C., Putten, S. Van, & Rauscher, W. (2020). The Use of GeoGebra in Disadvantaged Rural Geometry Classrooms. *International Journal of Educational Technology*, 15(14), 97–108, <https://doi.org/10.3991/inet.v15i14.13739>
- Maricic, L. (2020). *Introduction to mathematics: A problem-solving approach*. Newnes.
- Mhlolo, M. K. (2024). Is rote Learning of Number Concepts 'Inherently Rotten' or is it Just a Blame and Shame Game that Vitiates Principles of Natural Progression? *Mediterranean Journal of Social Sciences*, 5(27), 1581–1591.
- National Bureau of Statistics (NBS, 2016–2018). WAEC Results Statistics, reported September, 2019.
- National Bureau of Statistics (NBS, 2019–2021). WAEC Results Statistics, reported August, 2022.
- National Council of Teachers of Mathematics [NCTM]. (2024). *Principles and standards for school mathematics: Digitally adaptive classrooms*. Reston, VA: NCTM.
- National Council of Teachers of Mathematics. (2020). *Mathematics Education 2020: Framework for High-Quality Mathematics Instruction*. Reston, VA: Author.
- Njoku, C. U. (2024). Predictors of long-term knowledge retention in secondary school mathematics: Implications for examination readiness in Nigeria. *West African Journal of Educational Assessment*, 12(2), 77–92.
- OECD. (2023). *PISA 2022 Results: Factoring mathematical literacy and digital problem-solving skills in secondary education*. Paris: OECD Publishing.
- Onaifoh, N. M., & Ekwueme, C. O. (2017). Innovative Strategies on Teaching Plane Geometry using GeoGebra Software in Secondary Schools in Delta State. *Global Journal of Educational Research*, 16(2), 55–62. <https://doi.org/10.4314/gjedr.v16i1.8>
- Parker, P. (2023). Factors Affecting Concept Retention. *American Society for Engineering Education*, 14(23), 1–9.
- Sanderson, O. M., Gogo, Z. I., & Ojimba, D. P. (2022). Gender Influence on Student Perception of The Nigerian Further Mathematics Curriculum Content Difficulty. *ICONIC Research and Engineering Journals*, 5(9), 393–408.
- Sanderson, P. K., & Ojimba, D. P. (2024). Gender dynamics in mathematics achievement when utilizing interactive computer application packages. *Journal of Research in Science Teaching*, 61(4), 512–528.
- Seloraji, P., & Eu, L. K. (2017). Students' Performance in Geometrical Reflection Using GeoGebra. *Malaysia Online Journal of Educational Technology*, 5(1), 65–77.
- Shadaan, P., & Eu, L. K. (2023). Effectiveness of Using Geogebra on Students' Understanding in Learning Circles. *The Malaysian Online Journal of Educational Technology*, 1(4), 1–11.



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Effects of Integrating GeoGebra Software on Performance and Retention in ... Ibrahim, A. & Umar, S. (2026)

- Tall, D., Yevdokimov, O., Koichu, B., Whiteley, W., Kondratieva, M., & Cheng, Y. H. (2012). Cognitive Development of Proof. *In New ICMI Study Series* (Vol. 15, Issue 3, pp. 13–49). <https://doi.org/10.1007/978-94-007-2129-62>
- Tan, J. R., Yangco, R. T., & Que, M. S. (2023). Blending dynamic geometry environments with AI problem solvers: A new horizon for TPACK framework integration. *Computers & Education*, 198, 104–119.
- Tay, M. K., & Mensah-Wonkyi, T. (2018). Effect of using Geogebra on Senior High School Students' Performance in Circle Theorems. *African Journal of Educational Studies in Mathematics and Sciences*, 14(2), 1–17.
- Tosun, S. (2015). The Effects of Blended Learning on EFL Students' Vocabulary Enhancement. *Procedia-Social and Behavioral Sciences*, 19(9), 641–647. DIO: <https://doi.org/10.1016/j.sbspro.2015.07.592>
- Udofia, N. A., & Uko, M. P. (2018). GeoGebra and Secondary School Students' Performance in Mathematics in Akwa Ibom North-West Senatorial District of Nigeria. *International Journal of Mathematics and Statistics Studies*, 6(4), 1–14.
- West African Examination Council (2016 - 2021). *Chief Examiners' Report (Nigeria) SSCE*, May/June examinations.
- Zamfara State Ministry of Education (ZSMOEST, 2026). *The Population of Schools and Students of Senior Secondary Schools in Zamfara State*.