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Effects of GeoGebra and Desmos Software on Students' Performance in Coordinate Geometry in Warri South, Delta State, Nigeria

[1]CHARLES-OGAN, G. I. & [2]EFOR, Benjamin

Department of Curriculum Studies and Educational Technology, Faculty of Education, University of Port Harcourt, Rivers State, Nigeria.

Email: benjaminefor@gmail.com

Abstract: This study examined the effects of Geogebra and Desmos software on senior secondary schools 3 (SS 3) students' performance in Coordinate Geometry in the Warri South Local Government Area of Delta State, Nigeria. The research explored how the integration of dynamic Mathematics software – Geogebra and Desmos – impacts learning outcomes compared to traditional teaching methods. This study used a pretest-posttest control group structure in a quasi-experimental approach. Purposive sampling was used to conveniently choose 118 SS 3 kids from three schools out of the 2,350 students that made up the study's population. Two groups of participants were formed: the experimental group received education using Desmos and GeoGebra, while the control group was instructed using the traditional lecture method. The Coordinate Geometry Performance Test (CGPT) was used as the data gathering tool. The Kuder–Richardson Formula 21 (KR-21) method for CGPT yielded a reliability index of 0.89. The two research questions were addressed using mean and standard deviation, and the two hypotheses developed for the study were tested using Analysis of Co-variance (ANCOVA) at the 0.05 level of significance. Data were collected through pre- and post-test assessments and class observations. Findings reveal that students instructed with Geogebra and Desmos demonstrated significant improvement in conceptual understanding, problem solving skills and overall performance in coordinate geometry compared to their peers in the control group. Additionally, learners exhibited increased motivation, better visualization of geometric concepts. The results indicate that the use of interactive software can effectively enhance mathematical instruction and support learners in mastering coordinate geometry. The study concludes with recommendations for integrating technology – based tools into the Mathematics curriculum to improve academic achievement and foster positive attitudes towards learning Mathematics in Warri South and similar educational contexts.

Keywords: Geogebra, Desmos, Coordinate Geometry, Students, performance, Traditional.

Introduction

Mathematics is the foundation for logical reasoning, problem-solving, and decision-making across a broad range of subjects, it is crucial in many aspects of real life. According to Reference [1], Mathematics is essential for understanding and applying science and technology, and it is the cornerstone of both national and international progress. In order to solve problems, apply what they have learnt in the real world, and develop mathematical skills—all of which are goals of learning Mathematics—students must first understand mathematical concepts [2]. For both literate and illiterate members of society, Mathematics is important because of its uses in daily life, including transportation, all types of business, and advancements in science and technology [3]. According to [4], Mathematics is regarded as the mother of all disciplines, and the universe could not function without mathematical knowledge and skills. It is a tool for the progress of any science-based subject and equips people with the ability to approach problems methodically and draw intelligent conclusions. Algebra, statistics, and probability are examples of mathematical ideas that are essential for financial budgeting, data analysis, and project planning. Technological developments provide a solid basis for mathematical research, which pushes the boundaries in domains like big data, machine learning, and cryptography. Additionally, health and medicine depend on Mathematics. From calculating drug dosages to modelling the development of diseases, Mathematics is essential to effective healthcare delivery. For instance, the use of biostatistics and mathematical modelling has been crucial to the administration of public health during the COVID-19 pandemic. Mathematical models have proven invaluable in predicting the virus's transmission, refining vaccination strategies, and evaluating treatment outcomes. Students' fear of Mathematics and their belief that it is a difficult subject are the main causes of their poor performance. It has been demonstrated that the traditional teaching approach is inadequate in providing students with the opportunity to enhance their understanding of geometry concepts and develop a positive attitude towards the subject [5]. As a result, improving students' cognitive level via the traditional way is less effective. For instance, students frequently perceive geometry as a challenging mathematical subject and recall their negative experiences with it [6]. Since Mathematics requires abstract processes spanning several sub-learning domains, students find it difficult to learn. In order to provide students with opportunities for trial and error, test hypotheses, create assumptions, and draw inferences from the data by seeing themselves as mathematicians who make discoveries, dynamic software is essential in Mathematics teaching. Students can participate in these trial-and-error exercises in the geometry learning area, which is thought to be the most prominent of the Mathematics sub-learning areas. Because of its abstract conceptual structure and the need for students to use higher-order thinking skills, geometry is a difficult topic to learn [7].

Coordinate geometry, often known as analytical geometry, is a branch of Mathematics that uses algebraic equations to describe and analyse geometric figures and their properties. This field integrates algebra and geometry by allowing the algebraic solution of geometric problems through the use of a coordinate system, typically the Cartesian coordinate system. In daily life, coordinate geometry is helpful as it finds use in engineering, architecture, athletics, and the arts. Coordinate geometry is one of the disciplines taught to Senior Secondary School students. It is part of the Mathematics test that is prepared virtually every year by the West African Examination Council (WAEC) and the National Examination Council of Nigeria (NECO). Consequently, it establishes a link between algebra and geometry using line and curve graphs. Technology will inevitably affect how we teach and learn since we live in a technological age. Numerous research studies for innovative methods to the teaching-learning process that have been conducted for many years have produced new supportive strategies that promote efficient teaching and learning. One of these tactics is the employment of technology in the classroom. The utilisation of innovative teaching resources and computer-assisted training is becoming more widely acknowledged in the twenty-first century.

One of the numerous benefits of using technology in teaching and learning is that it gives students more opportunity to learn [8]. Students must be able to see, create, and comprehend the creation of shapes in order to relate them to relevant information in the teaching and learning of Mathematics, particularly geometry. Dynamic geometry software will undoubtedly be effective in igniting this enthusiasm in geometry education. Because of their capabilities, which include the ability to create geometric shapes, modify their angles and edges, drag the shapes, track the quantities measured as the geometric structure moves based on these changes, and measure variables like length, area, and angle, dynamic geometry software programs created for the geometry sub-learning area are used in geometry instruction. The open-source Geogebra program, which integrates geometry, algebra, and analysis into a single interface, is one of these tools. Markus Hohenwarter created GeoGebra, an application software program that combines geometry, algebra, and calculus into a single, user-friendly, open-source package, in 2002. A technical tool that integrates all facets of Mathematics is called GeoGebra. It provides multiple representations. It offers geometry, algebra, and a spreadsheet in one. Students may be able to do calculations more rapidly and receive assistance abstracting mathematical concepts when computers are employed in the classroom, especially when math software like GeoGebra is used. Numerous topics in Mathematics courses, such as calculus, trigonometry, statistics, algebra, and geometry, have been studied using GeoGebra over the years. The concepts that have been researched in the area of geometry include coordinate geometry, geometric transformation, analytic geometry, triangles, circles, the circle theorem, and polar coordinates.

Another useful and versatile technology tool for teaching and learning Mathematics is Desmos. Technology in the classroom enhances student performance and attitude, as evidenced by the [9] study. Technology helps teachers and students in maths classes in many ways, which promotes successful and long-term learning [10]. Geometry is a branch of Mathematics that examines the

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properties of space, such as the sizes, shapes, distances, and relative locations of objects. It is the branch of Mathematics that studies lengths, areas, and volumes. Geometry definitions deal with space and shape. In order to define a geometrical shape, features like angles and measurement are used.

It is thought that using ICT—more especially, Geogebra and Desmos—in secondary school maths classes can lay the groundwork for better handling of curriculum changes and innovations.The study looked at Coordinate Geometry, one of the subjects taught in the West African Examination Council's (WAEC) S.S.S. 3 Curriculum. It also looked into how teaching the subjects with Geogebra affected the performance of S.S.S. 3 students in a quasi-experimental way.

Statement of the Problem

Coordinate geometry is a significant area of Mathematics that is helpful in our daily lives and essential to many other professions. But for many years, the researcher saw that, in comparison to other areas of Mathematics, Coordinate Geometry continued to show low performance among senior secondary school three (SSS 3) students. With an average of 41.52% of candidates receiving credit pass and above (C6-A1) and 58.48% receiving pass and below (F9-D7) when taught using a traditional deductive learning strategy, the statistics of students' performance in the West African Senior Secondary Certificate Examination (WASSCE) in General Mathematics over the previous six years (2013-2018) show an appalling performance trend.

Table1.1: WASSCE Mathematics Result From 2013 to 2018

S/N	Year sat for exam	Total number of Candidates	Number of candidates with Credit pass and above (C6-A1)	Percentage (%) of Candidates with Credit pass and Above
1.	2013	1,543,683	555,726	36.00
2.	2014	1,692,435	529,732	31.00
3	2015	1,593,442	544,638	34.18
4.	2016	1,544,243	597,310	38.68
5.	2017	1,559,162	923,486	59.22
6.	2018	1,572,396	786,016	49.98
	Average			41.51

WASSCE Mathematics results from 2013 to 2018. Source: WAEC Examiner’s Report

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Students have a negative attitude towards the topic as a result of their ongoing poor performance, and this attitude seems to have carried over from generation to generation. For a variety of reasons, including the abstract nature of Mathematics, inadequate use of instructional materials, unqualified Mathematics teachers, and students' negative attitudes towards Mathematics, the majority of students struggle to understand some mathematical concepts, particularly coordinate geometry. Students are not actively involved in the learning and problem-solving processes of the traditional, teacher-centered education model, which is highly passive. The way students learn Mathematics and, consequently, coordinate geometry is altered by the use of technology in the classroom. Thus, it is crucial that educators incorporate technology into the classroom. The impact of Geogebra and Desmos software on the performance and attitude of senior secondary school 3 Mathematics students towards coordinate geometry is thus an issue that this study is well-positioned to address.

1.3 Aim and Objectives of the Study

The aim of this study was to investigate the effects of Geogebra and Desmos software on students' performance in coordinate geometry learning in Warri South Local Government Area of Delta State.

This study was guided by the following objectives, to:

1. determine the difference that exists in the mean performance score, between students taught using Geogebra software and those taught using conventional lecture methods.
2. determine the difference that exists in the mean performance score between students taught using Desmos software and those taught using conventional lecture method.

1.4 Research Questions:

The following research questions were raised in order to guide the study:

1. What is the difference in the mean performance score, between students taught using Geogebra software and those taught using conventional lecture methods?
2. What is the difference in the mean performance score, between students taught using Desmos software and those taught using conventional lecture methods?

1.5 Hypotheses:

The following hypotheses were formulated and tested at 0.05 level of significance:

1. There is no significant difference in the mean performance score of SS 3 Mathematics students, taught using Geogebra software and those taught using conventional instructional methods.
2. There is no significant diffrence in the mean performance score, between students taught using Desmos calculator and those taught using conventional lecture methods.

Methodology

This study employed a quasi-experimental design with a pretest – posttest control group structure. The design compared the effects of Geogebra and Desmos-assisted instructions (experimental groups) with conventional lecture teaching methods (control group) on students' performance in coordinate Geometry. Quasi-experimental design is a partly true experimental design in which study participants are assigned to groups. The experimental groups (EGs) and the control group (CG) are part of the design. For five weeks, the experimental groups were required to learn coordinate geometry using the GeoGebra and Desmos software, whereas the control group was taught coordinate geometry using traditional teaching techniques.

Due to their accessibility and utilisation in the study, a convenient sample of 118 S.S. 3 students was chosen. To ascertain the entry behaviour of the experimental and control groups of S.S. 3 Mathematics students, the researcher used the Coordinate Geometry

Performance Test (CGPT) criterion-referenced (pre-test). This was done to determine their "baseline knowledge" prior to the treatment. In order to assess students' performance following exposure to Geogebra and Desmos training, the CGPT consists of 20 multiple-choice questions covering subjects from Coordinate Geometry for both the pretest and posttest. The subjects covered in the first week of instruction included a general overview of the GeoGebra and Desmos software, as well as its innovations, advancements, and features. Additionally, the students learnt about the many GeoGebra and Desmos views, including Graphic View, Algebraic View, and Input View. The second lesson began: Using GeoGebra, find the midpoint of a line segment, the location of a point on a plane, and the distance between two points.

Sample and Sampling Techniques

Three of the twenty-one schools in the Warri South Local Government Area were specifically chosen because there were working computers in the schools. One school served as the control, and the other two served as experimental group. The study used three intact classes, one from each school. A sample of 118 S.S. 3 Mathematics students was chosen conveniently for the study due to their accessibility. There were 45, 38, and 35 students in each class.

Sample Distribution table

School	Group	Instructional strategy	Female	Male	Total
A	Experimental 1	Geogebra	26	19	45
B	Experimental 2	Desmos	25	13	38
C	Control Group	Lecture Method	13	22	35
Total			64	54	**118**

Validity of the Instruments

Validity is the degree to which an instrument measures what it purports to measure [11]. The degree to which extraneous variables have been controlled in the study to guarantee that the change in the dependent variable is truly the result of the therapy determines the validity of the results. The test items were evaluated for content validity by the researcher's supervisors from the University of Port Harcourt's Department of Curriculum Studies and Educational Technology and two measurement and evaluation experts from Delta State University in Abraka, and one seasoned Mathematics instructor. Before giving the CGPT to the respondents as a pre-test and post-test, the researcher took their recommendations and changes into consideration to make the test questions better. Every instrument was approved as sufficient and legitimate for the research.

Reliability of the Instruments

The researcher verified the reliability of the instrument (CGPT) with 20 students from SS 3 by using the split - half method. The test was applied to this sample not included in the sample of the study once. After the researcher administered the test the data collected was correlated using Kuder Richardson (KR-21) formula. A reliability index of 0.89 was obtained for the coordinate Geometry performance test (CGPT). The correlation coefficient represents very high correlation or relationship, thus the instrument for data collection was very reliable.

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Results and Analysis

Research Question 1: What is the difference in the mean performance between students taught using Geogebra software and those taught using conventional instructional methods?

Table 1: Mean and Standard deviation values of students' performance based onTeaching Mode

Methods		Pretest	Posttest	Mean Gain
Geogebra assisted instruction	Mean	49.78	57.18	7.40
	N	45	45	
	Std. Deviation	6.20	6.75	
Conventional method	Mean	47.57	50.46	2.89
	N	35	35	
	Std. Deviation	6.96	7.18	

Table 1 presents the mean and standard deviation values of students' performance in the pretest and posttest, based on the teaching mode, as well as the mean gain for each method.

Research Question 2: What is the difference in the mean performance score, between students taught using Desmos software and those taught using conventional lecture methods?

Table 2: Mean and Standard deviation values of students' performance based on Teaching Mode

Methods		Pretest	Posttest	Mean Gain
Lecture method	Mean	47.57	50.46	2.89
	N	35	35	35
	Std. Deviation	6.96	7.17	3.31
Desmos	Mean	52.32	58.89	6.58
	N	38	38	38
	Std. Deviation	7.09	8.77	6.20

Table 2 presents the mean and standard deviation values of students' performance scores in the pretest and posttest based on the mode of teaching (Lecture method and Desmos-assisted instruction)

Hypotheses

Hypothesis 1**:** There is no significant difference in the mean performance of SS 3 students, taught using Geogebra software and those taught using conventional instructional methods.

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Table 3: Summary of Analysis of Covariance of students' performance based on methods using Pretest as Covariate

Dependent Variable: Posttest

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	2905.829[a]	2	1452.914	64.271	.000	.625
Intercept	353.780	1	353.780	15.650	.000	.169
Pretest	2016.605	1	2016.605	89.207	.000	.537
Methods	479.565	1	479.565	21.214	.000	.216
Error	1740.659	77	22.606			
Total	239983.000	80				
Corrected Total	4646.488	79				

a. R Squared = .625 (Adjusted R Squared = .616)

Table 3 reveals a value of $F_{1,77} = 21.214$, p=.000 ($p < 0.05$) for the difference in the mean performance of SS 3 Mathematics students, taught using Geogebra software and those taught using conventional instructional methods. The null hypothesis is therefore rejected, indicating that there is a significant difference in the mean performance of SS 3 Mathematics students, taught using Geogebra software and those taught using conventional instructional methods.

Hypothesis 2: There is no significant difference in the mean performance score, between students taught using Desmos software and those taught using conventional lecture methods.

Table 4: Summary of Analysis of Covariance of students' performance based on methods using Pretest as Covariate

Dependent Variable: Posttest

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	4136.163[a]	2	2068.081	82.292	.000	.702
Intercept	131.626	1	131.626	5.238	.025	.070
Pretest	2839.085	1	2839.085	112.971	.000	.617
Methods	283.833	1	283.833	11.294	.001	.139
Error	1759.180	70	25.131			
Total	225512.000	73				
Corrected Total	5895.342	72				

a. R Squared = .702 (Adjusted R Squared = .693)

Table 4 reveals a value of $F(1, 70) = 11.294$, p = .001 ($p < 0.05$) for the difference in the mean performance of students taught using taught using Desmos software and those taught using conventional instructional methods., after controlling for the effect of the pretest scores. The null hypothesis is therefore rejected, indicating that indicating that there is a significant difference in the mean performance of SS 3 Mathematics students, taught using Desmos software and those taught using conventional instructional methods. The effect size, as indicated by Partial Eta Squared ($\eta^2 = .139$), suggests a moderate effect of the teaching method on students' performance.

Discussion of findings

The aforementioned highlights the differences between students taught with Geogebra software and those taught with traditional training. According to the descriptive analysis of Table 1's results, the experimental group's mean score was 49.78%, whereas the control group's was 47.57%. The results of this study show that students who were taught using Geogebra software performed significantly better than those who were taught using traditional teaching techniques. In a similar vein, the results of this study show that, in comparison to the traditional lecture method, students' academic performance in Mathematics was greatly enhanced by the usage of Desmos software. According to the analysis, students who received training using Desmos had a greater mean gain between the pretest and posttest than those who received instruction through traditional methods. The statistical findings verify that the manner of instruction significantly affected students' performance and support the rejection of the null hypothesis. Additionally, the effect size indicates that the teaching strategy has a moderate impact on students' academic performance. This result is consistent with earlier studies. According to Reference [12], students who received instruction using the Geogebra Learning Approach (GLA) outperformed those who received instruction using the Conventional Learning Strategy (CLS) in Mathematics. Similarly, [13] found that children who used Geogebra software did better in coordinate geometry than their colleagues who were taught using traditional techniques, highlighting the software's ability to improve academic performance. After adjusting for pretest scores, the findings of the Analysis of Covariance (ANCOVA) show a statistically significant difference in the posttest scores between students who were taught using Desmos and those who were taught conventionally. The statistical results support the rejection of the null hypothesis and confirm that the mode of instruction had a significant impact on students' performance. The effect size also suggests a moderate influence of the teaching method on students' academic outcomes

Conclusion

The study's findings shed important light on how well students acquire coordinate geometry using various teaching strategies, including Desmos-based education, GeoGebra-assisted instruction, and traditional lecture techniques. The results reveal that students' performance significantly improves with both GeoGebra-based and Desmos-based training, with the biggest mean performance gain occurring with GeoGebra-assisted instruction.
The study also emphasises the significance of taking into account technology-integrated teaching strategies, which have been demonstrated to improve students' learning results more successfully than traditional lecture-based strategies.

Recommendations

The study's conclusions lead to the following suggestions being put forth.

1. To improve students' comprehension and engagement, teachers should use GeoGebra-assisted instruction and Desmos-assisted instruction into the teaching of Mathematics, particularly for subjects like Coordinate Geometry.

2. To provide Mathematics teachers the abilities they need to use GeoGebra and other technology-assisted teaching tools like Desmos, and professional development programs should be set up.

3. To enhance teaching and learning results, curriculum planners should integrate technology-based teaching strategies, such as GeoGebra, into Mathematics curricula.

4. The long-term impacts of GeoGebra-assisted and Desmos-assisted education on students' performance and attitudes, as well as their influence on other subjects and grade levels, should be investigated further.

5. The infrastructure and resources required to facilitate the use of technology in the classroom should be supplied by policymakers and educational stakeholders.

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