



Comparing the effectiveness of algebrator and geogebra software on students' retention of algebra concept in port Harcourt metropolis, Rivers State, Nigeria

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Abstract

The study compared the effects of the Algebrator software-based strategy and GeoGebra software-based strategy on Senior Secondary School students' retention in Algebra in Port Harcourt Metropolis, Rivers State. The study was guided by two objectives, two research questions, and two null hypotheses. The quasi-experimental research design of the posttest, post post-test non-randomized and non-equivalent control group was used for the study. A sample of 157 SS2 students was selected from two co-educational public secondary schools using purposive stratified random sampling technique. The instruments for data collection were validated Mathematics Performance Test on Algebra with a reliability coefficient of 0.71 which was obtained through Kuder-Richardson 21 formula and Mathematics Retention Test on Algebra which is a reshuffled version of the performance test. Data collected were analyzed using mean and standard deviation to answer the research questions while Analysis of Covariance was used to test hypotheses at 0.05 level of significance. The findings of the study revealed that there is a significant difference in the mean retention score of students taught Algebra using Algebrator software-based strategy and those taught using GeoGebra software-based strategy, in favour of Algebrator software-based strategy. Also, the findings revealed that female students retained more knowledge of Algebra than male students. However, the difference between the male and female students in their retention of the knowledge of Algebra was not significant. The study thus recommended that teachers should shift from conventional methods of teaching to software-based instructional strategies to enable better understanding and consequent retention of the knowledge of seemingly difficult concepts such as Algebra.

Keywords: Algebrator, Geogebra, Software, Algebra, Retention

Introduction

Mathematics is a subject whose relevance to modern technology advancement and national development cannot be overemphasized. Its knowledge equips professionals to take a leap into the unknown to make life easier and more comfortable (Ahumaraeze & Ekwueme, 2019) [5]. Due to the contribution of Mathematics as a subject, many countries have accorded it an important status in the curriculum, and are making efforts to improve its teaching and learning. Algebra is the branch of Mathematics that helps in the representation of problems or situations in the form of mathematical expressions. It uses variables such as a, b, c, or x, y, z, and mathematical operations such as addition, subtraction, multiplication, and division to form meaningful mathematical expressions. All the branches of Mathematics such as trigonometry, calculus, and coordinate geometry, involve using algebra. A simple example of expression in algebra is $3a + 5 = 35$. Algebra is a perceived difficult concept in Mathematics and requires a problem-based approach in its teaching and learning. Algebra concept is very versatile in its applications, thus used in many concepts in mathematics, sciences, engineering, technology, and even in some social science courses. It also has its applications in many sectors of the nation such as production, manufacturing, and financial sectors. The knowledge of Algebra is therefore much needed by the students in solving real-life problems.

Mathematics software are virtual instructional resources designed for teaching different concepts in Mathematics. They are user-friendly and interactive in that they display step-by-step guide to the solution of mathematical problems. Examples of mathematics software and the mathematical concepts that they can be used to teach are:

1. Maple 15: for solving problems in calculus and algebra.
2. Mathematics an easy-to-use calculator.
3. Derive: for algebra, matrices, and calculus.
4. Math flashcards: for improving speeds in accuracy in division, subtraction, multiplication, and addition.
5. Mathcad: to plot graphs.
6. Graphical Calculators such as Desmos: for solving simultaneous equations and plotting of graphs.
7. Algebrator: for teaching algebra
8. GeoGebra: for arithmetic, geometry and algebra, calculus, spreadsheets, graphs, statistical analyses.
9. Matlab: for numerical computations, data analysis, graphics and algorithm development.
10. Geometry pad: for geometry and graphs.
11. SageMath: for algebra, calculus and advanced number theory.
12. Maxima: for calculus, linear algebra, differential equation
13. Photomath: to scan and solve mathematics problems.
14. MathSolver: for solving problems and plotting graphs.
15. Mathematica: for geometry, algebra, number theory, graphs, and data analysis.

The roles played by Mathematical Software in Mathematics teaching and learning include:

1. Arousing students' interest in Mathematics
2. Building on students' experience and knowledge
3. Strengthening students' problem-solving skills and reasoning ability
4. Providing opportunities for students deep and sustained interaction with key mathematical ideas.

Algebrator software is a Computer Algebra System (CAS), which was developed in the late 1990s by Neven Jurkovic of Softmath, San Antonio, Texas. This is a CAS specifically geared towards the learning of algebra. Algebrator software is an application that solves algebra problems using a WYSIWYG interface. Algebrator is used to supplement classroom lessons, and accurately and quickly solve mathematical problems. It solves algebraic problems such as matrices, equations, and linear systems using simple commands that help the students follow up on solving the algebraic problems step-by-step, with the appropriate explanation of each step. It is designed in a way that enables the student to develop a deep understanding of solving mathematical problems through practical application and discover the method of solving himself. The program provides the students with mathematical skills. It has all the necessary aids to make the learning process easy and interesting, as the students build on their previous learning, and this is fully consistent with the constructivist approach to learning (Aishara, 2021) ^[6]. Yulian (2016), as cited in Aishara (2021) ^[6], showed that the Algebrator program is characterized by its ability to solve all difficult mathematical problems (all levels) using traditional or modern methods, in addition to its ability to display the answer steps and be a teacher for students, it also depicts mathematical problems in the form of graphs. According to Aishara (2021) ^[6], the benefits of using Algebrator software are:

1. Helping the students to understand concepts and tangibly embody them.
2. Helping the students to link mathematical ideas together.
3. Helping the students to link Mathematics with life by employing it in life issues.
4. Building the student's confidence in himself and his ability to learn Mathematics.
5. Developing the skill of self-learning.
6. Improving students' achievement in Mathematics.
7. Develop thinking skills.
8. Develop positive attitudes towards Mathematics.
9. Allowing each student to demonstrate his full potential.

GeoGebra is an interactive geometry, algebra, statistics, and calculus application, intended for learning and teaching Mathematics and science from primary school to university level. GeoGebra is available on multiple platforms with its desktop applications for Windows, Mac OS, and Linux, with its tablet apps for Android, iPad, and Windows, and web applications based on HTML5 technology (Gamage & Charles-Ogan, 2019) ^[12]. GeoGebra software is equipped with features of both DGS and CAS. This particular software has established its place as a popular tool in the school system (Gamage & Charles-Ogan, 2019) ^[12]. The use of GeoGebra in teaching and learning of Mathematics and science aids the constructions of points, vectors, segments, lines, polygons, conic sections, inequalities, implicit polynomials, and functions. Elements can be entered and modified directly via mouse and touch, or through the input bar. GeoGebra can use variables for numbers, vectors, and points, find derivatives and integrals of functions, and has a full complement of commands like Root or Extremum. Teachers and students can use GeoGebra to make conjectures and to understand how to prove algebraic propositions. GeoGebra is loaded with built-in CAS, a built-

in spreadsheet, built-in statistics and calculus tools, and an interactive geometry environment with 2D and 3D. Geogebra is very appropriate in the 21st-century teaching and learning process which supports learner-centered approaches in which the teacher plays the role of a facilitator or scaffolder while the students construct knowledge by doing some specific task to achieve the aim and objectives set out for the lesson.

Algebrator and Geogebra software are gaining the attention of researchers in the teaching and learning of mathematics. Elaigwu *et al.* (2023) ^[10] found that students taught quadratic equations using Algebrator software instructional approach had higher retention scores than those taught using the conventional method. Elaigwu *et al.* (2023) ^[10] found a significant difference between the retention scores of the students taught quadratic equations using Algebrator software instructional approach and those taught using conventional method. Abari *et al.* (2019) found that the students taught geometry using Geogebra Instructional Package had higher retention mean scores than those taught using Expository method. Ado and James (2022) ^[4] similarly found that the students taught Calculus using Geogebra retained significantly better than those taught using Expository method. In the same vein, Kebin and Imo (2024) ^[17] found that GeoGebra Software enhanced students' retention in Geometry more than lecture method, and Nwakpa (2024) ^[18] found that GeoGebra Software Technique (GST) significantly enhanced senior secondary school students' retention scores in geometry.

Researchers have found gender differences in the retention of scientific concepts by students. Male students were found to have higher retention scores than female students by Nyebuchi (2019) ^[19] in Biology, Haruna (2020) ^[13] in Mathematics, and Emeji *et al.* (2021) ^[11] in Quadratic equations. On the contrary, Igallor (2021) ^[14] found that female students had higher retention scores than male students in Algebra, Uchendu *et al.* (2021) ^[21] found that female students had higher retention scores than male students in Mathematics, Elaigwu *et al.* (2023) ^[10] found that female students had higher retention scores than the male students in Quadratic equations, and Obafemi and Macaulay (2022) ^[20] similarly found that female students had higher retention scores than their male counterparts in Electrolysis. Furthermore, Abari *et al.* (2019) ^[1] found no significant difference in the mean retention scores of male and female students in Geometry, Iji *et al.* (2022) ^[15] found no significant difference between the retention scores of the male and the female students in Quadratic functions, Ehiwario *et al.* (2021) ^[9] found no significant difference between the retention scores of the male and the female students in Geometry, Emeji *et al.* (2021) ^[11] found no significant difference between the retention scores of the male and the female students in Quadratic equations, Adejoh *et al.* (2021) ^[2] found no significant difference between the retention scores of the male and the female students in Biology while Elaigwu *et al.* (2023) ^[10] similarly found no significant difference between the retention scores of the male and the female students taught quadratic equation using Algebrator approach. However, Akpoghol *et al.* (2016) ^[7] found a significant gender difference in students' retention of Electrochemistry, and Igallor (2021) ^[14] found a significant gender difference in students' retention of Algebra.

Algebra has been reported to be one of the Mathematical concepts that are difficult to understand by students, as discovered by Bichi *et al.* (2018) [8], Adelabu and Alex (2023) [3] as well as Imasuen and Omoni-Igho (2024) [16]. As revealed by the West African Examination Council (WAEC) Chief Examiners' Report (2023), the academic performance of secondary school students in the West African Senior School Certificate Examinations (WASSCE) Mathematics examination is still as poor as it has been over the years. Algebra is one of the difficult concepts that contribute to the persisting poor performance of Mathematics examination. It is obvious that the students will not be able to retain the knowledge of a concept that they did not understand, nor in which they did not perform well. Could the use of Algebrator and GeoGebra Software enhance students' retention of difficult Mathematical concepts such as Algebra? Which of the two software-based strategies (Algebrator Software-based strategy and GeoGebra Software-based strategy) will enable a better retention of Algebra concept by students. This research therefore compared the effects of Algebrator Software-based strategy and GeoGebra Software-based strategy on Senior Secondary School Students' retention of Algebra concept in Port Harcourt Metropolis, Rivers State.

Aim and Objectives of the study

This study compared the effects of Algebrator Software-based strategy and GeoGebra software-based strategy on Senior Secondary School Students' retention in Mathematics in Port Harcourt Metropolis, Rivers State. The objectives are to:

1. compare the effect of Algebrator Software-based strategy and GeoGebra software-based strategy on students' retention of Algebra concept.
2. compare the retention ability of the male and female students in Algebra concept.

Research Questions

The following research questions are raised and answered in this study:

1. Which of the two software-based strategies (Algebrator software-based strategy and GeoGebra software-based strategy) will enable a better retention of Algebra concept by students?
2. What difference exists between the male and female students' retention of Algebra concept?

Hypotheses

The following hypotheses were formulated to guide the study and were tested at 0.05 level of significance:

1. There is no significant difference between the students taught using Algebrator Software-based strategy and those taught using GeoGebra software-based strategy in their retention of Algebra concept.
2. There is no significant difference between male and female students' retention of Algebra concept.

Material and Methods

The study adopted the pre-test post-test quasi-experimental research design. The study compared the effects of two mathematical software-based strategies namely: Algebrator Software-Based strategy and Geogebra Software-Based strategy on students' retention of Algebra concept.

Symbolic Illustration of the Research Design

Group	Pretest	Treatment	Posttest	Post-Posttest
E ₁	O ₁	X ₁	O ₂	O ₃
E ₂	O ₁	X ₂	O ₂	O ₃

Where

- E₁ = Experimental group 1
- E₂ = Experimental group 2
- X₁ = Treatment using Algebrator Software-Based strategy
- X₂ = Treatment using Geogebra Software-Based strategy
- O₁ = Pretest for all the groups
- O₂ = Posttest for all the groups
- O₃ = Post-Posttest for all the groups

In this study, the dependent variable is the students' retention of the Algebra concept, the independent variable is instructional strategy (Algebrator Software-Based strategy and Geogebra Software-Based strategy), and the moderating variable is gender. The population of the study consisted of all the Twenty-one thousand and seventy-nine (21,079) Senior Secondary School 2 (SS2) students in the Thirty-eight (38) public Senior Secondary Schools in Port Harcourt Metropolis of Rivers State. The sample for this study comprised One hundred and fifty-seven (157) public Senior Secondary School 2 (SS2) students in Port Harcourt Local Government Area of Rivers State. For this study, a purposive stratified sampling was used to draw two co-educational schools. The criterion for the purposive sampling was based on co-educational public senior secondary schools that have functional computer laboratories (these take care of gender and availability of computers), Presentation of candidates for the Senior Secondary School Certificate Examinations for at least ten consecutive years, and each of the schools must have at least two (2) Mathematics teachers of which one of the teachers teaches Mathematics at the senior secondary school 2 classes. Thereafter, a simple random assignment technique was used to categorize each of the two drawn schools into two experimental groups. A further random sampling was used to draw one intact class of SS2 from each of the two sampled schools.

The instruments used for data collection were researcher-developed performance tests titled 'Mathematics Performance Test on Algebra' (MPTA) and 'Mathematics Retention Test on Algebra' (MRTA). Mathematics Performance Test on Algebra (MPTA) was used to obtain the performance of students in Algebra. It consists of 25 multiple-choice items with options A to E with only one correct response. Each of the multiple-choice questions attracts 4 marks while a wrong answer attracts zero (0) mark. The maximum obtainable mark is 100% while the least obtainable mark is 0%. Face, content, and construct validation of MPTA was done by experts in mathematics education, science education, and measurements and evaluation. Kuder-Richardson 21 formula (KR-21) was then used to obtain a reliability coefficient of 0.71 for MPTA. Mathematics Retention Test on Algebra (MRTA) which was a reshuffled version of MPTA was used to obtain the retention of Algebra concept by the students. Before the treatment, MPTA was administered to the students in each group as pre-test, after which experimental group 1 was taught the concept of Algebra using Algebrator Software-based strategy while experimental group 2 was taught the

same Algebra concept using Geogebra Software-based strategy for 80 minutes weekly for three weeks. MPTA was then re-administered to the students in each group as post-test. After two weeks of no contact with the students, MRTA was administered to the students in each group as post-posttest. The scores of the students in the post-test and post-posttest constituted the data for this study. The data collated for this study was analyzed using descriptive statistics consisting of mean and Standard deviation to

answer the research questions while Analysis of Covariance (ANCOVA) was used to test the hypotheses at 0.05 level of significance.

Results

Research Question 1: Which of the two software-based strategies (Algebrator software-based strategy and GeoGebra software-based strategy) will enable a better retention of Algebra concept by students?

Table 1: Mean and standard deviation values of students’ retention classified by instructional strategy.

Strategy	N	Post Test		Post-Posttest		Mean Gain
		Mean	Std. Dev.	Mean	Std. Dev.	
Algebrator Software-based strategy	94	72.15	10.46	74.06	10.23	1.91
GeoGebra Software-based strategy	63	51.62	15.75	51.17	16.76	-0.45

Table 1 shows that the students in the Algebrator Software-based strategy group had a posttest mean score of 72.15 and a standard deviation of 10.46 (Mean = 72.15, Sd = 10.46), a post-posttest mean score of 74.06 and a standard deviation of 10.23 (Mean = 74.06, Sd = 10.23), and a retention mean again of 1.91. The students in the GeoGebra Software instructional strategy had a posttest mean score of 51.62 and a standard deviation of 15.75 (Mean = 51.62, Sd = 15.75), a post-posttest mean score of 51.17 and a standard deviation

of 16.76 (Mean = 51.17, Sd = 16.76), and a retention mean again of -0.45 with. This result indicates that the Algebrator Software-strategy enabled a higher retention of the concept of Algebra as the students in the group retained better than the students in the GeoGebra Software-based strategy.

Research Question 2: What difference exists between male and female students' retention of Algebra concept?

Table 2: Mean and standard deviation values of students’ retention classified by gender

Gender	N	Post Test		Post-Posttest		Mean Gain
		Mean	Std. Dev.	Mean	Std. Dev.	
Male	89	64.49	15.79	65.39	16.53	0.90
Female	68	63.15	17.03	64.21	18.45	1.06

Table 2 shows that the male students had a post-test mean score of 64.49 and a standard deviation of 15.79 (Mean = 64.49, Sd = 15.79), a post-posttest mean score of 65.39 and a standard deviation of 16.53 (Mean = 65.39, Sd = 16.53), and a retention mean again of 0.90. The female had a post-test mean score of 63.15 and a standard deviation of 17.03 (Mean = 63.15, Sd = 17.03), post-posttest mean score of 64.21 and a standard deviation of 18.45 (Mean = 64.21, Sd

= 18.45) and a retention mean gain of 1.06. The findings revealed that the female students retained the knowledge of Algebra concept better than the male students.

Hypothesis 1: There is no significant difference between the students taught using Algebrator Software-based strategy and those taught using GeoGebra software-based strategy in their retention of Algebra concept.

Table 3: Summary of Analysis of Covariance (ANCOVA) of students’ retention scores classified by instructional strategy using posttest as a covariate

Dependent Variable: Post-posttest						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	39285.835 ^a	2	19642.917	396.938	0.000	0.838
Intercept	465.568	1	465.568	9.408	0.003	0.058
Posttest	19523.831	1	19523.831	394.531	0.000	0.719
Instructional Strategy	569.073	1	569.073	11.500	0.001	0.069
Error	7620.866	154	49.486			
Total	707764.000	157				
Corrected Total	46906.701	156				

a. R Squared = 0.838 (Adjusted R Squared = 0.835)

Table 3 shows the summary of Analysis of Covariance (ANCOVA) of students’ retention of the concept of Algebra classified by instructional strategy using post-test as a covariate. It shows the value of $F_{1,154} = 11.500$, $p = 0.001$ ($p < 0.05$), partial eta squared = 0.069 for the effect of instructional strategy on students’ retention of the concept of Algebra. The null hypothesis was thus rejected. This

result indicates that there is a significant difference between the students taught using Algebrator Software-based strategy and those taught using GeoGebra software-based strategy in their retention of Algebra concept. The partial eta squared value indicates that instructional strategy had a medium effect on the students’ retention of Algebra concept.

Table 4: Summary of Post Hoc Analysis of students’ retention scores classified by instructional strategy

Dependent Variable: Post-posttest						
Scheffe: Multiple Comparisons						
(I) Instructional Strategies	(J) Instructional Strategies	Mean Difference (I-J)	Std. Error	Sig. ^b	95% Confidence Interval for Difference ^b	
					Lower Bound	Upper Bound
Algebrator software-based strategy	GeoGebra software-based strategy	6.520*	1.521	0.000	3.522	9.518
GeoGebra software-based strategy	Algebrator software-based strategy	-6.520*	1.521	0.000	-9.518	-3.522

*. The mean difference is significant at the 0.05 level.

Table 4 shows the summary of Scheffe Post Hoc analysis of students’ retention of the concept of Algebra classified by instructional strategy. It reveals a mean difference = 6.520, $p = 0.000$ ($p < 0.05$) between the Algebrator software-based strategy and the GeoGebra software-based strategy, in favour of the Algebrator software-based strategy. This indicates that the Algebrator software-based strategy

contributed more to the significant difference between the effects of the two strategies on students’ retention of Algebra concept.

Hypothesis 2: There is no significant difference between the male and female students’ retention of Algebra concept.

Table 5: Summary of Analysis of Covariance (ANCOVA) of students’ retention scores classified by gender using posttest as a covariate

Dependent Variable: Post-posttest						
Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	38717.269 ^a	2	19358.634	364.034	0.000	0.825
Intercept	92.578	1	92.578	1.741	0.189	0.011
Posttest	38662.922	1	38662.922	727.046	0.000	0.825
Gender	0.507	1	0.507	0.010	0.922	0.000
Error	8189.432	154	53.178			
Total	707764.000	157				
Corrected Total	46906.701	156				

a. R Squared = 0.825 (Adjusted R Squared = 0.823)

Table 3 shows the summary of Analysis of Covariance (ANCOVA) of students’ retention of the concept of Algebra classified by instructional strategy using post-test as a covariate. It shows the value of $F_{1,154} = 0.010$, $p = 0.922$ ($p > 0.05$), and partial eta squared = 0.000 for the effect of gender on students’ retention of Algebra concept. The null hypothesis was thus retained. This result indicates that there is no significant difference between the male and female students in their retention of the concept of Algebra. The partial eta squared value indicates that gender had no effect on the students’ retention of the concept of Algebra.

Discussion of Findings

The findings of this study revealed that Algebrator Software-based strategy enabled a higher retention of the knowledge of Algebra than the GeoGebra Software based-strategy. The finding may be because the Algebrator Software is a Computer Algebra System (CAS), specifically built for the learning of algebra. It is an application that solves algebra problems using simple commands that help the students follow up on solving the algebraic problems step-by-step, with the appropriate explanation of each step making the students develop a deep understanding of solving mathematical problems through practical application, individually discovering the method of solving algebraic problems. This finding agrees with the finding of Elaigwu *et al.* (2023) [10] who found that students taught quadratic equations using Algebrator software instructional approach had higher retention scores than those taught using conventional method. The findings of this study further show a significant difference in the retention scores of students taught using Algebrator software-based strategy

and those taught using GeoGebra software-based strategy, in favour of the students taught using Algebrator software-based strategy. This finding aligns with the findings of Elaigwu *et al.* (2023) which revealed a significant difference between the retention scores of the students taught quadratic equations using Algebrator approach and those taught using conventional method.

The findings of this study further revealed that the female students retained the knowledge of Algebra better than the male students. The difference in the retention mean scores of male and female students was however not statistically significant. This finding may be because the two mathematical software used possess functions and interface that enable easy navigation and interaction by the students in the learning of Algebra, irrespective of gender. This is in agreement with the findings of Igallor (2021) [14], Uchendu *et al.* (2021) [21], Elaigwu *et al.* (2023), and Obafemi and Macaulay (2022) [20] who found that female students had higher retention scores than their male counterparts. The finding is however contrary to the findings of Nyebuchi (2019) [19], Haruna (2020) [13], and Emeji *et al.* (2021) [11] who found that the male students retained better than their female counterparts. Furthermore, the finding agrees with the findings of Abari *et al.* (2019) [1], Iji *et al.* (2022) [15], Ehiwario *et al.* (2021) [9], Emeji *et al.* (2021) [11], Adejoh *et al.* (2021) [2], and Elaigwu *et al.* (2023) [10] who found no significant difference between the retention scores of male and female students. The finding is however, at variance with the findings of Akpoghol *et al.* (2016) [7] and Igallor (2021) [14] who discovered a significant gender difference in students’ retention of scientific concepts.

Conclusion

This study has shown that the Algebrator software-based strategy significantly facilitated students' retention ability in Algebra than the GeoGebra software-based strategy. It also showed no significant difference between the male and female students in their retention of Algebra concept.

The knowledge of Algebra obtained in the Mathematics class is used in the study of many science courses and engineering courses, and as such the 21st Century students who are digital natives will find it easy to understand and perform well and consequently retain the knowledge of seemingly difficult concepts such as Algebra when mathematical software are incorporated in the teaching and learning of mathematical concepts.

Recommendations

Based on the research findings, the following recommendations are made:

1. Mathematics teachers should consciously introduce Mathematics Software-based instructional strategies into the teaching and learning of mathematical concepts to boost students' retention of the concepts.
2. Mathematics software-based instructional strategies should be incorporated into the Mathematics curriculum for the pre-service teachers' training programme to expose them to the use of these software-based strategies.

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