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Enhancing Senior Secondary School Students' Academic Performance In Algebra Using Geogebra And Algebrator Software In Port Harcourt Metropolis, Rivers State, Nigeria

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Abstract
The study investigated the effects of GeoGebra and Algebrator Software on senior secondary school students' academic performance in Algebra in Port Harcourt Metropolis, Rivers State. The study was guided by two objectives, two research questions, and two null hypotheses. A quasi-experimental research design of the pretest, post-test non-randomized, non-equivalent control group was used for the study. A sample of 157 SS2 students was selected from two intact classes in two co-educational public secondary schools using the stratified, purposive, and random sampling technique. The instrument for data collection was the Mathematics Performance Test on Algebra. Face, content and construct validation were conducted on the instrument by experts in Mathematics education, Science education and Measurement and evaluation. A reliability coefficient of 0.71 was obtained for it through the Kuder-Richardson 21 formula. The research questions were answered using mean and standard deviation while Analysis of Covariance was used to test hypotheses at 0.05 significance level. The findings of the study revealed that the students taught using the Algebrator software-based strategy performed significantly better than the students taught using the GeoGebra software-based strategy. The findings also revealed that though the female students outperformed their male counterparts, there was no significant difference between the performance scores of male and female students in Algebra. Given the reality that the process of learning algebra involve a very complex cognitive task that often poses difficulties to students, it is therefore pertinent that Mathematics educators explore the opportunities offered by new technologies to enhance their teaching styles such as Algebrator software-based strategy.The study recommends that teachers should shift from conventional method of teaching and use Software-based instructional strategies such as Algebrator software-based-strategy and GeoGebra software-based strategy to enhance teaching and learning in Mathematics.

Keywords: *Academic Performance, Geogebra Software, Algebrator Software, Mathematics, Algebra.*

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I. Introduction

The utilization of technology in teaching and learning is changing the traditional classroom lesson into an environment that facilitates learning and enables innovation and creativity. In many developed countries today, knowledge is now based on technology. The new forms of learning methods are linked with online learning, virtual learning, and e-learning (Kalantarnia et al., 2012). The Mathematics classroom over time has witnessed scenarios such as the teacher dictating the knowledge while the students are turned into passive learners. Technology allows the teacher to have a grip on the chosen method for solving problems. In comparison with many features of software learning, which enable students to inspect and survey every aspect; boards and papers have less chance to stand the trend toward electronic learning. Technology has become one of the most powerful resources of learning. Teaching and learning with the use of appropriate technology provide greater learning opportunities for students, enhancing students' engagement and encouraging discovery learning. Technology enables immediate feedback for the teacher, based on formative evaluation, as well as the ability to solve problems within a specific framework. The use of technology in Mathematics has numerous advantages. Learning objectives and educational goals are achieved when technology is used with teaching methods. Technology also enables individualized learning as well as lifelong learning. Little wonder technology such as computers and

calculators are recommended by the USA and Canada Association of Teachers who believe that technology helps the teaching and learning of Mathematics concepts (Kalantarnia et al.**,** 2012).

Computer software can provide real-time feedback to the users and lead the process within a specific framework. In addition, they limit the search fields to accelerate problem-solving (Kalantarnia et al., 2012). Several dynamic software tools geared toward Mathematics education provide visually rich contents that enable students comprehend concepts in a meaningful way. The National Council of Teachers of Mathematics (NCTM, 2000) highlights the importance of the use of multiple representations in improving students' mathematical thinking and reasoning. Dynamic mathematical software programs help students make connections among the representations easily and meaningfully, which could be difficult or impossible to teach, without such dynamic tools. By integrating ICT into everyday teaching practice, teachers can provide creative opportunities to support students' learning and foster the acquisition of mathematical knowledge and skills. It is in light of this trend in the use of technology in the classroom that Dahal, et al (2022), Gakbish, et al. (2021), and Gamage & Charles-Ogan (2019) observed that Mathematics educators are now introducing more and various forms of software and multimedia presentations into classroom activities, and some of such software are the GeoGebra and Algebrator.

Mathematics has great influence and relevance in human endeavors such that people from different works of life see and appreciate its scope and influence on national and human development (Ahumaraeze & Ekwueme, 2019). There are many definitions of Mathematics. Mathematics is the study of measurement, relationships, and properties of quantities and sets. It is also about logical analysis, deduction, and calculation within these patterns and structures (Ekwueme, 2013). Mathematics is also identified as a requirement for adequate understanding and interpreting of concepts in the social sciences. It is a tool that enhances the ability to think and reason logically, about the values in the changing world (Salman, 2003). In Nigeria, Mathematics is so important that it must be studied every day a child goes to school, throughout primary and secondary schools. This is in line with the dictates of the Federal Ministry of Education as enshrined in the National Policy on Education by the Federal Republic of Nigeria (FRN, 2014).

Dynamic geometry software that emerged in recent years has proved to be an effective technological tool for visualizing abstract mathematical structures (Gamage & Charles-Ogan, 2019). Dynamic mathematical software enables students to make connections among the representations easily and meaningfully. This would be quite difficult to achieve, if not impossible at all, without such dynamic tools. Several of such technology tools available include interactive whiteboards, graphing display calculators, Geometers Sketchpad, and GeoGebra which are an extract from CAS- Computer Algebra Systems, DGS-Dynamic Geometry Software, and GDC-Graphing Display Calculators.

GeoGebra is an interactive software on geometry, algebra, statistics, and calculus applications, intended for teaching and learning Mathematics. According to GeoGebra Community Newsletter (2021, 2022), GeoGebra is a free and multi-platform dynamic Mathematics software, for all levels of education. It combines geometry, algebra, tables of graphing, statistics, and calculus in one easy-to-use package and is currently available in over 44 languages. It is an innovative, open-source Mathematics software that can be freely downloaded from www.geogebra.com. GeoGebra works on a wide spectrum of operating system platforms on which Java Virtual Machine is installed. It was created by Markus Hohenwarter and a team of programmers for the teaching and learning of Mathematics, from middle school through college, and to the university level (Hohenwarter & Preiner, 2007). GeoGebra's basic interface is divided into four components which are the input bar, algebraic view, graphic view, and spreadsheet view. Data and objects are entered into the GeoGebra environment through the input bar and spreadsheet view using the keyboard, while the graphic and algebraic views display the graphical representation of the data and their algebraic equivalence respectively. The use of GeoGebra involves hands-on activities with students' participation as a key element in the teaching and learning process. As students work in the dynamic geometry environment, students develop and create more skills and knowledge at their own pace, which results in well-developed conceptual knowledge, procedural knowledge, and problem-solving capabilities. This will make teaching and learning of Mathematics meaningful in general, and Algebra in particular as it enables students to explore concepts and form conjectures.

Algebrator software (also called Softmath) is a Computer Algebraic System (CAS) first introduced/developed by Neven Jarkovis of Soft Math, San Antonio, Texas in the late 1990s. This is a CAS specifically geared towards algebra education. Besides the computation of results, it shows step-by-step the solution process and context-sensitive explanations. Algebrator is one of the most powerful software programs for math education ever developed. It will tackle the most frustrating math problems. Algebrator can show every step to every answer, serving as an automated tutor for mathematics students at every level. Students use Algebrator to supplement in-classroom learning, as well as to assist them in quickly and accurately completing their Mathematics assignments. The use of Computer Aided Instruction (CAI) especially GeoGebra and Algebrator may serve as a great relief to secondary school teachers in search of instructional methods for teaching the topics if properly researched into and integrated into the teaching pedagogy. One of the Mathematics software that has been used and found effective in other countries is the Algebrator software though relatively new. It can

equally be applied in Nigeria, hence, the focus of this study on the effect of GeoGebra and Algebrator Software on Senior Secondary School students' academic performance in Mathematics in Port Harcourt, Rivers State.

There is evidence in literature about the effectiveness of the Algebrator Software. Aishara (2021) noted that further effort in Mathematics can be enhanced when the subject is taught using Algebrator Software-BasedStrategy. Kalantarnia et al. (2012) found that Algebrator enhanced students' performance in mathematical problem-solving more than the traditional method. Saleh (2017) found that the Algebrator software enhanced the achievement of eleventh-grade students and motivated them to learn Mathematics more than the traditional method. Uba Umbara' (2018) cited in Aishara (2021) similarly submitted that the use of Algebrator Software aided the teaching of Algebra, making it simpler and more understandable to the students. Consequently, the students taught using the Algebrator Software-Based Strategy had a better performance than the students taught using the conventional method. Aishara (2021) and Villahermosa (2022) found that the Algebrator Software-Based Strategy significantly enhanced students' performance in mathematics. Elaigwu et al. (2023) similarly found that students taught quadratic equations using Algebrator software had significantly higher achievement scores than the students taught using the conventional teaching method.

Research has evidence of the enhancing effect of Geogebra in the teaching and learning of mathematical concepts. Gakbish et al. (2021) found that the students taught Algebra using GeoGebra software performed better than those taught using the traditional method. Ajaegba and Ekwueme (2019) found a significant difference between the performance of Senior Secondary School 2 (SS2) students taught Geometry using Geogebra and those taught using the Conventional method. Similarly, Agbo and Uzor (2021) found that the Senior Secondary School 2 (SS2) students taught Geometry using Geogebra achieved significantly higher than those taught using the traditional teaching method. Gamage and Charles-Ogan (2019) found that the students taught Circle geometry using GeoGebra software performed significantly higher than those taught using the traditional method, while Akpan et al. (2022) found that the students taught Solid geometry using GeoGebra Supported Model Based Learning performed significantly higher than students taught Solid Geometry using Engagement Learning Strategy. Ado and James (2021) also found that the students taught using Geogebra achieved significantly better than those taught using the Expository method.

Gender difference has been an issue of research in mathematics over the years. Gamage and Charles-Ogan (2019), Gakbish et al. (2021), and Akpan and Obafemi (2023) found that the performance of the female students was better than that of the male students, while Ahumaraeze and Ekwueme (2019), Agbo and Uzor (2021), Mamman and Isa (2019), Macaulay and Obafemi (2022), Elaigwu et al. (2023) and Ndukwe and Obafemi (2023) found that the male students performed better than the female students. Furthermore, Gamage and Charles-Ogan (2019), Ado and James (2021), Ehiwario et al. (2021), Gakbish et al. (2021), Akpan et al. (2022), Macaulay and Obafemi (2022), and Akpan and Obafemi (2023) found that there was no significant gender difference in the performance of male and female students, while Mamman and Isa (2019), Ahumaraeze and Ekwueme (2019), and Anigbo and Ndukwe (2019) found that there was a significant gender difference in the performance of students.

Students' declining performance in Mathematics has been a serious issue in the Nigerian educational system. The rate at which students fail Mathematics, both in internal and external examinations is alarming. Despite the various research and innovations in the teaching of Mathematics, the academic achievement of secondary school students remains poor. This is revealed by the West African Examination Council (WAEC) Chief Examiners' Report (2023) on the academic achievement of students in the West African Senior School Certificate Examinations (WASSCE) Mathematics examination. The poor students' academic achievement has been more prominent in some Mathematical concepts than others. Mathematical concepts such as Algebra have been reported to be difficult to understand by the students as found by Bichi et al. (2018), Adelabu and Alex (2023) as well as Imasuen and Omoni-Igho (2024). Researchers have been concerned about how to remedy this poor Mathematics performance, hence the multitude of research seeking suitable instructional methods/strategies to address the worrisome situation, over the years. Could the use of GeoGebra and Algebrator Software remedy the poor academic performance of students in Mathematical concepts such as Algebra? This research therefore investigated the effects of GeoGebra and Algebrator Software on Senior Secondary School Students' academic performance in Mathematics in Port Harcourt Metropolis, Rivers State.

Aim and Objectives of the study

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

1. investigate the effects of GeoGebra software-based strategy and Algebrator software-based strategy on students' performance in Algebra.
2. determine the influence of gender on students' performance in Algebra.

Research Questions

The following research questions guided the study:

1. What is the effect of GeoGebra software-based strategy and Algebrator software-based strategy on students' performance in Algebra?
2. What is the influence of gender on students' performance in Algebra?

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 performance of students taught using GeoGebra software-based strategy and those taught using Algebrator software-based strategy.
2. There is no significant difference between the performance of male and female students in Algebra.

II. Methodology

The aim of this study was to investigate the effect of GeoGebra software-based strategy and Algebrator Software-based strategy on Senior Secondary School Students' academic performance in Mathematics in Port Harcourt Metropolis, Rivers State. This study adopted the pre-test, post-test, non-randomized, and non-equivalent control group quasi-experimental design. The illustration of the research design is presented below:

Symbolic illustration of the research design

Groups	Pre-test	Treatment	Post-test
E_1:	O_1	X_1	O_2
E_2:	O_1	X_2	O_2

Where

E_1 = Experimental group 1
E_2 = Experimental group 2
X_1 = Treatment for Experimental group 1 (Geogebra Software based-strategy),
X_2 = Treatment for Experimental group 2 (Algebrator Software based-strategy),
O_1 = Pre-test for all groups
O_2 = Post-test for all groups

The population of the study consists of Twenty-one thousand and seventy-nine (21,079) Senior Secondary School 2 (SS2) students (Male = 9,699; Female = 11,380) in the public Senior Secondary Schools in Port Harcourt Metropolis of Rivers State. Stratified, Purposive, and random sampling techniques were used to select two co-educational senior secondary schools in Port Harcourt Metropolis. Co-educational senior secondary schools were used because gender is the moderating variable in this study, while instructional strategy is the independent variable and students' performance is the dependent variable. An intact class of SS2 students was randomly selected from each of the two selected schools, to give a sample of 157 (One hundred and fifty-seven) SS2 Mathematics students. The selected sample had 63 students (male = 33, female = 30) for experimental group 1 (Geogebra Software based-strategy) and 94 students (male = 56, female = 38) for experimental group 2 (Algebrator Software based-strategy) respectively.

The instrument used for data collection was the Mathematics Performance Test on Algebra (MPTA). It was developed by the researcher to measure the performance of students in Algebra. MPTA has two sections A and B. Section A was used to gather the students' bio-data, while section B contains 25 multiple-choice questions with options A to E with only one correct response. Each correct answer attracts 4 marks making a total of 100 marks. MPTA went through the face, content, and construct validation process done by experts in mathematics education, science education, and measurement and evaluation. Thereafter, the reliability of the instrument was obtained using the Kuder-Ricahrdson 21 formula (KR-21) to obtain a reliability coefficient of 0.71.

The instrument was administered to the students in each group as Pre-test, after which the students were taught Algebra. The first group was taught using the Geogebra Software-based strategy while the second group was taught using the Algebrator Software-based strategy. Thereafter, MPTA was re-administered to the students in each group as Post-test. The students' pre-test and post-test scores constituted the data for this study. The data was analyzed using descriptive statistics 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.

III. Results

Table 1: Mean and standard deviation values of students' performance in Algebra classified by instructional strategy

Strategy	N	Pre-test		Post-Test		Mean Gain
		Mean	Std. Deviation	Mean	Std. Deviation	
GeoGebra Software-based strategy	63	32.51	15.23	51.62	15.75	19.11
Algebrator Software-based strategy	94	45.74	11.65	72.15	10.46	26.41

Table 1 shows the mean and standard deviation values of students' performance in Algebra classified by instructional strategy. It reveals that the students taught using the GeoGebra Software-based strategy had a pre-test mean score of 32.51, post-test mean score of 51.62 with a mean gain of 19.11, the students taught using the Algebrator Software-based strategy had a pre-test mean score of 45.74, post-test mean score of 72.15 with a mean gain of 26.41. The result shows that students taught using the Algebrator Software-based strategy had higher mean performance score than those taught using the GeoGebra Software-based strategy. This indicates that students taught using the Algebrator Software-based strategy performed better than the students taught using the GeoGebra Software-based strategy. Algebrator Software-based strategy enhanced students' performance in Algebra more than the GeoGebra Software-based strategy.

Table 2: Mean and standard deviation values of students' performance in Algebra classified by gender

Gender	N	Pre-test		Post-Test		Mean Gain
		Mean	Std. Deviation	Mean	Std. Deviation	
Male	89	41.35	13.66	64.49	15.79	23.14
Female	68	39.24	15.94	63.15	17.03	23.91

Table 2 shows the mean and standard deviation values of students' performance in Algebra classified by gender. It reveals that the male students had a pre-test mean score of 41.35, post-test mean score of 64.49, and a performance mean gain of 23.14, while the female students had a pre-test mean score of 39.24, post-test mean score of 63.15, and a mean gain of 23.91. The findings revealed that the female students outperformed their male counterparts in Algebra.

Table 3: Summary of Analysis of Covariance (ANCOVA) of students' performance in Algebra classified by instructional strategy using pre-test as a covariate

Dependent variable: Post-test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	34164.158[a]	2	17082.079	360.629	0.000	0.824
Intercept	13941.050	1	13941.050	294.317	0.000	0.656
Pretest	18266.178	1	18266.178	385.627	0.000	0.715
Instructional Strategy	2818.795	1	2818.795	59.509	0.000	0.279
Error	7294.594	154	47.367			
Total	682740.000	157				
Corrected Total	41458.752	156				
a. R Squared = 0.824 (Adjusted R Squared = 0.822)						

Table 3 shows the Summary of Analysis of Covariance (ANCOVA) of students' performance in Algebra classified by instructional strategy using pre-test as a covariate. It shows the value of $F_{1,154} = 59.509$, $p = 0.000$ ($p < 0.05$), partial eta squared = 0.279 for the effect of instructional strategy on students' performance in Algebra. The null hypothesis was thus rejected. This result indicates that there is a significant difference between the students taught using GeoGebra software-based strategy and Algebrator software-based strategy, in their performance in Algebra. The partial eta squared value indicates that instructional strategy had a large effect on the students' performance in Algebra.

Table 4: Summary of Post Hoc Analysis of students' performance in Algebra classified by instructional strategy

Dependent Variable: Posttest						
Scheffe: Multiple Comparisons						
					95% Confidence Interval for Difference[b]	
(I) Instructional Strategy	(J) Instructional Strategy	Mean Difference (I-J)	Std. Error	Sig.[b]	Lower Bound	Upper Bound

GeoGebra software based-strategy	Algebrator software based-strategy	-9.019*	1.387	0.000	-11.754	-6.285
Algebrator software based-strategy	GeoGebra software based-strategy	9.019*	1.387	0.000	6.285	11.754
*. The mean difference is significant at the 0.05 level.						

Table 4 shows the Summary of Scheffe Post Hoc analysis of students' performance in Algebra classified by instructional strategy. It reveals a mean difference = 9.019, p = 0.000 ($p < 0.05$) between the Algebrator software-based strategy and the GeoGebra software based-strategy. Algebrator software-based strategy contributed more to the significant difference between the two strategies.

Table 5: Summary of Analysis of Covariance (ANCOVA) of students' performance in Algebra classified by gender using pre-test as a covariate

Dependent variable: Post-test

Source	Type III Sum of Squares	df	Mean Square	F	Sig.	Partial Eta Squared
Corrected Model	31363.971[a]	2	15681.986	239.235	0.000	0.757
Intercept	11220.112	1	11220.112	171.167	0.000	0.526
Pretest	31293.996	1	31293.996	477.403	0.000	0.756
Gender	18.608	1	18.608	0.284	0.595	0.002
Error	10094.780	154	65.551			
Total	682740.000	157				
Corrected Total	41458.752	156				
a. R Squared = 0.757 (Adjusted R Squared = 0.753)						

Table 5 shows the Summary of Analysis of Covariance (ANCOVA) of students' performance in Algebra classified by gender using pre-test as a covariate. It shows the value of $F_{1,154} = 0.284$, p = 0.595 ($p > 0.05$), partial eta squared = 0.002 for the influence of gender on students' performance in Algebra. The null hypothesis was thus retained. This result indicates that there is no significant difference between the performance of male and female students in Algebra.

The partial eta squared value indicates that gender had a small effect on the students' performance in Algebra.

IV. Discussion

The findings show that the Algebrator software-based strategy enhanced students' performance more than the GeoGebra software-based strategy, though the GeoGebra software-based strategy also improved students' performance. This may be attributed to the technological affordance inherent in Algebrator software being a Computer Algebra System (CAS) and GeoGebra, a Dynamic Geometry System that provides opportunities for students' deep and sustained interaction with key mathematical ideas. The finding may also be because Algebrator software can be used on an Android phone. It may also be because the Algebrator software motivates students to learn mathematics, as found by Saleh (2017). The finding of this study aligns with the findings of Kalantarnia et al. (2012), Saleh (2017), Uba Umbara' (2018) in Aishara (2021), Aishara (2021), Villahermosa (2022) and Elaigwu et al. (2023) who found that Algebrator Software-Based Strategy significantly enhanced students' performance in mathematics concepts than conventional teaching method.

The findings of this study also revealed that Geogebra software also enhanced students' performance in Algebra, though not as much as the Algebrator software. This finding agrees with the findings of Ajaegba and Ekwueme (2019), Ado and James (2021), Agbo and Uzor (2021), Gakbish et al. (2021), Gamage and Charles-Ogan (2019) and Akpan et al. (2022), that Geogebra software enhanced students' performance in mathematical concepts than the conventional method.

Furthermore, the findings of this study revealed that the female students outperformed their male counterparts. The finding may be because of the engaging, interactive, and inclusive nature of both Algebrator software-based strategy and GeoGebra software-based strategy, irrespective of gender. The finding agrees with the findings of Gamage and Charles-Ogan (2019), Gakbish et al. (2021), Akpan et al. (2022), and Akpan and Obafemi (2023) where the performance of the female students was shown to be better than that of the male students. The finding is however at variance with the findings of Ahumaraeze and Ekwueme (2019), Agbo and Uzor (2021), Macaulay and Obafemi (2022), Elaigwu et al. (2023) and Ndukwe and Obafemi (2023) that the male students performed better than the female students.

The findings of the study further show that the difference between the performance of male and female students was not statistically significant. The finding is also in consonance with that of Gamage and Charles-Ogan (2019), Ado and James (2021), Ehiwario et al. (2021), Gakbish et al. (2021), Akpan et al. (2022), Macaulay and Obafemi (2022), Akpan and Obafemi (2023) and Ndukwe and Obafemi (2023) who found that there was no significant gender difference between the performance of male and female students. The finding is however at

variance with the findings of Ahumaraeze and Ekwueme (2019), and Anigbo and Ndukwe (2019) where a significant gender difference was found in the performance of students.

V. Conclusion

This study has shown that Algebrator software-based strategy was more effective than GeoGebra software-based strategy in the teaching and learning of Algebra. The most desired outcome of teaching and learning in Mathematics is the optimum performance of students in the subject. Therefore, the search for a good instructional delivery strategy that may motivate students to learn algebra and facilitate their overall performance in Mathematics cannot be overemphasized. The process of learning algebra is a very complex cognitive task that can be very imposing on the students. It is therefore pertinent that Mathematics educators explore the opportunities offered by new technologies to enhance their teaching styles, motivate the students in the classroom, and facilitate good achievement of students.

VI. Recommendations

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

1. Teachers should use Mathematics software-based instructional strategies to enhance teaching and learning in schools.
2. Mathematics software-based learning strategies should be encouraged among learners to help the weak ones develop rapidly and speedily and encourage teamwork, allowing them to construct their own knowledge, and perform better.

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