ORIGINAL ARTICLE

European Journal of Education and Pedagogy
www.ej-edu.org

Effect of Geometer's Sketchpad on Senior High School Students' Performance in Quadratic Graphing

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ABSTRACT

Arguably the teaching and learning of algebra in schools have been perceived as difficult [1] at all levels due to the non-usage of modern technology especially in Africa. This study sought to explore how the geometer's sketchpad (GSP) could be used to improve students' performance in quadratic graphs. The study employed true-experimental (Post-test) design as a strategy of enquiry using Geometer's Sketchpad application software in which the mixed method strategy was used in the sampling of study area, study respondents and analysis. A total of 80 students were sampled for the entire study but 40 for the Experimental Group and 40 for the Control Group not undermining gender fairness. The study revealed a positive improvement in student's performance after using the Geometer's Sketchpad Application (GSP) software. The study can confirm that the integration of GSP technology in teaching and learning of quadratics can improve students' motivation, excitement and concepts understanding.

Keywords: Algebra, Geometer's Sketchpad Application (GSP), student performance, graphing skills, pedagogy

Published Online: December 5,2020

ISSN: 2736-4534

DOI :10.24018/ejedu.2020.1.1.4

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I. Introduction

Mathematics has been used as a critical filter in accessing students to progress to their next step to education at all levels in most parts of the world. Meanwhile the teaching and learning of Mathematics especially algebra in schools have been perceived as difficult [1] especially in Africa of which Ghana is not an exception. This notion has resulted to students' poor performance in the subject at the Junior High School (BECE) and Senior High School levels [2], [3]. The poor performance of Mathematics (emphasis on algebra) has been attributed to non-integration of ICT into teaching and learning [4], [5], non-changed learning methods [6], [7], over concentration on teacher centered approaches in teaching [7], differences in pedagogical orientation [8] and other compelling factors. [9], [10] affirms these as causes of the poor peromance in Mathematics (algebra) in Ghanaian students.

Alternatively, numerous studies [11-16], conducted globally revealed that the integration of ICT tools for that matter the use of Geometers' Sketchpad Application (GSPA) improved students' mathematics performance. On the contrary in Ghana, the use of technology as a tool to manipulate numbers has not improved; rather pencil and paper are used most of the time. It was therefore not surprised that, the Chief Examiners' Reports of 2007 revealed that candidates had challenges in solving equation of the form $ax^2 + bx + c = 0$ where $a \neq 0$ [17] and again had conceptual difficulties in sketching quadratic graphs and determining the roots of quadratic equations using the graphical method [18]. Therefore, this study sought to equally investigate the effect of using Geometer's Sketchpad in the graphing of quadratic functions among selected Senior High School students in the context of Ghana, with a case of Presbyterian Senior High School, La in the Ladadekotopon Municipality.

Several organizations, including schools, have acknowledged the significance of the usage of computers in the work environment, as it helps individuals to acquire an inquiring, critical and creative mind to capitalize on the opportunities driven by the explosive growth of information, knowledge and technology.

ICT integration into education in general has provided a lot of digital resources to both the teacher and the learner where one need not to physically or personally visit the library for books rather subject or issue related e-books are readily available on the internet for use. This has made the search for information for research purposes convenient, less costly and above all has increased proximity. According to the National Council of Teachers of Mathematics [19], the integration of technology in mathematics has lots of benefits and despite its challenges, will go a long way to help teachers and students in their teaching and learning of mathematics respectively. It added that the integration of

technology into mathematics lessons has a very positive influence in the teaching and learning of mathematics, therefore it is incumbent on every mathematics teacher to integrate technology into their lessons and to encourage their students to employ it in their learning. It further stressed that, it is essential that teachers and students have regular access to technologies that support and advance mathematical sense making, reasoning, problem solving, and communication. They concluded that most teachers do not seem prepared to integrate ICT in their teaching practices and that teachers' use of ICT to facilitate learning merits ongoing research and reflection.

Therefore there has been a major push toward integrating computer technology into public classrooms because of the vast promise it offers such as cheap, accessible and instantaneous information, enormous potential for interactivity and media-rich communication and powerful educational tools it will put at the service of students [20]. According to [21], if teachers were to transform their classrooms with computers, ordinary students would make massive gains, wherever illiteracy is a problem, it would be dissolved, and students would have immense new views opened to them. [22] , stated that the use of computer-aided technology in the classroom will, no doubt, inspire the teachers to approach their tasks with a greater sense of purpose and, more importantly, a sense of play to make the learning process fun for students. Using computer-based technology such as data-logging and simulations is essential for exhibiting subjects such as science and mathematics. Additionally, the net provides vast amounts of up-to-date information for teaching and learning of different subjects and it is also very efficient since textbooks can become archaic with out of date information that could misguide students into believing that there is no further development after that discovery.

II. Research Questions:

The study sought to find answers to the following research questions:

1. What is the effect of the use of Geometer's Sketchpad Application (GSP) on students' academic performance in mathematics.
2. What are Students' Perceptions about using the Geometer's Sketchpad Application *(GSP)*

III. LITERATURE

Learning with Technology

Williams [23] described ICT integration as the means of using any ICT tool (Internet, e-learning technologies, CD ROMs, etc.) to assist teaching and learning. For the purpose of this study, Williams' definition of ICT integration is adopted. [24], linked ICT integration with the concept of wholeness, for instance, content and pedagogy which are the two important elements of teaching and learning must be linked when technology is used in lesson. Therefore, there is the need to connect all elements of the system together to become a whole not just offering students' series of ICT tool (e.g. CD ROMs, multimedia, etc) without teacher tackling the pedagogical issues. Integration of ICT into education is a procedure in which instructional technologies such as computers and software are applied regularly to support both teaching and learning across levels and subject matter [25] as cited in [26].

According to Fuchs, computer algebra systems mainly deal with the symbolic and numeric representation of mathematical objects and allow for manipulating a variety of algebraic expressions and functions, and can deal for example with basic mathematical operations, simplification, factorization, derivatives, integrals, sequences, and matrices [27], and furthermore, allow for graphically displaying explicit whereby those graphical representations usually can not be modified directly by using the mouse [28].

Dynamic mathematics software is designed to combine certain features of dynamic geometry software, computer algebra systems, and also spreadsheets into a single package. [29] Pure dynamic geometry software is operated mainly with the mouse by activating different geometric tools and applying them to the drawing pad or already existing objects. Examples of dynamic geometry software are Cabri Geometry [30] and Geometer's Sketchpad [31].

The use of information and communication technology (ICT) could help teachers not only in the teaching of mathematical concepts but also to lighten their workload and allow teachers to solve students' problem individually [32].Computers can offer dynamic visual images that may open up some areas of mathematics to a much wider audience [33]. [34], the use of technology in mathematics instruction has positive impact on students' understanding and has therefore recommended its use for African instructors in mathematics. [35], believe that "there is substantial evidence that, in the right hands and used appropriately for specific purposes in specific contexts, ICT can be an effective tool in supporting teaching and learning". They further found that new digital technologies in Sub Saharan Africa have the potential to revolutionize the quality of subject teaching and learning when carefully integrated into the classroom.

Learning with Geometer's Sketchpad (GSP)

According to [31], Geometer's Sketchpad is a dynamic geometry software program for constructing and investigating mathematical concepts in the field of algebra, geometry, trigonometry, calculus, and other areas. It is a dynamic tool for construction, demonstration and exploration that adds a powerful dimension to the learning of geometry and many other areas of mathematics. Further, research has shown that Geometer's Sketchpad can be an innovative tool for enhancing students' learning of plane geometry [36], [37].

White and Norwich presented nine exercises on using different technological tools in explaining Calculus concepts (Geometers' Sketchpad was one of them) and they found that GSP can be used in teaching some of Calculus concepts such as vertices of a triangle, midpoint, equation of a line, slope of a line and the trigonometric identities of sine, cosine and tangent functions [38].

Extensive research has been undertaken to study the effects of the use of Geometer's Sketchpad on geometry curriculum, pedagogy, and learning. It has been shown to assist student understanding of geometric relationships [39], [40], in making mathematical generalizations, and benefits

students with special needs [41]. [42], has highlighted the speed and ease with which students can manipulate figures using Geometer's Sketchpad and how slow and tedious and perhaps not even feasible these same tasks are done with pencil and paper [42]. This frees students from rote practice of routine calculations and allows them to focus on concepts and problems that are more meaningful to them. Thus, technology can promote higher-level thinking because students spend more time reflecting and analyzing [43].

A study conducted by Kamariah Abu Bakar, et al, they attempted to explore and compare the effects of integrating the GSP and the traditional teaching strategy in the teaching and learning process. Specifically, the effects on mathematical performance in secondary mathematics and students' attitudes towards the respective approaches used to teach the groups were investigated. Bases on the independent samples t-test, the results showed that there was no significant difference in mean mathematical performance between the GSP group and the traditional teaching strategy group, [t (90) = 1.552, p>0.05]. Findings also indicated that the use of GSP induced higher mathematical thinking process amongst the GSP group and also the use of Geometers' Sketchpad had an impact on both mathematical thinking process and performance [44].

In another research, found that positive correlations existed between levels of attitudes toward problem solving with perceived ease of use and perceived usefulness towards utilization of technology among Geometers' Sketchpad application learners [45]. Other research concluded that students who used the software (Geometers' Sketchpad) had higher significant achievement scores on a test containing the concepts of reflection and rotation [46].

Students using the GSP performed significantly better than those using books only. A qualitative study on students' development of 3D visualization in the Geometer's Sketchpad environment, where students were taught geometric solids among other concepts found that the GSP was effective in helping students develop 3D visualization and achieve conceptual understanding of geometry content and other concepts and also found that students have progressed significantly in terms of their geometric thought due to the instant feedback which allowed the students to verify or change their conjectures [47].

On the pedagogical usability of Geometers' Sketchpad application digital module conducted by Norazah, et al, it was found that students were more investigative in trying out their ideas and the use of Geometers' Sketchpad application may produce generation who are not only ICT literate but also Mathematics literate [48].

[49] used GSP to construct dynamic graphs of functions to geometrically present successfully the fundamental ideas of calculus and suggested making dynamic visualizations a part of every calculus teacher's explanations and also found Geometer's Sketchpad to be effective in learning by the way of visualization in the various areas in mathematics [50]. [51] discussed how they have attempted to help students gain a working understanding of perspective by using GSP. The students explore drawing isometric views guided by a skillful teacher and found that the students were prepared to encounter more formal study of perspective. Teacher coaching was found to be a very important factor in students gaining the understanding of perspective as cited in [52].

Students enjoy Sketchpad for its visual interest, animation, and interactivity, which has an effect on their motivation and confidence to successfully perform and solve problems, reducing math anxiety and boredom [53], [54]. Thus encouraging student's willingness to work longer, and recognize the power of mathematics and may be open to further study [55].

Teachers have found Sketchpad activities effective for their 'low-ability' or 'learning difficulty' or even disabled students, by offering individual feedback, multiple representations, and the ability to work at an individual's own pace, but they also recognize that Sketchpad facilitates challenge as well, supporting a tendency to go beyond the confines of a problem and pose extensions [54], [56]. Working with Sketchpad is equally positive for teachers and it can be configured to suit a wide range of learning modes, from step-by-step activities to open-ended explorations and it makes sense to start students with a fluent tool that they can grow with, can use knowledgeably and confidently to make their mathematical education rewarding, lasting, and enjoyable [57]

Some Difficulties Students Encounter Learning Quadratic Functions

Students discontinue studying mathematics because of their perception as boring, hard and useless. This is confirmed by Brown, Brown and Bibby , that the low participation of mathematics in UK was due to the perceived difficulties lack of confidence, dislike, boredom and lack of relevance on the subject [58].

Several issues appear in the literature on student difficulties with regard to quadratic functions, which include misconception of variable, student struggle stirring between representations, and student struggle with the relationship between the diverse expressions of the algebraic forms of a quadratic function [59-63].

Some main obstacles in student understanding of a quadratic function have been identified such as graphical interpretation, relation between a quadratic function and a quadratic equation and change in form of a quadratic function [63]. Besides this obstacles identified, it was also evident that students preferred to work with the standard form of a quadratic function y=ax2+bx+c rather than other forms, such as vertex form [63].

One topic in mathematics in which students have learning difficulty which results from poor method of teaching is quadratic functions [64], [65].These students' learning difficulties in quadratic function are reported in numerous studies. For example, [65] identified fours cognitive obstacles that students face in learning of quadratic functions. These cognitive obstacles are: (1) lack of making and investigating mathematical connections between algebraic and graphical aspects of the concepts, (2) the need to make an unfamiliar idea more familiar, (3) disequilibrium between algebraic and graphical thinking, and (4) the image of the quadratic formula or absolute value function. Eraslan remarked that students lack the ability to make and investigate mathematical connections between algebraic and graphical aspects of the quadratic functions.

Borgen and Manu, illustrated the idea that students who

perform well in class and appear to have some understanding of quadratic functions in reality may not. They videotaped two students on a problem to find the stationary point for a quadratic function and to determine if the point is a maximum or minimum, it was evident that although the paper answer was correct, the students' understanding of these concepts was weak. A student was hooked on the calculator and there was also misunderstanding between the standard form and the vertex form of a quadratic function, which led to improper imaging [59]

IV. METHODOLOGY

The study merged the quantitative and qualitative research designs due to the strengths acknowledged by researchers, [66], [67]. In all a total of 80 students were sampled who were mainly second year students from General Arts programme and General Science in the Presbyterian Senior High School, La-Accra. A purposive and simple random sampling methods were adopted at different stages due to its supportability to the study with regards to time and financial resources [68], [69]. Post-Treatment Test (Achievement tests) and structured questionnaire were used in collecting relevant data from study participants. Additionally, the researcher observed and recorded unprompted comments from the students while they engaged with the software due its originality and validity [70-72]. During this period, an intervention was used to practically achieve the study objectives. The intervention was based on ASSURE instructional model. The ASSURE Model is an instructional guide for planning and conducting lessons that aim to integrate media and technology while focusing on the learner's needs and has a goal of producing more effective teaching and learning. This model is based on six classroom procedures that Analyze Learners, State Objectives, Select Methods, Media, and Materials, Utilize Media and Materials, Require Learner Participation, and Evaluate and Revise [73].

Through an experimental design approach, the students were then put into two groups which consist of a control (group A) and an experimental (group B). The 'Group A' was taught without the use of Geometer's Sketchpad whiles 'Group B' was taught using Geometer's Sketchpad so that the performance of the two groups could be compared. The Geometer's Sketchpad software was used for the intervention to help students enhance and enrich their understanding of graph of quadratic relations. The procedure was to take students through the process of plotting graph and interpretation of the graphs. The school computer laboratory was used as the venue for the delivery of a prepared lesson and a follow-up discussion on the lesson. The experimental group representing half of sample was taught using the Geometer's Sketchpad software application throughout the unit. The rest (control group) had the same lessons using a traditional approach with paper and pencil activities.

The intervention which was done mainly after school session lasted for a month and students were met twice a week for 60 minutes duration for each session. Forty minutes was used for drills and the 20 minutes for practice. The first week was used for the introduction and exploration of the software (Geometer's Sketchpad software) including its features. The rest of the weeks were used for the teaching of the quadratic graphs (changes that take place when the coefficients of the x^2 is increased, decreased or halved). After the intervention, a post-treatment test was administered based on the quadratic function (parabola). After the intervention, an assessment was conducted and the results analysed. The quantitative data collected from the post-treatment test and the questionnaires conducted were systematically analysed using an SPSS software. Data gathered from the questionnaire were expressed as percentages while data gathered through observation of unprompted student comments were analyzed qualitatively to explain students' perception of the software used and its effectiveness.

V. DISCUSSIONS

We investigate through experimental design, the use of Geometer Sketch-Pad (GSP) and discuss the findings to find out the effect of GSP on student performance in mathematics as well as their interest in using this technological approach in graphing.

Demographic Information

The study involved eighty (80) students in total with forty (40) students from the General Arts programme and another forty (40) from the General Sciences. Out of these forty for each programme, twenty (20) students were placed into the Experimental group and twenty (20) into the control group. The experimental group was made-up of twenty-two (22) boys and eighteen (18) girls while the control group was made-up of twenty-one (21) boys and nineteen (19) girls. The average age of the participants in the two groups was 18 years.

Table 1: Academic Programme of Participants

Programme	Group		Frequency(total)	Percent	Average Age
	Control	Experimental			
General Arts	20	20	40	50.0	18
General Science	20	20	40	50.0	17
Total	**40**	**40**	**80**	**100**	**18**

Extent to which the use of Geometer's Sketchpad Increase Students' Performance in Quadratic Graphs.

The major question was the effect of Geometer's Sketchpad application software on students' performance in quadratic graphs. Students' responses in the post achievement test outlined the impact of GSP on students' learning outcomes. Students' performance was examined under the following themes:

i. Recognition of quadratic equation and its nature;
ii. Recognition of roots of quadratic function;
iii. Identification of y-intercept when a given quadratic function changes;
iv. Recognition of the Axis of symmetry of a given quadratic function;
v. Identification of the coordinates of vertex (turning point).

Analyzing the findings along the themes, the study shows that students ability to identify and recognize quadratic equations and their nature with the co-efficient like this [y=x^2] was positive.

As shown in the table, participants' correct responses on recognition of quadratic equation and their nature for both control and experimental groups recorded an average score of 46.3% and 55.6% respectively. This suggests that the experimental group performed above average compared to the control group by 9.3%. Although students' performance on the item "The nature of quadratic graph when the co-efficient of x^2 is positive" was high for both groups, the experimental group performed better than the control group with the response of 80% and 65% respectively. However, the experimental group showed a weak performance when it came to the item "Which of the following parabolas opens upward and appears narrower than $y = -2x^2 + 2x - 1$?"

A. $y = 5x^2 - 2x - 1$
B. $y = -5x^2 - 2x - 1$
C. $y = -2x^2 + x + 3$
D. $y = x^2 + 4x$

With the correct response of 42.5% ($n = 17$) against the control group with the correct response of 55% ($n = 22$).

Table2: Participants' Correct Responses on Recognition of Roots of Quadratic Function

Item Question Number	Content tested	Participants making the Correct Responses			
		Number correct		Percentage (%)	
		Control	Experiment	Control	Experiment
5.	Calculate the roots of the equation $y = (x-3)(x-5)$	30	34	75	85
6.	Which of the function represents the quadratic graph?	21	32	52.5	80
7.	The factored form of $y = x^2 - 4x - 12$	30	38	75	95
	Average percent correct for the three items			**67.5**	**86.7**

Table 2 revealed that the average percentage of correct responses for the three items for both control and experimental group were 67.5% and 86.7% respectively. Thus, both performances for the control and experimental group were above the 50% average mark and shows that majority of the students have no major problem with recognizing roots of quadratic function. Although both performances were encouraging, the experimental group did perform better than the control group with the difference of 19.2%.

Participants' correct responses on how to "calculate the root of the equation y=(x-3)(x-5)" for both control and experimental group were equally high with response of 75% (n=30) and 85% (n=34) respectively. Same applied to the correct response of 75%: 95% regarding the control group and experimental group.

Identification of Y-Intercept when a given Quadratic Function Changes

Participants were asked to provide answers to the multiple choice questions such as determine the y-intercept of the function y= ⟦-2(x-3)⟧ ^2-4 and the effect of the function if the constant "c" is changed. The correct responses for the control and experimental groups which was analyzed quantitatively as shown in Table 4.4, reveals an encouraging average percentage of 50% and 60% respectively. Also the control group performance was 7.5% better than that of the experimental group with correct response of 62.5% (n=25) and 55% (n=22) respectively on the item "determine the y-intercept of the function"

However, Table 3 also shows that the major challenge for the control group was in "The changing of the function: $y = x^2 - 2x - 2$, to $y = 8 - 2x + x^2$ and later to$y = x^2 - 2x + 5$?"

A) Direction of openness of the graph
B) Narrowness of the graph
C) Position of the vertex
D) y-intercept

With a correct response of 37.5% (n=15) as against the experimental group with the correct response of 65% (n=26). On this score, although the results showed both control and experimental performed better, the average correct responses indicate the performance of experimental group was better than the control group with a difference of 10%.

Table 3: Participants' Correct Responses in Identification of Y-Intercept when a given Quadratic Function Changes

Item Question Number	Content tested	Participants making the Correct Responses			
		Number correct		Percentage (%)	
		Control	Experiment	Control	Experiment
8.	Determine the y-intercept of the function $y = -2(x-3)^2 - 4$	25	22	62.5	55
9.	The effect of the function if the constant "c" is changed	15	26	37.5	65
	Average percent correct for the two items			**50**	**60**

Recognition of the Axis of Symmetry of a given Quadratic Function

The Table 3 presents the correct responses provided to the multiple choice questions, the equation of the axis of symmetry of $y = 2 - 4x - 2x^2$ and the axis of symmetry based on $y = a(x+h)^2 + k$.

Table 4: Participants' Correct Responses on Recognition of the Axis of Symmetry of a given Quadratic Function

Item Question Number	Content tested	Participants making the Correct Responses			
		Number correct		Percentage (%)	
		Control	Experiment	Control	Experiment
10.	The equation of the axis of symmetry of $y = 2 - 4x - 2x^2$	17	21	42.5	52.5
11.	The axis of symmetry based on $y = a(x+h)^2 + k$	16	24	40	60
	Average percent correct for the two items			**41.25**	**56.25**

Table 4 represents the correct responses of participants' ability to recognize the axis of symmetry of a given quadratic function for control and experimental group with the average percentage score of the two items of 41.3% and 56.3% respectively. The table suggests that the experimental group performed above average of 50% than that of the control group by 15%. The control group performances on both items were also below 50%, which indicate their weak performance. In summary, the results showed that the experimental group performed better than the control group when it comes to recognizing the axis of symmetry of a given quadratic function.

Identification of the Coordinates of Vertex (Turning Point)

Participants were required to provide answers to the

following multiple choice questions: identify function that has a maximum vertex and y-intercept as -2, identify the function with the minimum vertex (2,3), find the quantity sold for a company to maximize profit and the profit (vertex), and determine the coordinates of the vertex for the function $f(x) = -2(x-1)^2 - 6$. The correct responses for the control and experimental group, answers to the theme "Identification of the coordinates of vertex (turning point)" were analyzed in Table 4.6 quantitatively.

Table 4: Participants' Correct Responses in Identification of the Coordinates of Vertex (Turning Point)

Item Question Number	Content tested	Participants making the Correct Responses Number correct		Percentage (%)	
		Control	Experiment	Control	Experiment
12.	Identify function that has a maximum vertex and y-intercept as -2	26	22	65.0	55.0
13.	Identify the function with the minimum vertex (2,3)	15	28	37.5	70.0
14.	Find the quantity sold for a company to maximize profit and the profit (vertex)	20	25	50.0	62.5
15.	Determine the coordinates of the vertex for the function $f(x) = -2(x-1)^2 - 6$	24	32	60.0	80.0
Average percent correct for the four items				**53.125**	**66.9**

Table 4 indicates the correct responses of participants' ability to identify the coordinates of vertex (turning point) of the control and experimental group. The average percentage of the correct response for the four items of control and experimental group were 53.1% and 66.9% respectively. Therefore the performance of both groups was encouraging since it is above the average of 50%.

However, Table 4 also shows that the weakest areas for the control group was in "From these functions, determine the one with the minimum vertex (2, 3)."

$A)\ y = (x-2)^2 + 3$
$B)\ y = (x-2)^2 - 3$
$C)\ y = (x+2)^2 + 3$
$D)\ y = (x+2)^2 - 3$

Which a correct response of 37.5% ($n = 15$) as against the experimental group with the correct response of 70% ($n = 28$). Thus, even though the results showed that the performances of experimental group and the control group were encouraging, there were some weaknesses on the part of the control group when it comes to identifying the function with the minimum vertex (2, 3) from given quadratic functions.

The Effect of Geometer's Sketchpad on Students' Performance on Quadratic Graphs

The effect of the Geometer's Sketchpad intervention used in this study was analyzed by examining the student's performance in learning quadratic graphs in the post-treatment tests. The performance (scores) of post-treatment tests between the control group which used the traditional teaching and the experimental group were compared

4.4.1 Determining the Statistical Significance of the Difference in the Scores between the Control Group and the Experimental Group

Results from the qualitative and quantitative data were analyzed to assess the effectiveness of the use of Geometer's Sketchpad in enhancing students' performance in quadratic graphs. Scores from the post-treatment test were used to compare the experimental and control groups' performance in quadratic graphs. In order to measure this, an independent samples t-test was used at 95% confidence level with the grouping variable being experimental and control groups. The results are shown in the Table 5a and Table 5b.

Table 5a: Descriptive Statistics of the Groups Performances

	Participant Category as Experimental or Control	N	Mean	Std. Deviation	Std. Error Mean
Scores of the Achievement test (100)	Experimental	40	68.88	14.718	2.327
	Control	40	51.65	11.329	1.791

From the statistics table 5a, the mean for the experimental group was 68.88 with standard deviation of 14.718 and the mean for the control group was 51.65 with standard deviation of 11.329. Therefore, it is clear that the experimental group did better than the control group with the use of GSS.

Table 5b: Results of Independent Sample Test

		F	Sig.	T	Df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	Lower	U
Scores of the achievement test out of 100	Equal variances assumed	3.178	.079	5.865	78	.000	17.225	2.937	11.379	2
	Equal variances not assumed			5.865	73.205	.000	17.225	2.937	11.373	2

Test statistic (the hypothesis);

H_0: There is no significant difference in the students' performance in graphing of quadratic functions between the experimental and control group.

H_1: There is significant difference in the students' performance in graphing of quadratic functions between the experimental and control group.

An independent sample t-test was conducted to compare the scores of the experimental group and the control group (table 4.7b). The results indicated that the scores of the experimental group were significantly higher(M=68.88,SD=14.718), than the scores of the control group(M=51.68,SD=11.329),t(78)=5.865,P=0.00<0.05 C.I=(11.379,23.071). The study therefore rejects the null hypothesis and consider the alternate hypothesis that is, there is significant difference between the experimental and control groups in students' performance in quadratic graphs. The description in table 4.7a confirm this finding.

The extent to which the use of Geometer's Sketchpad increase students' performance in quadratic graphs were explained based on the qualitative data collected from the questionnaire administered on some selected students from the experimental group.

Questionnaires administered to twenty (20) selected students of the experimental group to measure their views on the effectiveness of Geometer's Sketchpad application software in learning of quadratic graphs. About 65% (N=13) of students indicated that the use of Geometer's Sketchpad helped them to understand the topic better.

Similarly, about 95% (N=19) of students indicated that the use of Geometer's Sketchpad helped to visualize the

curve and the axis of symmetry correctly. The entire study population strongly agreed or agreed to the statement that "The use of GPS made learning easier and interesting" than otherwise.

Whiles using the Geometer's Sketchpad application software to solve problems involving quadratic graphs in a laboratory setting, observations made by the researcher complemented the findings of the quantitative data – students becoming competent in using the software to draw the quadratic graphs, look for its maximum or minimum, axis of symmetry and determine the roots. It was observed that students worked with each other in finding solutions under the nature of the graph and came out with the unprompted comments such as "The curve opens wide upwards when the coefficient of x^2 is positive". Other comments included "Yes, I have got it" and "Wow! this is simple and stress-free". These show students willingness to learn and support the hypothesis that the use of GPS software promotes learning among students.

In conclusion, the results from quantitative and qualitative data showed that the use of Geometer's Sketchpad software enhanced students' performance in quadratic graphs. Hence, the use of Geometer's Sketchpad has positive effect on students' performance in the study of quadratic graphs.

Discussion of Major Findings for Research Question 1

The study was conducted to investigate the effectiveness of using Geometers' Sketchpad application software on students' performance in learning quadratic graphs.

With regards to the above, the independent samples t-test results indicated that the difference in mean scores of the control group and experimental group was statistically significant. The study found that the experimental group performed better than the control group in the post treatment test. This suggests that the use of technology resources statistically influenced students' technology use and their understanding in learning Mathematics. By implication, this finding depicts that the use of Geometers' Sketchpad application software improved students' performance in quadratic graphs which is in tandem with [74] who found that the availability of technology resources such as ICT syllabuses/manual, computers and computer laboratories have a significant influence on students' technology use at the SHS level in Ghana and also affirmed by Teoh Boon Tat and Fong Soon Fook, in their study to examine the effects of using the GSP and the graphic calculator (GC) in the learning of the vertex form of quadratic functions among field dependent (FD) and field independent (FI) cognitive style of students. They found that the students performed well when using GSP or the GC in the learning of quadratic function by way of visualization of graphs [52]. Other researchers who have found GSP to be effective in learning by way of visualization in the various areas in mathematics [75-77], [49]. This can be seen from the questionnaire where about 95% (N=19) of the students indicated that the use of Geometer's Sketchpad help to visualize the curve and the axis of symmetry correct.

A study conducted by [78], to investigate the effect of using the Geometer's Sketchpad software in teaching and learning of graph functions among Form Six (grade 12) students in Malaysian Secondary Schools indicated that the result of the experimental group had a significant mean difference compared to the control group. This shows that the use of Geometer's Sketchpad in Mathematics classroom has a positive effect on the students' Mathematics achievement and attitude towards the learning of graph functions [78]. The study agrees to this earlier finding by Kwan, because this study reveals same.

Furthermore, [45] in his study investigated the effect of using the GSP on students' understanding of some of the geometrical concepts. The sample consisted of 52 students from the Model School, Yarmouk University, Jordan. The result of the study indicated that there was a significant difference between the means of students on the post-test and more gain in the scores from the pre-test to the post-test in the case of the experimental group.

Other studies on integration of technology into schools show an increase in test scores related to the use of technology [79].

Result of Research Question 2 (What are Students' Perceptions about using the Geometer's Sketchpad Application (GSP)

The students' perceptions about the use of Geometers' Sketchpad in learning quadratic graphs were sought through questionnaire and observation. Table 4.8 shows the response of students' perception about the use of the software (Geometer's Sketchpad).

Table 6: Students' Perception in Learning Quadratic Graphs with Geometers' Sketchpad (N=20)

	Strongly Agree (%)	Agree (%)	Undecided (%)	Disagree (%)	Strongly Disagree (%)
Geometers' Sketchpad helped me in understanding the topics better	5	60	15	20	0
GSP help to visualize the curve and get the Axis of symmetry correct	50	45	5	0	0
Geometers' Sketchpad makes me feel comfortable learning quadratic graphs	40	40	0	20	0
The use of GSP made learning easier and interesting	45	55	0	0	0
The use of GSP encourages us learn from one another	60	30	5	5	0
I feel confident to use Geometer's Sketchpad to learn other topics in Mathematics	40	35	20	0	5

According to Table 6, majority of the students sixty-five percent (65%) strongly agreed or agreed that Geometer's Sketchpad helped them to understand the topic (quadratic graphs) more than otherwise. In response to the statement "Geometer's Sketchpad helped to visualize the curve and the axis of symmetry correct", about 95% of respondents which constituted the majority agreed or strongly agreed that sketchpad help them to visualize the curve and the axis of symmetry correctly when learning quadratic graphs.

Also about 80% of the students' respond to the statement "Geometer's Sketchpad makes me feel comfortable learning quadratic graphs" strongly agreed or agreed that the software made them feel comfortable when learning quadratic graphs Majority of the students 100 % strongly agreed or agreed to the statement that "The use of GPS made learning easier and interesting" than otherwise.

In response to the statement "The use of GPS encourages us learn from one another", about 90% of respondents which constitute the majority strongly agreed or agreed that the use of sketchpad encourages group learning.

Similarly, in response to the statement "I feel confident to use Geometer' Sketchpad to learn other topics in mathematics", 75 % of the respondents strongly agreed or agreed that they feel confident to use Geometer's Sketchpad software to learn other topics in Mathematics. The researcher also made some observations in the course of the treatment. The observations were; the researcher observed that participants showed keen interest in getting familiar with the Geometer's Sketchpad application software at the beginning of the treatment as all groups where enthused to participate in each instruction given.

Participants appreciated the use of Geometers Sketchpad software so much that they were asking the researcher to come to the ICT laboratory to mark their exercises on the computers. Examples of observations made on unprompted student comments include:

> *"Please Sir, prepare to come to the lab to mark our workfor us."*
> *"This is nice can we try more examples?"*
> *"Can we use this software to do our graph work and other topics in mathematics?"*

Although students acknowledged the importance of Geometer's Sketchpad software (GPS) in learning and better understanding of quadratic graphs, they encountered some challenges in learning with the GPS, which had to do with the basic ICT skills (such as entering data, clicking, identifying the themes at the menu bar, the slider etc) the students lacked. As a result, some students had initial difficulty working with the software to explore the mathematical concepts being taught. Some unprompted comments the students made included:

"Sir we are not getting it, the graph is not appearing when we entered the equation". (We, referring to the group)

"At first we couldn't get it but now it is prefect."

From the questionnaire and observations made, it can be deduced that students' perception in using Geometer's Sketchpad application software is very positive and hence motivate students in their learning of quadratic function and mathematics in general.

VI. Conclusion

This study sought to investigate the effectiveness of Geometer's Sketchpad application software on The Senior High School students' performance in learning quadratic graphs. It also considered how students perceive the use of the software in their learning of quadratic graphs. The study found that the use of Geometer's Sketchpad application software had positive effect on students' performance in quadratic graphs and also changed students' perception, attitudes as well as motivated them in their learning of quadratic graphs. This indicated that the GSP group would not avoid using the software to learn with. The positive attitudinal change detected in this study supported the works of [14] [80].

The use of mathematical software such as Geometer's Sketchpad and Spreadsheet (Microsoft Office Excel), promote collaborative learning among students as was observed during the treatment sessions of this study. Consequently, it can be deduced from these findings that the use of relevant ICT tools could appeal to the diverse learning needs and styles of today's students.

VII. Recommendations

We recommend that, African mathematics teachers integrate the current ICT tools in teaching and facilitating their instructional pedagogies such as Geometer sketchpad since this was tested to contribute to student understanding of graphing techniques. Students get involve in the lesson and tend to appreciate the adopted pedagogical approach.

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