GEOGEBRA SOFTWARE AND STUDENTS` PERFORMANCE IN TEACHING AND LEARNING OF CIRCLE GEOMETRY

By

Gamage T. and Charles-Ogan G. I

Department of Curriculum Studies and Educational Technology Faculty of Education
University of Port Harcourt, Nigeria. gladyscharlesogan@yahoo.com

Abstract

This study investigated GeoGebra software and students` performance in teaching and learning of circle geometry. The study was guided by two objectives, two research questions and two null hypotheses which were tested at .05 alpha level. The pretest-posttest quasi-experimental research design was employed for the study. The population and sample were all the 25,913 and 117 senior secondary school two students respectively from the 33 public schools in Yenagoa Local Government Area of Bayelsa State. The purposive sampling technique was employed to select the sample. The instrument used for the collection of data was Geometry Performance Test (GPT). A reliability index of .75 was established for GPT using the test-retest method. The mean, standard deviation and analysis of covariance was used to analyze the data. The result showed that students in the experimental group that were taught circle geometry using GeoGebra software performed higher than their counterparts in the control group that were taught using the traditional method. The result further showed that there was a significant difference between the mean performance of students taught circle geometry using GeoGebra and those taught using the traditional method. There was no significant difference between the mean performance of the male and female students taught circle geometry using the GeoGebra software. It was concluded that use of GeoGebra software to teach circle geometry improved students' performance than the traditional method.

Keywords: GeoGebra, Performance, Circle Geometry, Software, Teaching.

Introduction

Global economy as a knowledge-based economy is no longer news but a reality. The request of the global popular industries of finance and technology for people with abilities of critical thinking, problem-solving, and ICT complaint is a pointer that the mathematical ability of a country's citizens is an important indicator of national competitiveness. The motivation of industrial innovation is dependent upon the elevation of mathematical literacy and a higher mathematical ability of all citizens, in order to face the rapidly changing environment. Bhakta, Wood and Lawson (2010) highlighted the need for a numerate workforce and this is not limited to those who study Mathematics at degree level.

Development of a nation greatly depends on its inclination in Science and Technology as exemplified by United States of America, Germany, Japan, China, Singapore, South Korea, Indonesia, India and Malaysia which use Mathematics as a tool, key and gate for their success stories. As (Baiyelo 2007) observed, Mathematics is widely regarded as the language of science and technology which implies that without Mathematics, technology has no place in existence.

A visible knowledge of Mathematics is a necessity for the social and economic transformation of any nation (Charles-Ogan, 2015). This simply implies that a nation can hardly make significant achievement without technology, which roots are Mathematics and science. Succinctly, Mathematics has been conceived as the key in the need of daily life hence, occupies a central position as a hub where the scientific and technological growth of any nation lies on. This position of Mathematics in the society has no doubt made its relevance clear as the measure of civilisation that has conditioned everyone who would want to be educated in Science and Technology and many other fields of studies to its fold. (Avong, 2013) and a host of many other factors are responsible for the low output? Or is something more required to guide and reinforce students in other to visualise and have a proper understanding of circle geometry in their course of learning Mathematics?

Teaching and Learning of Mathematics with the use of technology provides greater learning opportunities for students, enhances students` engagement and encourages discovery learning (Praveen & EU, 2013). In the teaching and learning of Mathematics, especially geometry, it is important for students to be able to imagine, construct and understand the relationship that exists between concepts which in turn develops their conceptual knowledge through learning by doing as advocated by a Chinese saying: “I hear and I forget, I see and I remember, I do and I understand.” And this is possible with the introduction of Information and Communication Technology (ICT) into the Mathematics classroom which is in accordance with the demands of the 21^{st} – century. The use of ICT also gained its support from the United Nations Educational, Scientific and Cultural Organization (UNESCO). In this era of technology, Mathematics skill is not being proficient in arithmetic. Rather, it depends on understanding relationships in time and space and expressing them with precise and clear formulas. Owing to this fact, one cannot depend on the rote memorization of rules and formulas. Hence, conceptual understanding, intuitive understanding and insight are critical and essential for true learning of Mathematics. The insights gained are products of the practical approach employed using technology which enables students to visualize relationships, and creatively interact with calculation procedures.

Geometry is a perceived difficult area in Mathematics and requires a problem-based approach in its teaching and learning as it entails different geometrical problem scenarios that compel learners to explore different problem- solving approaches (UNISA, 2011). In a bid to make the teaching and learning of geometry real, computer software programs are the viable platform by which problem-based skills are developed in learners through interactions with computers to construct knowledge. Dynamic geometry software that emerged in recent years has proved to be an effective technological tool for visualising abstract mathematical structures, (NCTM, 2003). The rationale was that Mathematics uses everyday words with different meanings in different contexts (Aydos, 2015) and DGS was successful in creating opportunities that would link real life and abstract mathematical concepts in a variety of contexts (Aktumen & Bulut, 2013). Therefore, a computer will assist students in imagining and making observations (Dogan, 2010). Dynamic mathematical software programs enable students to make connections among the representations easily and meaningfully, which would be quite difficult to reach, if not impossible at all, without such dynamic tools. A number of technology tools are available such as 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 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 with its web application based on HTML5 technology (Wikipedia, 2017). 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 (Tatar, Akkaya & Kagizmanli, 2011). 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. All of them can be changed dynamically afterwards. Elements can be entered and modified directly via mouse and touch, or through the input bar. GeoGebra has the ability to 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 geometric theorems. GeoGebra is loaded with built-in CAS, built-in spreadsheet, built-in statistics and calculus tools and interactive geometry environment with 2D and 3D. Teaching and Learning in the 21st-century support child-centred approach whereby 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 any lesson. Teaching and Learning geometry requires many hands-on activities that will enable the learner to transform abstract and complex problems into concrete and real-life situations. The use of GeoGebra involves hands-on activities with student participation as a key element in the teaching and learning process and as students work in the dynamic geometry environment, they develop and create more skills and knowledge at their own pace, which end products are well developed conceptual knowledge, procedural knowledge and problem-solving capabilities. This will make teaching and learning of Mathematics meaningful in a general perspective and geometry in particular as it enables students to explore concepts and form conjectures.

Statement of the Problem

The backdrop of students' performance in Mathematics in national examinations over the years is a source of concern to stakeholders in the field of education. Wonu and Zalmon (2017) in a study to diagnose and remediate senior secondary students' common learning difficulties in mathematics concluded that from 1991-2016 an average of only 27.31% passed at credit level and above while the remaining 72.69% had below credit in Mathematics in the May/June WASSCE. This poor performance has earlier been identified in a study conducted by Maduabum and Odili (2006) to analyse students` performance in general mathematics at senior school certificate level between 1991-2002 with a result that students did not attain up to 38% pass at credit level in the twelve-year period under review. In an effort to improve performance, the WAEC Chief examiner took it upon himself to highlights areas of weakness and possible remedies each year but significant changes have not been observed. One of such key areas that the Chief exam has pondered on is its report on geometry.

Hence, one begins to reason if students lack cognitive and process abilities in understanding geometrical concepts in general and circle geometry in particular or does the teaching methods, strategies, materials, environment, parental attitude, interrupted teaching might play a role in filling up the gap by assisting students to visualise and understand circle geometry through exploration and exploitation.

However, in the Nigerian context, there has not been much research in this direction. Thus, this study intends to investigate the impact of Teaching and Learning circle geometry using a dynamic geometry software called GeoGebra.

Aim and Objectives of the Study

The aim of the study was to find out how use of GeoGebra software affects students` performance in teaching and learning of circle geometry. The specific objectives of the study were to:

1. Examine the impact of GeoGebra software on the performance of students in circle geometry.
2. Compare the impact of GeoGebra software on the performance of the male and female students in circle geometry.

Research Questions

The following research questions were raised to guide the study.

1. What is the mean difference in the performance scores of students taught circle geometry using GeoGebra software and those taught using the traditional method?
2. How does gender affect the performance of students taught circle geometry using GeoGebra software?

Hypotheses

The two hypotheses were tested at 0.05 alpha level.

HO_1. There is no significant difference between the mean performance of students taught circle geometry using GeoGebra software and those taught using the traditional method.

HO_2. There is no significant difference between the mean performance of the male and female students taught circle geometry using GeoGebra software.

Research Design

This study adopted a quasi-experimental research design. A pre-test and post-test with experimental and control groups were used to carry out the study in two selected public senior secondary schools in Yenagoa Local Government Area of Bayelsa State. Since human being was being used for this study, the situation of taking total control over some threats to validity may not be visible and the assignment of subjects to groups does not employ randomization rather in-tact classes were used for the study.

Population for the study

The target population of this study consisted of all the 25,913 senior secondary school two (SS2) students from the 33 public schools in Yenagoa Local Government Area of Bayelsa State.

Sample and Sampling Technique

The sample of the study consisted of 68 male and 49 female students. All the participants were senior secondary two (SS2) students. A purposive sampling technique was used to select two senior secondary schools. A simple random sampling technique was adopted in assigning the two selected schools into experimental group and control group.

The selection of schools was guided by the following criteria:

1. School with a functional laboratory equipped with computers, mathematics software and projectors.
2. Co-educational school (male and female students.)

Instrument for Data Collection

The instrument for data collection was a Geometry Performance Test (GPT) which included pre-performance and post-performance. GPT was used to measure performance index (how students performed in circle geometry test) with the pre-performance test used for determining z-level of students in both experimental and control groups before treatment and the post-performance test was used to determine the level of student's achievement after the treatment. This test consisted of six (6) subjective questions to be answered by both groups before and after the treatment.

Validation of the Instrument

The instrument, GPT and the lesson plan used for gathering data for this research work were subjected to face and content validity by curriculum and instruction experts in the field of Mathematics education for adequate criticism and correction before it was administered to the sample.

Reliability of the Instrument

The reliability of Geometry Performance Test (GPT) was determined through a test-retest method for a measure of its stability. This is to measure the confidence that scores obtained from a test are approximately the same scores that would be obtained if the test was retaken by the same students at another time, or by different students A random sampling method was used to draw twenty (20) senior secondary two (SS2) students who were not part of the sample for this study but with similar characteristics to the study population. The instrument was administered and results recorded. After a space of two weeks, the same test was given to the same set of students and results recorded. After collecting the data, Pearson's Product Moment Correlation was used to determine the reliability coefficient and was established to be 0.75 for the GPT.

Administration of the Instrument

At the beginning of the study, all participants were given a pretest of GPT before the instruction began. During the instruction phase, the experimental group was instructed using GeoGebra dynamic software installed in computer systems and the control group was instructed using the traditional method of instruction. The researcher used a lesson plan that included activities that were common to both the experimental and the control groups, such activities are definition of basic terms in circle geometry, stating of theorems and drawing of shapes while other activities that were different between the two (2) groups are the use of computers and rigorous patterns/steps involved in proving theorems. A post-test was administered to both groups and thereafter data were collected for analysis.

The materials used for this research work are a set of lesson plan on circle geometry from the New General Mathematics for senior secondary schools two (2) and an instructional guide that contains the content areas of circle geometry designed by the researcher to enhance better performance of the students in the experimental group.

The experimental group was introduced to the dynamic geometry software (GeoGebra) using the study guide to explore its basic features and functions at the initial stage. Later, the experimental group was taught circle geometry by the intact class teacher and assisted by the laboratory attendant using the dynamic tool in the computer laboratory where the teacher uses power point on a projector to demonstrate the concept of circle geometry (circle theorems) and the students worked on individual desktop computers but were free to communicate with each other and where necessary sought the attention of the laboratory attendant. Discovery teaching strategies were used for the delivery of instruction.

The control group also underwent teaching and learning using the “chalk and talk” approach. The lesson lasted for four (4) weeks for each group.

A 2-day training session was organized by the researcher for the SS2 Mathematics teacher and the laboratory attendant on how GeoGebra can be used for teaching and learning Mathematics using the study guide.

Method of Data Analysis

Students’ scores from the pre-test and the post-tests were collected and analyzed via Statistical Package for Social Sciences (SPSS). Descriptive statistics (mean and standard deviation) were used to answer the research questions and inferential statistics, Analysis of Covariance (ANCOVA) was used to test the hypotheses.

Results

Research Question 1: What is the mean difference in the performance scores of students taught circle geometry using GeoGebra software and those taught using the traditional method?

Table 1: Mean ($\bar{x}$) and standard deviation (SD) of students taught using GeoGebra and traditional method

		Pre-test		**Post-test**			
Group	**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean Gain**	**Mean Difference**
GeoGebra	64	19.83	11.90	54.77	6.68		22.21
Traditional Method	53	18.02	8.46	30.75	10.57		

Table 1, showed that students in the experimental group who were taught circle geometry using GeoGebra software had a pre-test mean ($\bar{x}$) value of 19.83 and a standard deviation of 11.90, while their post-test score gave a mean ($\bar{x}$) value of 54.77 and standard deviation (SD) of 6.68. The pre-test score of students taught circle geometry with traditional method in the control group gave a mean ($\bar{x}$) value of 18.02 and standard deviation of 8.46, while their post-test scores gave a mean ($\bar{x}$) value of 30.75 and standard deviation (SD) of 10.57. A mean gain of 22.21 was recorded between the experimental and control groups in favour of the experimental group. This indicated that the students taught circle geometry with GeoGebra software showed a significant increase in performance than those taught with the traditional method. Also, the mean difference of 24.02 recorded was in favour of the GeoGebra group. The table1 revealed that posttest mean of the experimental group 54.77 was higher than the posttest mean of the control group 30.75.

Research Question 2: How does gender affect the performance of the male and female students taught circle geometry using GeoGebra software?

The test scores obtained from the Geometry Performance Test (GPT) was used to answer this research question.

Table 2: Mean ($\bar{x}$) and standard deviation (SD) of male and female students taught using GeoGebra

		Pre-test		Post-test			
Group	**N**	$\bar{x}$	**SD**	$\bar{x}$	**SD**	**Mean gain**	**Mean difference**
Male	38	19.50	11.99	53.95	7.17	34.45	
Female	26	20.31	12.01	55.96	5.81	35.65	1.20

Table 2 showed that the male students in the experimental group who were taught circle geometry using GeoGebra software had a pre-test mean ($\bar{x}$) value of 19.50 and standard deviation of 11.99 while the female students in the experimental group had a mean value of 20.31 and standard deviation of 12.01. For the post-test mean score, male students obtain a mean of 53.95 and standard deviation of 7.17, while the female students obtain a mean performance score of 55.96 and standard deviation of 5.81. The mean gain scores for the two groups were 34.45 for male and 35.65 for female students respectively. Also, the difference in the mean gain scores of both groups was established at 1.20.

Hypothesis 1: There is no significant difference in the performance test scores between students taught circle geometry with GeoGebra software and those taught using traditional method.

Table 3: Summary of ANCOVA on the difference in performance between students taught geometry with GeoGebra and traditional method.

Source	**Type III Sum of Squares**	**df**	**Mean Square**	**F**	**P-value**	**Sig.**
Corrected Model	17166.508[a]	2	8583.25	116.59	.00	< 0.05
Intercept	43892.937	1	43892.94	596.23	.00	< 0.05
Pretest	234.006	1	234.01	3.18	.08	> 0.05
Group	16465.865	1	16465.87	223.68	.00	< 0.05
Error	8392.415	114	73.62			
Total	251807.000	117				
Corrected Total	25558.923	116				

The result in Table 3 showed that there is a significant difference between the mean performance scores of students taught circle geometry using GeoGebra and those taught using the traditional method. The result showed that with respect to the groups taught circle geometry using GeoGebra and those taught using traditional method, an F-ratio of 223.667 was obtained with an associated probability value of 0 .000. Since the associated probability value of 0.000 was less than 0.05 alpha level, the null hypothesis ($H0_1$) which stated that there is no significant difference in the mean performance scores of students taught circle geometry using GeoGebra and those taught using traditional method is rejected. Thus, the inference drawn therefore was that there was a significant difference in the mean performance scores of students taught circle geometry using GeoGebra and those taught using traditional method with those taught using GeoGebra having a higher mean gain. This shows that the use of GeoGebra software in the teaching of circle geometry has more effect on students' performance in circle geometry than the traditional method. This shows that GeoGebra teaching method has more effect on students' performance in circle geometry than the traditional method.

Hypothesis 2: There is no significant difference in performance mean scores between the male and female students taught circle geometry using GeoGebra software.

Table 4: Summary of ANCOVA on the difference in performance mean score between the male and female students taught circle geometry with GeoGebra software.

Source	Type III Sum of Squares	df	Mean Square	F	P-value	Sig
Corrected Model	66.130[a]	2	33.065	.735	.484	> 0.05
Intercept	50526.249	1	50526.249	1123.479	.00	< 0.05
Pretest	3.502	1	3.502	.078	.781	> 0.05
Gender	63.556	1	63.556	1.413	.239	> 0.05
Error	2743.354	61	44.973			
Total	195863.00	64				
Corrected Total	2809.484	63				
R Squared= .024 (Adjusted R Square = -.008)						

The result in Table 4 showed that with respect to the mean scores of the male and female students taught circle geometry using GeoGebra software, an F-ratio of 1.41 was obtained with an associated probability value of 0.239. Since the associated probability value of 0.239 was greater than 0.05 set as level of significance, the null hypothesis (H_{02}) which stated that there is no significant difference in the mean performance scores of male and female students taught circle geometry using GeoGebra software was upheld. Thus, the inference drawn therefore was that the mean scores of male and female students did not differ significantly when taught circle geometry using GeoGebra software. This means that gender is not a significant factor in determining students' performance in circle geometry.

Discussion of Findings

The outcome of research question one as reflected in table 1, showed that students in the experimental group who were taught circle geometry using GeoGebra software had a mean score of 54.77 in post-test as against those in the control group that was taught without GeoGebra software with a mean score of 30.75. This simply means that students taught with the dynamic geometry software (GeoGebra) performed better than those taught without GeoGebra as measured by their post mean scores. There is a significant difference between the performance of students taught with GeoGebra software and those taught without the software as revealed by statistical analyses of data. The result from hypothesis one (1) as reflected in table 4 showed that the computed F-ratio of 223.67 with an associated probability level of 0.00 is statistically significant at 0.05 alpha level of significance and therefore the null hypothesis of there is no significant difference in the mean performance scores of students taught circle geometry using GeoGebra software and those taught using the traditional method was rejected. Alternatively, since Fcal = 223.67, $p < 0.05$ is greater than $P(F_{0.05}(1,115) = 5.15$, we reject Ho: and retain H_1:

The finding revealed that students taught with GeoGebra software performed better and were able to achieve more in circle geometry than their counterparts who were taught circle geometry without GeoGebra. However, this finding has revealed that the contribution of information and communication technology tools to the teaching and learning of mathematics cannot be overemphasized in the 21^{st}-century classroom where spatial thinking and visualization are useful. The high level of performance by the GeoGebra software group may be as a result of the enabling environment provided for the lesson by the software application as it saves time for drawing shapes and motivate students to discuss task as well as allowing students to see the relationship between concepts visually. This aligns with researchers' claim that the desired success level was reached because GeoGebra appeals to more learning modalities. On the contrary, the unhealthy performance by the group taught without the GeoGebra software (control group) may be attributed to lack of conceptual understanding, procedural knowledge, and problem-solving skills due to inadequate instructional materials and students not having the technical skills of handling manual tools to construct geometric shapes as well as not knowing the rigorous ways of getting proofs done. Therefore, since the control group is exposed to the traditional teaching method, the students failed to understand the material at the desired level because the traditional teaching method appeals only to the auditory learning modalities.

The findings of this study corroborate to that of Williams, Charles-Ogan, and Adesope (2017) in a study on GeoGebra Interactive Software and Senior Secondary School Three Students Interest and Achievement in Mathematics carried out in Rivers State which found out that GeoGebra application increases students' interest and performance in mathematics. That is, the group taught with GeoGebra (experimental group) outperformed the group taught without the software (control group). Similar results were held in related studies by Arbain and Shukor (2014), Saha, Ayub, and Tamizi (2010), Dogan and Icel (2011), Tutkun and Ozturk (2013).

The results of research question two (2) as indicated in table 4.2 shows that students taught with GeoGebra software (experimental group) pre-test score of students gave a mean ($\overline{X}$) value of 19.50 and standard deviation of 11.99 for the male and 20.31 and standard deviation of 11.99 for the female students. For the post-test mean score, male students obtain a mean of 53.95 and standard deviation of 7.17. The female students obtain a mean performance score of 55.96 and standard deviation of 5.81. The mean gain scores for the two groups were 34.45 for male and 35.65 for female students respectively. The mean score of both groups are relatively close, hence it suffices that both groups are at the same level of performance. Also, the difference in the mean gain scores of both groups is established at 1.2. This signifies that gender does not determine students' performance using GeoGebra teaching method.

The reason for the equal performance of male and female students may not be unconnected with the fact that both male and female see themselves as equal and capable of competing and collaborating in classroom activities. Rather, it shows that performance is a function of motivation, effort, ability, confidence, and orientation and not gender. Bain and Rice (2016), female perform as much as their male counterpart if not better except that they just see them differently than males. This contradicts the finding that learning with technology is a dominant activity for males as perceived by females with equal access to the technology (Kadijevich, 2000; Li &Kirkup, 2007). This is not different from the findings of (Kaino, 2008) that females indicate more interest in the usability of technology in learning but enjoyed it less than the males.

However, the findings of Kadijevich (2000) and Kaino (2008) did not signify if males perform better than females or vis-à-vis which is inconsonant with the results of the current study. This can be evidently affirmed by looking at research work done by some scholars. In a study based in Nigeria, (Oche, Clement &Abari, 2015) on the Effect of GeoGebra on senior secondary school students interest and achievement revealed no significant gender difference in the use of GeoGebra in learning circle geometry. In tandem with Oche et al., the work of Adegoke (2015) further concrete the findings of this study on the premise that gender does not have any significant influence on students learning circle geometry with GeoGebra. Other related results that conform to the findings of this study are (Myers, 2009; Yusuf and Afolabi,2010).

Conclusion

Based on the findings it was concluded that the use of GeoGebra in learning circle geometry is effective to both male and female students which shows no significant difference in performance. This implies that with equal access to technology, males are not dominant over their female counterparts but each individual performed based on motivation received from the ICT use, personal effort, confidence, and ability level.

Recommendations

Based on the findings the following recommendations were made:

1. Computer Assisted Instruction (CAI) such as GeoGebra, Cabri-2, Math-Lab., Cinderella, etc. should be used by Mathematics teachers in the teaching and learning of geometry in particular and Mathematics in general.
2. Mathematics Curriculum Planners should incorporate into the scheme GeoGebra as a tool for teaching Mathematics.

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