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Effect of using Geogebra on senior high school students' performance in circle theorems

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Abstract

The main aim of the study was to find out the effect of using GeoGebra on senior high school students' performance in circle theorems. This study employed quasi-experimental design, using non-equivalent quasi-experimental design. Purposive sampling technique was used to select two schools for the study. Also, one intact class in each school was used as the control group and the other class as the experimental group. The sample size consisted of 49 students comprising 24 in the control group and 25 in the experimental group. The experimental group was taught circle theorems using GeoGebra while the control group was taught using the traditional way of teaching circle theorems. Pre-test and post-test were carried out simultaneously on the groups using teacher-made achievement test. The test format was based on Ghana Education Service syllabus. Paired samples t-test and analysis of covariance were used to analyse the scores of teacher-made achievements test. The finding showed that there is a statistically significant positive effect for the students who used GeoGebra to learn circle theorems. Thus, the students taught with GeoGebra method performed better than their counterpart who did not use the GeoGebra to learn circle theorems. Also, the GeoGebra method made the lessons more interesting, practical and easy to understand. It was recommended that teachers should incorporate GeoGebra in the teaching of circle theorems.

Keywords GeoGebra; circle theorems; teaching geometry

Introduction

As a result of the constructive-based approach of the current Mathematics curriculum, teaching and learning Mathematics has improved substantially due to accessibility of educational technology (National Council of Teachers of Mathematics, 2003). Confirmations from literature show that teachers who utilize educational technology comprehensively in their Mathematics instruction environment are likely to build high confidence in pedagogical technology skills and focus their lessons on a student-centred approach which improves students' performance in Mathematics (Bos, 2009). Also, Bos pointed out that when technological tools are available in mathematics classrooms, learners can pay attention on reflection, problem solving, reasoning, and decision making. With these, learners can gain in various ways from technology integration into mathematics instruction every day. This will help guide students to explore and visualize Mathematics, especially geometrical concepts. The use of ICT in education permits learners to involve in certain cognitive activities such as carrying out scientific procedures, studying natural

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phenomenon through simulation, looking up information, analysing data and solving real life problems (Anamuah-Mensah, Mereku, & Asabere-Ameyaw, 2004).

The effect of technology usage in Mathematics classrooms on students' performance has drawn the attention of Mathematics educators to the need to utilize technological software in Mathematics classrooms. In view of this, the Mathematical Association of Ghana (MAG) has made a remarkable step towards the use of ICT in the teaching and learning of Mathematics which will be an effective tool for social transformation (Suleman, 2012). The Association is of the view that teaching and learning Mathematics with technology will aid students to visualize, think, reason, analyse and articulate logically. The use of the computer makes it suitable for teachers to design lessons which make learners become more interested and eager to study and enjoy Mathematics (Suleman, 2012).

However, despite the impact educational technology and strong advocacy for the need to utilize ICT in the teaching and learning of mathematics, classrooms in Ghana are still characterized by traditional method of teaching. The traditional method is the teaching approach characterised by lecture/oral exposition. This teaching approach is more of teacher-centred rather than learnercentred. This situation produces students who are able to calculate but do not know how to solve everyday life problems that involve concepts and mathematical skills. This teaching approach has resulted in general detest for mathematics by students and poor performance in mathematics in West African Senior Secondary Certificate Examination (WASSCE) and international examinations (e.g. Trends in International Mathematics and Science Study, [TIMSS]). Thus, national and international reports show that Ghanaian students perform poorly in higher order thinking problems. The National Education Assessment (NEA) report shows that the mean score of mathematics for P3 and P6 were 41.8% and 39.6% respectively (Ministry of Education [MOE], 2009). The 2003 TIMSS report by Anamuah-Mensah, Mereku and Asabere-Ameyaw (2004) indicates that Ghanaian students scored zero in advance and higher-level thinking in the content domains tested. Unfortunately, Geometry was one of the topical areas candidates' performance was weak.

Most senior high school students are unable to construct, visualize and justify geometrical concepts (Circle Theorems) due to traditional approach of teaching and learning process in Ghanaian classrooms. This method of teaching makes students passive listeners, and deficient in geometrical analysis and reasoning. Also, this approach to teaching and learning Geometry lays more emphasis on how much a student can remember and less on how well the student can think and reason, and it makes the teacher dominate the classroom and turns students to mere listeners (Mereku, 2010). For these reasons, students are not encouraged to discuss, interact with each other and to explore the content collaboratively, and repeatedly fail to build the exploration and visualization skills demanded for geometrical ideas, geometry reasoning and problem-solving skills. Therefore, this discourages students from learning Geometry, which leads to poor performance as noted by Battista (2007) and Idris (2006).

Several reports of the West African Examination Council (WAEC) indicate that students who write WASSCE have been performing poorly in Circle Theorem questions (WAEC, 2012). Very often, students avoid questions on Circle Theorems when they have other alternatives. On rare occasions, most of the few who attempt questions on this topic display nothing but their lack of knowledge in the subject matter (Fletcher & Anderson, 2012). In the May/June 2011 Mathematics examination, the Chief Examiner for Mathematics states that question 3 (a) posed a serious problem to candidates who attempted it (see. Figure 1). They could not recall the appropriate Circle Theorem relations to answer the question (WAEC, 2011).

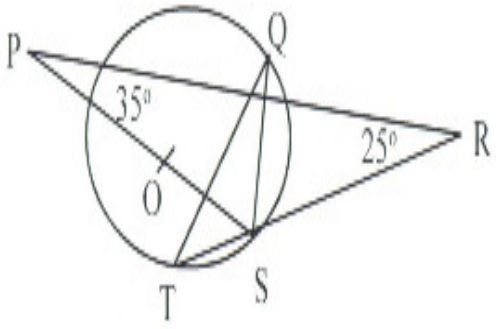


Figure 1 WASSCE May/June Question 3(a)

In support of this, Chief Examiner's Report of WASSCE (2012) also points out that majority of the candidates could not solve for $< ZWO$, they failed to recognize that $< ZWO$ and $< WZO$ are base angles of isosceles triangle WZO (see Figure 2), hence their inability to solve for $< ZWO$. The report adds that the performance of students on this question was not encouraging.

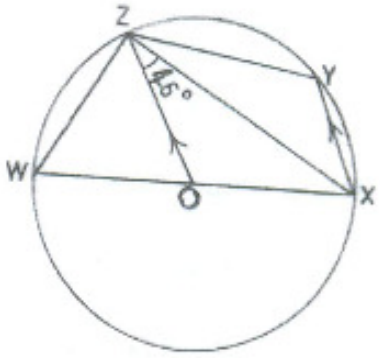


Figure 2 WASSCE May/June Question 2(b)

These learning difficulties the students faced when learning Circle Theorems were due to the fact that learning environment in most Ghanaian classrooms is dominated by traditional teaching approach teachers usually adopt in their classrooms. This teaching approach is mainly dominated by the teacher. In this teaching and learning environment, the teacher is mostly an information giver instead of being a facilitator and the students are recipients of knowledge, instead of negotiator of Mathematics concepts.

A number of authors, including Johnston-Wilder & Mason (2005), have also blamed students' lack of interest and understanding of Geometry on teachers' poor teaching skills and lack of resources for presenting geometrical shapes to students. Johnston-Wilder and Manson (2005) argue that the ordinary primary tutor has an anxiety of the very word 'geometry.' One suspects, therefore, that it is difficult to encourage any form of geometry to be taught at all in primary schools, and some books for primary teachers devote little time or space to it. Pupils who proceed to the senior high school, therefore, have very weak foundation in Geometry in general and Circle Theorems in

particular. Perhaps, one of the reasons why so much time is spent on arithmetic than on Geometry in the primary school is that skills and techniques in arithmetic are very much more in evidence.

With the dominance of traditional methods in Mathematics instruction in Ghana coupled with students' learning difficulty in Circle Theorems, one probable approach for enhancing instruction and student learning could be implementing realistic instructional method such as the use of GeoGebra.

GeoGebra is the one of the educational technology tools used in mathematics instruction and any other subject. This software was developed by Markus Hohenwarter at University of Salzburg in a year 2001 as his master's thesis. It is a Dynamic Mathematics Software (DMS) for Mathematics instruction and simple to use since it offers basic features of Computer Algebra Systems (CAS) to link some gaps between Algebra, Calculus and Geometry. GeoGebra is open source software under the GNU General Public License and freely available at www.geogebra.org (Majerek, 2014).

Of all the ICT-based lessons, the dynamic software, GeoGebra has been newly used to create the visual and dynamic interaction in teaching and learning Mathematics (Hohenwarter & Fuchs, 2004). This software has made it possible for students to discover theorems about circle by dragging point on the circumference of a circle with the mouse. GeoGebra motivates learners to approach Mathematics with an experimental method (Hohenwarter & Fuchs, 2004).

For instance, Kutluca (2013) found out from his study that GeoGebra instruction employed on the experimental group was better on increasing Van Hiele geometry thinking levels of students than traditional approach of teaching circle. He indicated that GeoGebra helped students in creating their own geometric shapes, testing and constructing their own knowledge. GeoGebra, as both learning and teaching tool, also helped the teachers to change their classroom to an investigative environment whereby students were actively involved in instructional process. More so, students learning under such environment were able to contribute their thoughts at ease, argue the results with colleagues and make their individual understanding about Geometry (Kutluca, 2013). It is obvious from Kutluca's (2013) study that when GeoGebra is fully utilised in classroom, it will enhance better teaching and learning.

Also, Bhagat and Chang (2015) used quasi-experimental research design to survey "the effect of using GeoGebra, on student's Mathematics attainment in learning Geometry" among fifty students divided into an experimental and a control group. The experimental group was taught using GeoGebra while students in the control group was instructed through traditional teaching approach. Bhagat and Chang (2015) observed in their work difference in the mean achievement scores of students taught with GeoGebra and that of students taught with traditional method. It was again revealed that students' cognitive and visualization skills improved tremendously. Again, GeoGebra facilitated the learners in the demonstration of mathematical ideas in diverse way, which can influence students to learn Mathematics. It is clear from the study of Bhagat and Chang (2015) that teaching and learning Geometry with GeoGebra, helped students to improve their reasoning, visualization skills and representation of mathematical concepts in diverse ways. Notwithstanding, this software is a better option for schools in rural areas where Internet connection is a problem.

A study conducted by Mwingirwa and Miheso-Connor (2016) on "status of teachers' technology uptake uses of GeoGebra in teaching secondary school Mathematics in Kenya" through training thirty-three Mathematics tutors on GeoGebra use. They also tried to implement what teacher had learnt from the training. The outcomes from Mwingirwa and Miheso-O'Connor's (2016) work uncovered that the prepared educators appeared to be excited about utilizing GeoGebra in their

classes. This was because GeoGebra instruction in their classes enabled students to grasp difficult and unique concepts in Geometry and also saved teachers time whereby they were able to cover the syllabus more effectively. The outcome of Mwingirwa and Miheso-O'Connor's study also pointed that GeoGebra was the most appropriate software or teaching learning resource for teaching Geometry due to its abstract nature. They also found out that teachers usually had trouble teaching geometry when they were solicited to demonstrate areas from mathematics they discovered hard to teach. The instructors accentuated these challenges they experienced because of absence of assets for teaching, the unique idea of Geometry and students' failure to envision geometrical objects.

While it is promising to see that several previous studies have demonstrated positive effects of GeoGebra instructional approach lessons on students' achievement, a reading of the literature available indicates that many of these studies are not centred on GeoGebra instructional approach in teaching and learning Circle Theorems as a sub-topic under Geometry, particularly in Ghana. Also, the findings of the study pointed the challenges teachers faced in teaching Geometry to lack of resources to teach Geometry, its abstract nature and inability of students to visualize geometrical images. Therefore, it is the aim of this study to determine the effects of using GeoGebra as an instructional tool in teaching Circle Theorems on performance of SHS 2 students. This will enable students visualize geometric images in GeoGebra interface and discover properties about circle.

Hypotheses

To determine the effect of using GeoGebra or traditional method as instructional tools in the teaching of Circle Theorems on the performance of students, the following hypotheses are formulated to guide the study.

1. H_0: GeoGebra as an instructional tool has no effect on the academic performance of students in Circle Theorem.
2. H_0: The traditional method as an instructional tool has no effect on the performance of students in Circle Theorems.
3. H_0: There is no significant difference in the performance of students taught Circle Theorems with GeoGebra method and those taught with traditional method.

Methodology

The study used quasi-experimental research design specifically, non-equivalent quasi-experimental design because intact classes of unequal number of students were used and the respondents were not randomly selected and allocated to the groups (Creswell, 2008). Consequently, variables of this study were categorized into independent variables and dependent variable. In this study, there were two independent variables, which were the approaches used in teaching and learning circle theorems, thus, GeoGebra approach and the traditional approach. The dependent variable of this study was students' scores on circle theorems achievement test (CTAT) while the possible covariate of this study was students' scores on readiness test for geometry concepts (RTQC). These scores were analysed to establish whether a significant difference exist between the control group and experimental group or not.

The target population for this study was all second year Senior High School 2 (SHS2) students of 2016/2017 academic year in the Central Region of Ghana. The accessible population consisted of a set of second year students of School A and School B in Twifo Hemang Lower Denkyira District

and Agona East District respectively in the Central Region of Ghana. Both districts are in the Central region of Ghana and are in same Option 1 Schools rated by the Ghana Education Service (Ghana Education Service, 2017). A purposive sampling technique was used to select two schools (School A and School B) and simple random sampling technique was used to select one intact class from each school. Therefore, the sample size consisted of 49 students of which 24 were in the control group (School A) and 25 (School B) were in the experimental group. The control group was made up of 14 boys and 10 girls and the experimental group was made up of 15 boys and 10 girls.

Teacher-made achievement test used as a main instrument for the data collection. The items on the teacher-made achievement test were constructed based on the lesson taught and the learning objectives in the SHS mathematics curriculum. The aim of this instrument was to provide a measurement of achievement. The teacher-made-achievement test was preferred in this study to other types of tests due to the following reasons: it reflects instruction and curriculum; it is sensitive to student's ability and needs; it provides immediate feedback about student progress; and finally, it can be made to reflect small changes in knowledge (O'Malley, 2010). The pre-test consists of 12 easy type of questions which were based on core mathematics syllabus objectives 2.7.2, 2.7.3 and 2.7.4 (Ministry of Education, 2010). The questions covered all the five theorems treated. Student from each group was given 60 minutes to complete the test. The pre-test was done to determine the initial entry points and compare difference between experimental and control group before treatment. Also, post- test also consists of 12 essay type of questions that are slightly different from questions in the pre-test, however the questions measured the same difficulties level of students.

Treatments

The GeoGebra approach was applied to the experimental group whereas a traditional method of instruction was applied to the control group throughout this study.

The GeoGebra approach refers to the teaching approach involving both the teacher-led demonstrations and students' hands-on activities using GeoGebra. Lessons of the experimental group was held in the computer laboratory where student explored the concepts of Circle Theorems using computer. In the computer laboratory, students were taught Circle Theorems by using GeoGebra software with worksheets which were designed hand in hand with the lesson plan by the researcher according to activities in senior high school students' Mathematics curriculum. This means that the treatment in the experimental group was affected by collaborative learning unlike the control group where all the lessons was taught using teacher-centred approach. Lesson plan was designed to help ensure that classroom instruction followed the curriculum aims and objectives of the topic (Circle Theorems) treated. The lesson plan for this study indicated the lesson objectives, duration of the lesson, contents to be treated, teacher or learner activities, assessments and remarks. For instance, to illustrate the concept "the opposite angles of a cyclic quadrilateral are supplementary (add to 180°)," this concept can be illustrated with GeoGebra by drawing a single circle, measuring and comparing its angles, all on the screen (see Figure 3.2). When the various points are moved around on the circumference of the circle, the opposite interior angles always add up to 180. In this case, time is saved here and results obtained are accurate.

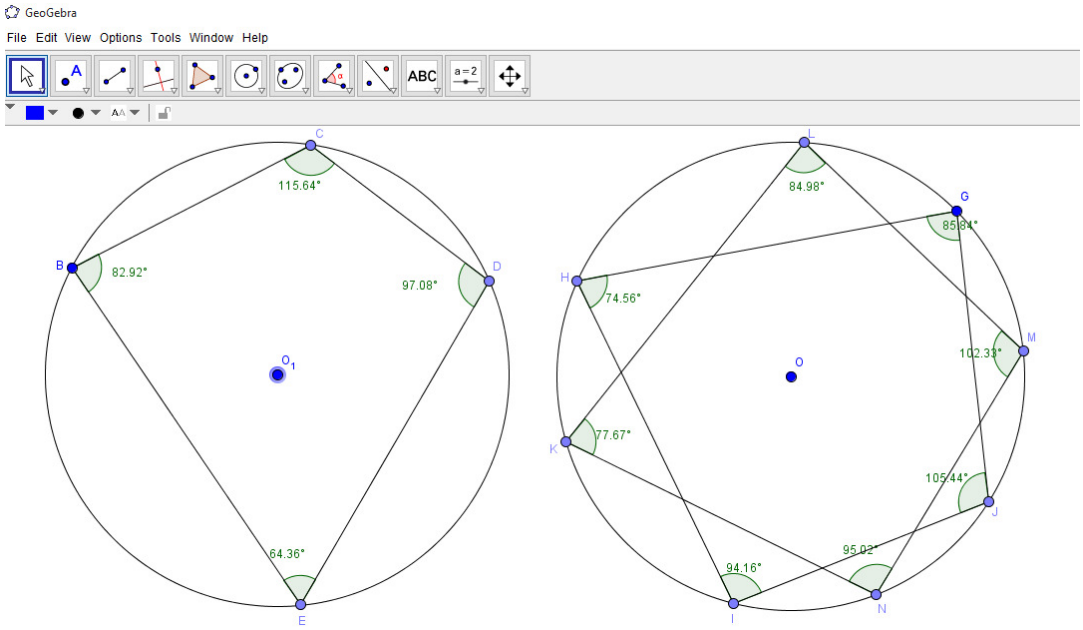


Figure 3 Snapshot from GeoGebra software

On the other hand, traditional Approach is a term used in this study to refer to teaching using chalk and board for teachers; pen and paper for students. Also, teachers use other methods such as demonstration using examples, lecture methods, question-answer methods, among others. Thus, the researcher gave the input orally or wrote on the board and the learners strictly followed the instruction the teacher gave, and active participation of the students were not encouraged. The students were not given any hands-on activities to help them explore geometric concepts about circle and form their own knowledge. In other words, Geometry instruction was not in line with the constructivism approach but mainly in lecture format and, therefore, instruction was teacher-centred. For example, to illustrate the concept "the opposite angles of a cyclic quadrilateral are supplementary (add to 180°)," the teacher would have to draw several circles on a chalk board, measure angles and compare with opposite angles. The accuracy of the results obtained here cannot be assured as it would depend on the reliability of the drawing and measuring instruments. Unlike the GeoGebra approach, this same concept can be illustrated with GeoGebra by drawing a single circle, measuring and comparing its angles, all on the screen. When the various points are moved around on the circumference of the circle, the opposite interior angles always add up to 180. In this case, time is saved here and results obtained are accurate.

Nevertheless, with regards to traditional method of exploring various properties of Circle Theorems, teaching can be very stressful and time consuming. A lot of time is wasted on unwarranted accuracy. These routine activities do not need a large amount of concentration. Despite the drawbacks of the traditional approach, it is cheap and does not require much rigorous advanced lesson preparation on the part of both the teacher and the learner. It can also be conducted anywhere. It is good for both audio learners and reflective learners because such learners do better through listening.

The researcher piloted the instrument on a small sample of twenty-five Form Two SHS students of Swedru Business Senior High School. The piloting was done in this school because it has the

same characteristics as one sampled for the study. In this study, the split-half method was used to check the reliability of the instruments. The spilt-half method requires the construction of a single test consisting of a number of items. These items are then divided or split into two parallel halves (usually, making use of the even-odd item criterion). Participants' scores from these halves were correlated using the Spearman-Brown formula used in reliability testing. The value of the reliability coefficient is 0.784 which indicates a high degree of reliability of the items in the instrument (Fraenkel & Wallen, 2003). The reliability coefficient of 0.784 means that 78.4% of variability in scores is due to true score differences among students while remaining 21.6% is due to measurement error. Agreeing with George and Mallery (2003) and Kline (1999), a reliability coefficient greater than 0.70 shows a homogeneous test. That is, the test is likely to relate with alternative forms. For that reason, the reliability coefficient of 0.784 found in this study establishes that the achievement test used in the main study is within the acceptable standard of instrument being reliable.

Descriptive statistics such as means, standard deviations, percentages, tables and Box plot were used to describe the general performance of students in both groups in the pre-test and post-test. Box plot was used to give pictorial representation of the performance of the students in the achievement tests. The paired samples t-test was used to find whether the performance of students within each group improved or not while the effect size (eta statistic square) was used to determine the magnitude of improvement in each group. The purpose was to determine whether there were statistically significant different between each student score in the pre-test and post-test

Also, Analysis of covariance (ANCOVA) was used to test the hypothesis, 'there is no significant difference between the performance of those taught with GeoGebra and those taught without GeoGebra.' ANCOVA is an extension of analysis of variance that allows you to explore differences between groups while statistically controlling for an additional (continuous) variable. This additional variable (called a covariate) is a variable that one suspects may be influencing scores on the dependent variable. In any experiment, there may be unmeasured variables that confound the results (a variable that varies systematically with the experimental manipulation). In this case, ANCOVA is ideally suited to remove the bias of these variables (Field, 2005). ANCOVA can be used when you have a two-group pre-test/post-test design (Pallant, 2001). The scores on the pre-test were treated as a covariate to control for pre-existing differences between the groups. ANCOVA is very useful when the difference existing between the two groups have quite small or medium effect size. In addition, an eta statistic squared was used to determine the magnitude of the difference (effect size) between means of the scores. This is because the difference might occur by chance. According to Pallant (2001), the criterion for interpreting eta squared values are 0.0 = small effect, 0.06 = moderate effect and 0.14 = large effect.

Results and Discussion

In answering the hypotheses, the results obtained in the pre-test and post-test were examined and compared for the two groups – experimental and control groups. The next three sections present the descriptive statistics on the overall performance of the students before and after the experiment.

Analysis of Performance of the Students Taught with GeoGebra Teaching Approach

The results of analysis of the effect of the GeoGebra teaching approach on students' performance is presented in Table 1.

Table 1 Descriptive statistics of students taught with GeoGebra teaching approach (N = 25)

Test	Minimum	Maximum	Mean	Std. Deviation
Pre-test	0	25	9.40	6.42
Post-test	14	37	28.36	6.304

Source: Fieldwork, 2017

Table 1 compares the pre-test and post-test results of the students within the experimental group. In the experimental group the results showed an improvement in students understanding of circle theorems in the post-test. The minimum score students obtained in the pre-test was 0, while the maximum score was 25 out 40. However, in the post-test, the minimum score was 14, while the maximum score was 37. The mean score of students in the pre-test was 9.40, while that of the post-test was 28.36, an increase of 18.96. This is an indication that in the post-test, every students' performance had increased in the experimental group. This improvement in scores might be due to the use of the GeoGebra approach of teaching circle theorems. To ascertain whether or not the difference observed in the means are statistically different when taught with GeoGebra method, a paired samples t-test was conducted to compare the pre-test and post test scores. Table 2 presents the results of the paired samples t-test on the pre-test and post-test performance of students taught with GeoGebra method

Table 2 Results of the paired samples t-test on the pre-test and post-test performance of students taught with GeoGebra method

Test	Mean Difference	Std. Deviation	Std. Error Mean	*t*	*df*	Sig.	Eta square
Pre-test – Post-test	18.960	8.329	1.666	11.382	24	.0001	0.844

Source: Field work, 2017

A paired sample t-test was conducted to compare the pre-test and post test scores for the students taught with the GeoGebra teaching approach (experimental group). The paired sample t-test was examined to find out if the mean score difference (M = 18.960, SD = 8.329) between the post-test and the pre-test of the experimental group was statistically significant. This was done to evaluate the effect of GeoGebra on students' achievement in Circle Theorems. The results from Table 2 indicate a statistically significant increase in the students' achievement from the pre-test to the post-test, $t(24) = 11.382$, $p < 0.0001$. The eta squared statistics (0.844) indicate large effect size. This means that 84.4% of the variance in the scores of the achievement tests, that is, the pre-test and the post-test of the experimental group was elucidated by the teaching method (GeoGebra) for teaching Circle Theorems. Also, the results imply that after the students had gone through the intervention, they improved massively in their understanding and achievement of the concept on Circle Theorems. Thus, GeoGebra as an instructional tool had a positive impact on the students' achievement in Circle Theorems. To display the massive improvement from the pre-test to the post-test, box plot was used as shown in Figure 4.

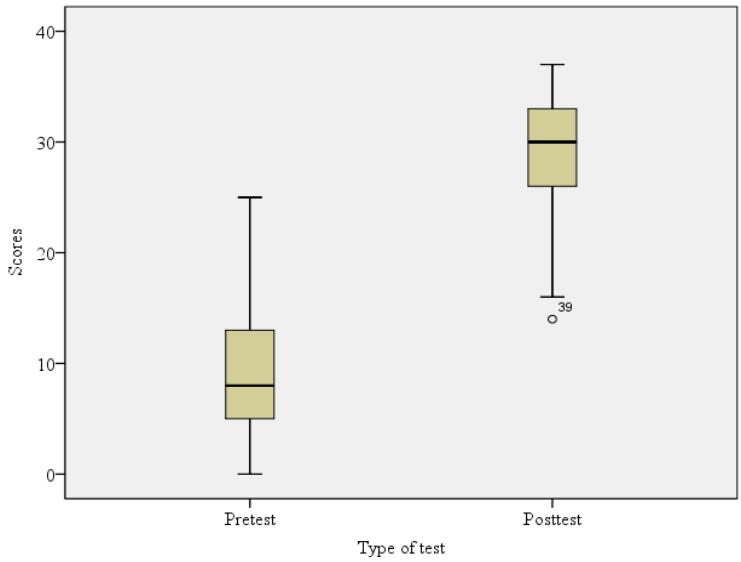


Figure 4 Box plot showing the difference of performance between the pre-test and post-test scores

Graphically, Figure 1 exhibits the distance the students had proceeded in terms of performance. Thus, there has been increase in the achievement test scores from pre-test to post-test.

Analysis of Performance of the Students Taught with Traditional Teaching Approach

The results of the analysis of the effect of the traditional teaching approach on students' performance is presented in Table 3.

Table 3 Descriptive statistics of students taught with traditional teaching approach

Test	N	Minimum	Maximum	Mean	Std. Deviation
Pre-test	24	0	27	9.67	6.631
Post-test	24	10	33	19.79	5.291

Source: Field work, 2017

Table 3 shows comparison of the pre-test and post-test results of the students within the control group. The minimum score students obtained in the pre-test was 0, while the maximum score was 27 out 40. However, in the post-test, the minimum score was 10, while the maximum score was 33. The mean score of students in the pre-test was 9.67, while that of the post-test was 19.79, an increase of 10.125. This is an indication that in the post-test, every students' performance slightly increased in the control group. To determine whether or not the difference observed in the means are statistically different, a paired samples t-test was conducted to compare the pre-test and post test scores to test the null hypothesis that there is no significant difference between the pre-test and post-test performance of students taught with traditional learning approach. Table 4 presents the results of the paired samples t-test on the pre-test and post-test performance of students taught with traditional learning approach.

Table 4 Paired samples test of the students taught with traditional teaching approach

Test	Mean Difference	Std. Deviation	Std. Error Mean	*t*	*df*	Sig.	Eta square
Pre-test – Post-test	10.125	6.765	1.381	7.332	23	.0001	0.700

Source: Field work, 2017

A paired samples t-test was examined to compare the pre-test and post test scores for the students taught with traditional teaching approach (control group). The result as presented in Table 4 reveals that the mean score difference between the post-test and pre-test of the control group was 10.125 with corresponding standard deviation of 6.765. The paired sample t-test was examined to find out if the mean score difference (M = 10.125, SD = 6.765) between the post-test and pre-test of the control group was statistically significant. This was done to assess the effect of traditional method on students' achievement in circle theorems. The results from Table 4.6 indicated that there was statistically significant increase in the students' achievement from the pre-test to the post-test, t (23) = 7.332, p = 0.0001 < 0.05. In addition, the eta square statistics (0.700) discovered that traditional teaching approach also has a large effect on students' performance in circle theorems. Graphically, Figure 2 displays the distance the students had progressed in terms of performance. This indicated that there was a significant improvement in the scores of the control group before and after the treatment. From this result, it can be seen that students also gained from traditional teaching approach of learning circle theorems. This outcome is an indication that a well-structured traditional approach of teaching can also improve students' performance in learning circle theorems.

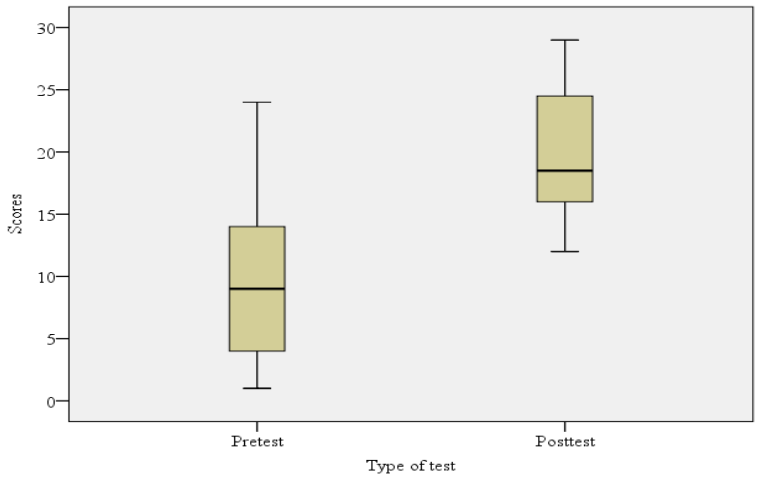
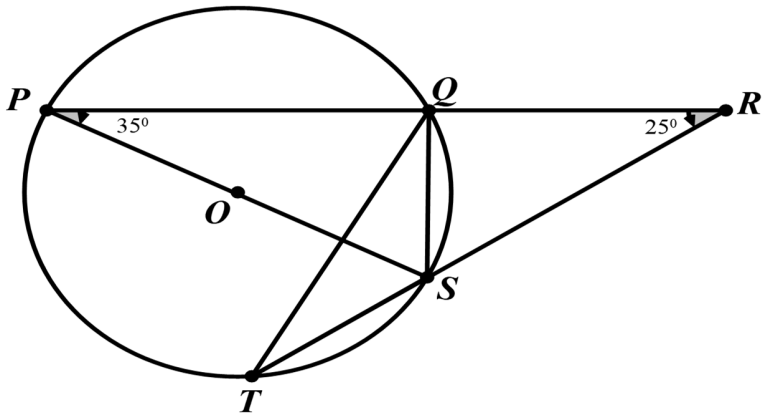


Figure 2 Box plot showing the difference of performance between the pre-test and post-test scores of the students taught with Traditional teaching approach

The progress in the students' performance could be the use of sequences of exercise the students were taken through. Though in this group the lesson was mainly based on traditional method and no manipulation of GeoGebra, the students were focused throughout the lesson. This infers that when traditional method of teaching merge with series of students' activities in teaching and learning are used, students' performance can be improved to some point.

Though the students' performance improved significantly, the analysis of the students' performance on the individual items of the achievement test indicated that most students in the group taught with traditional method of teaching did well to recognize the correct theorem or property to use for some of the questions but failed to answer questions that request the use of their relevant previous knowledge to solve the questions that demanded application. For instance, the students taught with traditional method exhibited poor performance on Question 10 of the achievement test in the box below.

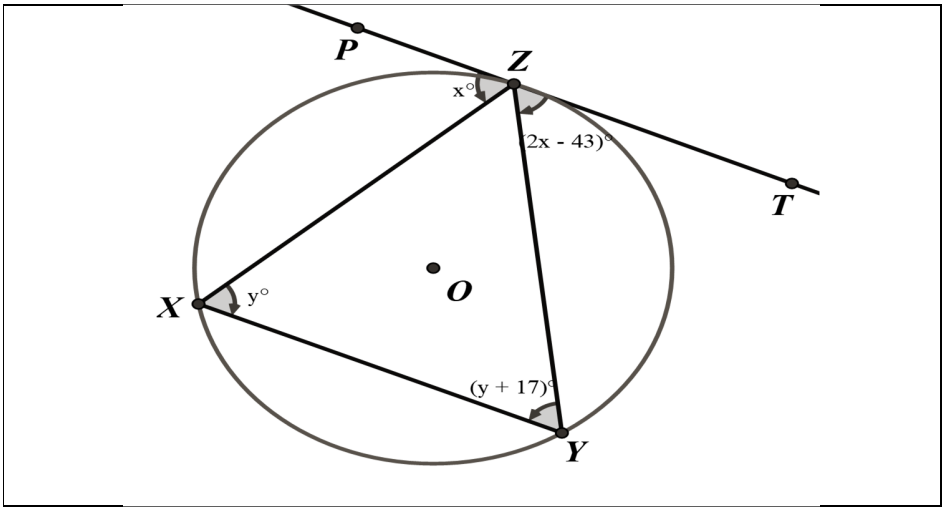
In the diagram, PQR and TSR are straight lines, $\angle QRS = 25^0$ and $\angle QPS = 35^0$. Find $\angle SQT$



On this item, students were expected to apply their previous or background knowledge to recognize that the sum of the interior angles ($\angle QRS + \angle QPS$) of the triangle PRS is equal to exterior angle ($\angle$PST) of the triangle PRS. Besides, 22 out 24 students representing 88.0% taught with traditional approach of teaching and learning circle theorems were not able to identify that $\angle QRS + \angle QPS$ = $\angle$PST . Therefore, only 2 (8.0%) out of 24 were able to solve for correct answer of angle SQT.

Also, the students taught with the traditional approach of teaching and learning circle theorems showed same poor performance on the Question 11 of the achievement test shown in the box below.

In the diagram, $\angle ZXY = y^0$, $< ZYX = (y + 17)^0$, $\angle PZX = x^0$, and $\angle YZT = (2x - 43)$, Find the value of y.



This question required students to recognize that angles in alternative segments are equal ($\angle ZXY = \angle YZT$ and $\angle PZX = < ZYX$), to find the value for x and y. However, only 8 out of 24 (33.3%) students taught with traditional method were able to identify in the diagram that angles in alternative segments are equal. Due to this, 19 out of 24 (79.2%) were not able to compute or provide correct missing value for y. This poor performance of students on the achievement test (post-test) in the control group with respect to the questions discussed above could mean that students did not have opportunity to observe multiple representations of the theorem stating that angles in alternative segments are equal.

Comparing the performance of the students taught with GeoGebra approach and those taught with traditional approach

As indicated above, analysis of covariance (ANCOVA) was used to test the null hypothesis that 'there is no significant difference between the performance of those taught with GeoGebra approach and those taught with traditional approach', at a significance level of 5%. The ANCOVA compares the effectiveness of the GeoGebra approach and traditional approach on the performance of the students' achievement scores. The students' scores on the pre-test of the achievement test were used as covariate in this analysis. The scores from the post-test were then compared using the ANCOVA with $\alpha = 0.05$, to adjust for pre-test differences that existed between control and experimental groups. In the pre-test the mean scores of control and experimental groups were 9.67 and 9.40 respectively. ANCOVA was used to adjust the post-test scores statistically to compensate for the 0.27 mean point difference between the two groups. This adjustment resulted in more accurate post-test comparisons. Table 5 shows the result of the test of differences between the two groups using ANCOVA.

Table 5 Summary of ANCOVA of the Performance of students Taught with GeoGebra Method and Traditional Method (N = 49)

Source	Sum of Squares	*df*	Mean Square	F	Sig.	Eta Squared
Pre-test	98.090	1	98.090	3.009	.090	.061
Group	910.992	1	910.992	27.944	.0001	.378
Error	1499.628	46	32.601			
Corrected Total	2496.694	48				

a. R Squared = .399 (Adjusted R Squared = .373)

The statistics from Table 5 indicate that there is a statistically significant main effect on the students who used GeoGebra to learn Circle Theorems, [F (1, 46) = 27.944; p = 0.0001 < α = 0.05]. Consequently, the students taught with GeoGebra method performed better than their counterpart who did not use GeoGebra to learn Circle Theorems. The eta statistics squared value was found to be 0.378. This value indicates a large effect size. That is, 37.8% of the variance in the dependent variable (scores of the achievement test) is expounded by the independent variable (teaching method). This implies that the magnitude of the difference between the mean score performance of the students taught with the GeoGebra method and the traditional method is large. With the high scores of students in the experimental group, it implies that the use of GeoGebra in the teaching and learning of Circle Theorems improved the performance of the students.

The rationale for hypotheses are to find out whether there is any statistically significant difference between the achievement mean scores of students taught Circle Theorems using GeoGebra as an instructional tool and those taught using the traditional method of teaching. The outcome of the study portrays that there was statistically significant difference in the Mathematics achievement mean scores of the experimental group and that of the control group [F (1, 46) = 27.944; p = 0.0001 < α = 0.05]. This finding implies that the experimental group performed better than the control group in the Circle Theorems achievement test. This means that when students are taught using GeoGebra as an instructional tool, their performance would improve drastically more than students taught using the traditional method in most Ghanaian classrooms.

This finding is corroborated by the findings of Kutluca (2013) who found out that the GeoGebra teaching and learning approach employed on the experimental group was more effective on increasing Van Hiele geometry thinking levels of students than the traditional method in the instruction of Circle. Also, this finding is in support with Ahmad and Rohani (2010) who found out that there was a statistically significant difference in mathematical achievement between the traditional teaching approach and GeoGebra group. Their results disclosed that the students in the GeoGebra group achieved better than the students in the traditional group. The finding is further validated by Bu and Schoen (2011) who found out that GeoGebra helped students to co-ordinate various representation of a mathematical idea in visualisation.

In essence, the import of the finding from this study shows that the students taught with GeoGebra method performed better than those taught with the traditional method. Also, the students taught with GeoGebra were able to apply the theorems to solve questions on Circle Theorems that require application. Therefore, having observed the tremendous success that GeoGebra as a teaching and learning resource had in this study, it would be appropriate to use it more often in teaching and

learning Mathematics in Ghanaian classrooms, as this could be the solution to the poor performance in Geometry questions, especially Circle Theorems at West African Secondary School Certificate Examinations.

Conclusion and Recommendation

The findings from the study indicate that if senior high school students are taught Mathematics, specifically Circle Theorems, using GeoGebra software as an instructional tool, their performance would be better than when they are taught using the traditional method of teaching and learning. Also, the findings reveal that if students are taught using GeoGebra as an instructional tool, their performance would improve far more than students taught using the traditional method of teaching, as GeoGebra makes lesson more practical, easy to understand, interesting and also enhances students' visualisation instead of memorisation of theorems. The study, therefore, concludes that GeoGebra is one of the solutions to the abysmal performance in questions involving Circle Theorems. Thus, if GeoGebra is introduced in the teaching and learning of Geometry concepts in senior high schools in Ghana, there would be an improvement in Mathematics performance.

From the summary of the main findings of the study, two recommendations are made for teachers, policy makers, school authorities and future researchers.

1. Teachers should consider students' knowledge in Plane Geometry I such as exterior angle theorem, properties of special triangles (isosceles and equilateral), and properties of the quadrilaterals before introducing Plane Geometry II thus circle theorems. This is because most of the difficulties students faced in learning Circle Theorems were related to geometric and algebraic relations
2. Seminars/workshops should be organized for senior high school Mathematics teachers on the use of appropriate technological tools such as GeoGebra in the teaching and learning of mathematical concepts by experts in the teaching universities. This is because the application of GeoGebra in teaching and learning requires skills on the part of teacher.

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