



EFFECTIVENESS OF USING GEOGEBRA IN TEACHING AND LEARNING CIRCLE THEOREMS ON STUDENT-TEACHERS' PERFORMANCE

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Abstract:

This paper aims to explore the effect of using GeoGebra in teaching and learning circle theorems on student-teachers' performance. This paper is based on the results of the four-week experiment of GeoGebra software in teaching and learning the concepts of circle theorems of the geometry of student-teachers at the College of Education. The effectiveness of using GeoGebra software was explored by measuring the achievement level with the help of achievement tests and perceptions of using GeoGebra software through the questionnaire. The data were analyzed and interpreted by using a frequency distribution table, percentage, mean, standard deviation, and t-test. The findings showed that there was a higher mean score in achievement in circle theorems of the experimental group, that is, those taught with GeoGebra software than that of the control group, that is, those taught without GeoGebra software, and the difference was significant at 0.05 level. Similarly, the student-teachers of the experimental group had a positive perception to support the use of GeoGebra software in teaching and learning circle theorems in geometry and mathematics in general. Thus, the use of GeoGebra software is an effective tool to increase achievement; promote curiosity and creativity; make clear sense of concepts and encourage overall learning of students in mathematics. Finally, this study suggests that mathematics teachers need to use ICT tools including GeoGebra for effective teaching and learning.

Keywords: teaching and learning, GeoGebra, circle theorems, student-teachers, achievement, perception

1. Introduction

Mathematics is considered to be key in students' lives because mastering mathematics enhances one's chance of social development. A student's performance in the West Africa

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Secondary School Certificate Examination (WASSCE) in Ghana determines whether a student will be admitted to a tertiary institution. Again, for a student to attend secondary school, he/she must get a credit grade in mathematics, which is considered a requirement to attend any tertiary institution. This implies that a student who lacks mathematics competence and interest will find it difficult to gain admission to a tertiary institution.

In Ghana's College of Education (CoE), mathematics is studied by almost all students. The course curriculum encourages the teaching and learning of geometry in mathematics for all student-teachers through ICT tools like GeoGebra, calculator, etc. The CoE trains student-teachers who learn and teach mathematics including geometry at the basic school of Ghana. The college of education curriculum stresses the need to know the circle theorems under geometry in mathematics using ICT tools to enhance understanding of the concept. Geometry studied in the CoE can be said to be the branch of mathematics that is concerned with shapes, sizes, relative position of figures, and properties of space. As a geometry topic at this level, the circle theorems aimed to understand the circle and its theorems, including using GeoGebra to teach and learn. The circle theorems help us to understand concepts like tangent, chord, sector, diameter, radius, etc. of circles. The circle theorems also help in solving various problems in geometry.

The research done by Battista (1990) indicated that *"most geometric thought is spatial reasoning which is the ability to see, inspect and reflect on spatial objects, images relationships, and transformations"*. In teaching concepts and topics involving geometry, the teacher expects his/her students to be able to visualize figures, shapes, and planes that may not be clear to the student. The concepts in geometry which include circle theorems are seen to be unique and challenging to learn and teach. However, GeoGebra promises to alleviate this complication when used knowledgeably in the teaching and learning process.

In teaching and learning geometry, it has been noted that student-teachers like other students still need to have the total understanding or cognitive and process abilities of the concept of circle theorems. Although teachers try their best to teach the concept of the course outline, student-teachers have difficulties in understanding and accomplishing classroom tasks. Though it is required to assist student-teachers to manipulate and visualize the circle theorems to truly understand the concept, the student-teachers have some challenges in studying geometry in particular circle theorems. Most student-teachers find it difficult to grasp the concept and required knowledge (Prescott, Mitchelmore & White, 2022; Barai, 2017; Battista, 1999). GeoGebra is seen to play the role of filling the gap by helping students manipulate, visualize, and understand circle theorems through explanation. Literature review shows the use of GeoGebra has a good impact on students' understanding of geometry. Asare and Atteh's (2022) research indicated that GeoGebra is one sure tool that can aid performance improvement and understanding of problems in geometry. Also, Dogan (2010) indicated that the use of GeoGebra had positively affected student learning, achievement and improved their motivation.

Some other researchers have described the effects of GeoGebra software on mathematics teaching and learning. GeoGebra is said to be an open-source community that has supported mathematics teaching and learning environment that contributes several dynamic representations, several mathematical sub-fields, and a wide range of modeling and simulation-related computing tools. GeoGebra has a more user-friendly interface than a graphing calculator. Additionally, GeoGebra supports mathematics projects, diverse presentations, and guided and explanatory learning. The National Council of Teachers of Mathematics (NCTM) declared technology as one of their six principles for school mathematics. NCTM (2000) indicated that technology is essential in teaching and learning mathematics and it influences the mathematics that is taught and enhances students' learning.

Majerek (2014) in a study conducted on the topic "application of GeoGebra for teaching mathematics" concluded that all students from any level of mathematical knowledge can be encouraged to study mathematics by using GeoGebra. He again concluded that the current trends in the teaching of science and mathematics call for the use of visualization techniques and GeoGebra fits perfectly in this trend.

Also, several kinds of literature highlight the importance of using ICT tools including GeoGebra in teaching and learning mathematics. In this sense, Sah (2017) indicated that there is a positive attitude among teachers toward the use of media tools in their classroom teaching. The use of ICT in teaching and learning enhances motivation to make the concepts clear and meaningful in any subject matter (Keong, Horani, & Daniel, 2005). Similarly, using the internet as teaching learning material is a prime source of knowledge. It was identified that there are priorities in using shadow learning materials and students are only centered on teacher's notes and lecture because there seems to be less use of authentic materials in teaching and learning mathematics.

The issue of authentic teaching and learning materials can be solved by using various ICT tools such as the internet, mobile, and their mathematical software in addition to daily use of learning resources in mathematics. According to Barai (2017) research conducted on the "perception of students on the use of GeoGebra in teaching school geometry" concluded that students had positive perceptions towards using GeoGebra. Similarly, Lamichane (2017) indicated that the students taught by using GeoGebra have better performance than traditional teaching approaches in mathematics. Also, the use of GeoGebra is said to enhance student performance in teaching coordinate geometry at the school level (Saha, Ayuw & Tammiz, 2010). The findings of their study showed that computer-assisted learning software like GeoGebra helps students to increase achievement in mathematics rather than using the traditional approach of learning by using paper and pencil. GeoGebra has the best place position in present technology for teaching mathematics as stated by NCTM's six significant principles of mathematics education (Majerek, 2010).

The research of Chalaure and Subedi (2020) on the "effectiveness of GeoGebra in teaching school mathematics" concluded that blending mathematics teaching with ICT, particularly with GeoGebra is seen as an important and effective way for meaningful

understanding of mathematical concepts. They also concluded that, GeoGebra is an effective tool to increase achievement; promote curiosity and creativity; make clear sense of concepts; and encourage overall learning of students in mathematics. They again suggested that school mathematics teachers need to be encouraged to use ICT for effective teaching and learning. A study conducted by Garba (2019) found and concluded that, in preparing students to be successful in problem-solving in mathematics, GeoGebra needs to be used to solve these real-world problems. He again stated that, with GeoGebra, teachers can make graphical representations of mathematics concepts.

In teaching and learning geometry, it has been observed that students still lack the total basic knowledge and skills. However, the teacher delivers the required knowledge to assist students in understanding the concepts of circle theorems. The student-teachers are the students who have studied mathematics including geometry at the Senior High School (SHS). West Africa Examination Council (WAEC) in 2015 and 2017 indicated that there is a lack of skills in answering almost all the questions asked in general mathematics and poor performance in geometry topics involving circle theorems such as cyclic quadrilaterals, tangent, and chord theorems. Some observations and discussions conducted indicated that the CoE level 100 student-teachers like other students' still lack the knowledge and skills in circle theorems of geometry. Hence, this study aimed to examine the effect of GeoGebra on student-teachers in teaching and learning circle theorems. This study was guided by the two research questions below:

- 1) What is the effect of teaching and learning circle theorems using GeoGebra on student-teachers' achievement?
- 2) What are student-teachers' views on using GeoGebra in teaching and learning circle theorems?

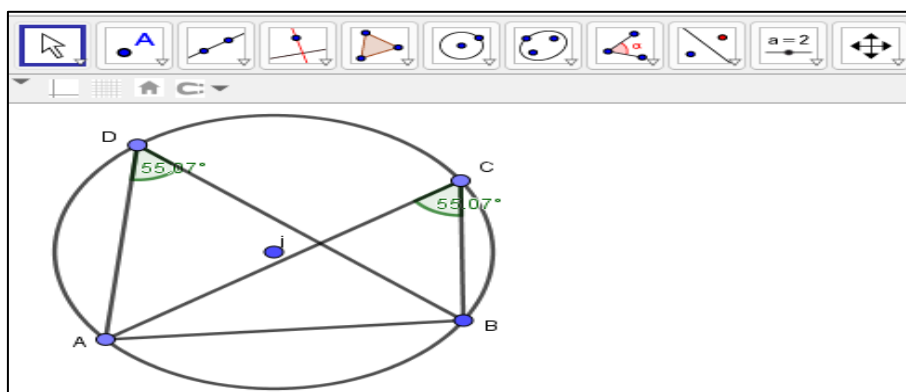
2. Methods

The experimental research in which pre-test-post-test non-equivalent control group design was used to examine the effectiveness of GeoGebra software in teaching and learning circle theorems of geometry for student-teachers at the College of Education. Four weeks were used to teach both the experimental and control groups during the intervention stage. Two classes of CoE level 100 students were selected by using convenience and purposive sampling techniques. The researcher employed a random sampling technique by tossing a coin to define the experimental and control groups with the help of a colleague tutor. The experimental group was taught the concept of circle theorems using GeoGebra software while the control group was taught the concept of circle theorems using the conventional method. These groups were treated equally in all aspects to control the external and internal validity threats and to ensure the effect of treatment in the experimental group. The same achievement tests were used for the groups in the pre-test and post-test. The achievement tests were constructed by considering also the concepts student-teachers learned from JHS and SHS curriculum on circle theorems. The pre-test was constructed with ten objective questions and two essay-

type questions. The achievement tests were finalized after piloting and validating by the experts. After the analysis of the achievement results of the pre-test of the groups, the researcher started four weeks of teaching both groups with the same content of circle theorems of geometry for the level 100 student-teachers with the help of a colleague tutor. However, the pre-test and post-test questions were different. Furthermore, the questionnaires were prepared with five Likert scale alternatives: strongly disagree, disagree, neutral, agree and strongly agree to measure the views of using GeoGebra in teaching circle theorems for the student-teachers of the experimental group. Finally, the data obtained were analyzed and interpreted by using descriptive statistics like frequency distribution table, percentage, mean, standard deviation, and the inferential statistics t-test at 0.05 levels of significance. The results of the data obtained were analyzed and interpreted under several sub-headings as described below and discussed the findings with the literature.

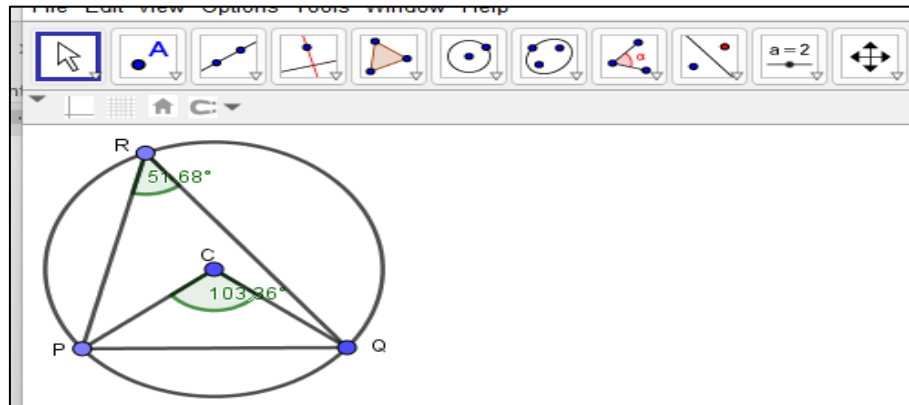
2.1 The Experiment

After the analysis of the achievement scores of the pre-test and tossing the coin to select the experimental group and control group, the researcher began the experiment. The experimental group was taught by using GeoGebra software while the control group was taught by using the traditional method. Below are some snapshots of GeoGebra software which was used during my experiment with the experimental group. The GeoGebra software outputs were developed based on theorems principles and guided questions from the curriculum to assist the student-teachers in understanding the concept of the circle theorems. The task was to assist student-teachers in using GeoGebra software based on combined figures and words to determine that, in a circle the angles in the same segment are equal.



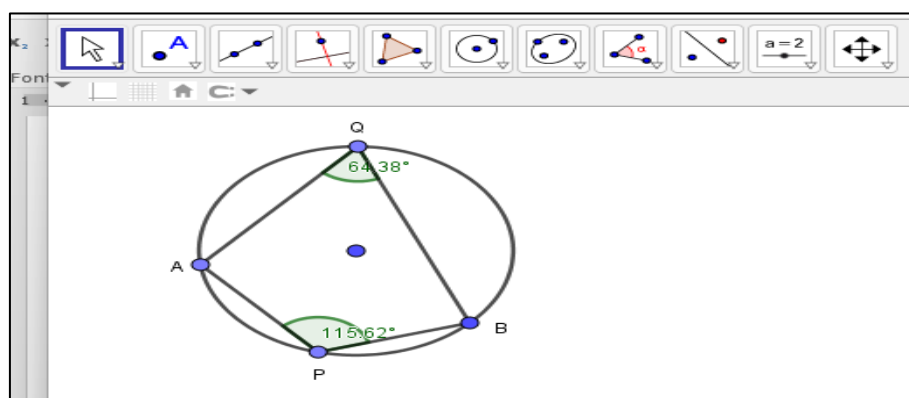
The software output above was developed by clicking the circle icon and using it to draw the circle, draw the chord AB, and other line segments to form the angles at C and D by selecting and using the line segment icon. Then click on angles and use it to measure angles $\angle ACB$ and $\angle ADB$. Compare the values of the angles and conclude if the angles on the same segment are equal.

The next task was to use the GeoGebra software to assist the student-teachers in understanding the theorem that, the angle subtends at the centre of a circle by an arc is twice the angle that it subtends at the circumference.



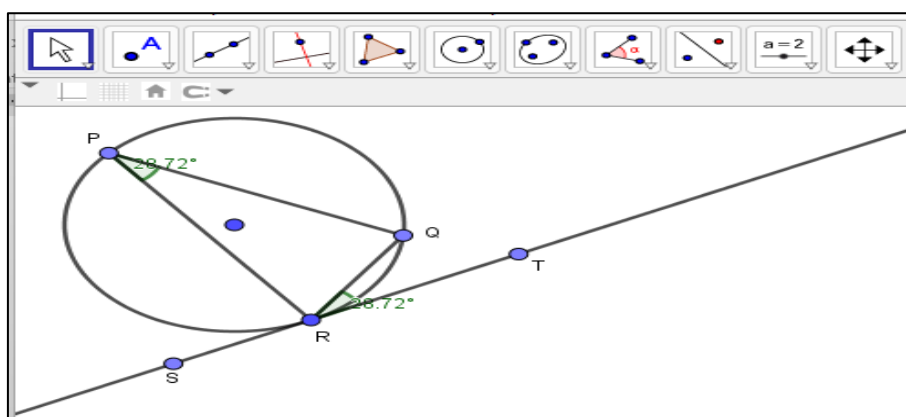
The software output was developed by clicking on the circle icon and using it to draw the circle. Click on the line segment icon and use it to draw lines segments to form angles at the centre and on the circumference of the circle. The student-teachers were then assisted in selecting the angle icon and using it to measure the angles $\angle PCQ$, $\angle PSQ$ and $\angle PRQ$. The angles were varied at the centre and compared with the angle on the circumference of the circle to establish that angles formed at the centre are twice the angle formed on the circumference of the circle by an arc.

Also, the GeoGebra software was used to show that, angles in opposite segments add up to 180° . To develop this output, the circle icon is selected and used to draw a circle. The line segment icon then is selected and used to draw line segments. Then the angle icon is selected and used to measure and compare the angles. That is, the angles $\angle ACB$ and $\angle ADB$ add up to 180° as shown below.



Similarly, the GeoGebra software was used for student teachers to realize that, if a straight line touches a circle forming a tangent, and from the point of contact a chord is drawn, the angles which the chord makes with the tangent are equal to the angles in the alternate segment. To develop this output, the researcher assisted the student teachers in

selecting the circle icon on the GeoGebra software to draw the circle and locate the points P, Q, and R on the circle. Select and use the line segment icon to draw the line segments PQ, PR, and QR. Then, select the tangent icon and use it to draw a tangent to touch the circle at R and label the tangent \overline{ST} as shown below. Also, select the angle icon and use it to measure and compare the angles $\angle QRT$ and $\angle QPR$. Thus, angles $\angle QRT$ and $\angle QPR$ are equal.



Thus, it was experienced that the use of GeoGebra software in teaching circle theorems was effective in learning the mathematics concept as compared to the traditional approach of teaching mathematics. Below are the results of this study.

3. Results

3.1 Analysis of Achievement Scores of Pre-Test

The pre-test was conducted to analyze the achievement level of level 100 student-teachers in circle theorems before the experiment. Thus, the pre-test was administered to both experimental and control groups. The table below shows the mean and standard deviation of the achievement score of the pre-test and their corresponding t-value.

Table 1: Mean and Standard Deviation of Pre-Test

Groups	N	Mean	S. D.	T	Significant (2-tailed)
Experimental	28	7.35	2.10	1.189	0.247
Control	23	7.78	2.52		

Note: t-value significant at $p < 0.05$

Table 1 indicated that the mean achievement score of the control group was greater than that of the experimental group in circle theorems by 0.43. Similarly, the result showed that, the 28 participants of the experimental group ($M=7.35$, $SD=2.10$) compared to 23 participants of the control group ($M=7.78$, $SD=2.52$). The paired sample t-test of $t(22)=1.189$, $p=0.247$ of the pre-test suggests that the control group did not perform significantly better than that of the experimental group. However, the mean difference was not significant because its p-value of 0.249 is greater than 0.05. It means that the

experimental and control groups are not different in terms of mean achievement scores in circle theorems based on pre-test results. Both groups seem similar in circle theorems achievement. Below is the analysis of the achievement scores of the post-test.

3.2 Analysis of Achievement Scores of Post-Test

The post-test was conducted to analyze the achievement level of level 100 student-teachers in circle theorems after the experiment. Thus, the post-test was administered to both experimental and control groups. The mean and standard deviation of the achievement score of the post-test results and their corresponding t-value are in the table shown below.

Table 2: Mean and Standard Deviation of Post-Test Scores

Groups	N	Mean	S. D.	T	Sign. (2-tailed)
Experimental	28	15.91	1.593	-3.386	0.003
Control	23	13.57	2.50		

Table 2 indicates that there is a difference between the mean scores of the experimental and control groups of the post-test. The result shows that the 28 participants of the experimental group were taught by using the intervention (M=15.91, SD=1.59) compared to the 23 participants of the control group (M=13.57, SD=2.50). The paired sample t-test, $t(22)=-3.386$, $p=0.003$ of the post-test suggests that the experimental group performed significantly better than the control group. The result reveals a mean difference of 2.34 and a standard deviation difference of 0.91. These values indicated that the difference in the mean score of the two groups is significant. Again, the result shows that the student-teachers taught by using GeoGebra software are better than the student-teachers' taught by the traditional method. Therefore, this reveals that the student-teachers in the experimental group have higher achievement performance than the control group. This indicates that the use of GeoGebra in teaching and learning at the CoE level increases student-teacher achievement scores.

3.3 Perception of Student-Teachers towards the Use of GeoGebra Software

The GeoGebra software's effectiveness in teaching-learning of CoE mathematics was measured by evaluating the perception of student-teachers towards using it. The student-teachers' perception was measured with the help of a questionnaire which was developed based on a 5 5-point Likert scale but combined the responses on strongly disagree and disagree into disagree, and strongly agree and agree into agree for the process of analysis. There were statements of different dimensions of perceptions in the questionnaire. The questionnaire was distributed to twenty-eight (28) student-teachers of the experimental group and they were returned after thirty minutes by attempting their views toward GeoGebra software usage for circle theorems. The questionnaire consisted of four main sub-headings such as GeoGebra in mathematics, GeoGebra in circle theorems, GeoGebra in subject matter of mathematics, and GeoGebra in curriculum. The table below shows the student-teacher perception score towards the use of GeoGebra.

Table 3: Perception of Student-Teachers toward GeoGebra Software

SN	Item	Disagree (%)	Neutral (%)	Agree (%)
1	I like to learn and study circle theorems by using GeoGebra software through the teacher.	7.1	3.6	89.3
2	I got a clear concept while the teacher used GeoGebra in teaching Mathematics.	3.6	14.3	82.1
3	I feel GeoGebra is an essential and important software for teaching mathematics.	10.7	17.9	71.4
4	GeoGebra mostly encourages me and my friends to take the path and improve our mathematics performance.	3.6	25.0	71.4
5	GeoGebra software made me more clearly about any figure that is visualized through the teacher in circle theorems.	14.3	7.1	78.6
6	I like to study circle theorems lessons using GeoGebra software.	17.9	10.7	71.4
7	The use of GeoGebra software in circle theorems topic ensures long-term memorization of what the teacher taught.	17.9	7.1	75.0
8	The GeoGebra software gives us a very clear concept about circle theorems connecting real-life problem.	17.9	39.3	42.9
9	The GeoGebra software gives us meaningful information on the subject matter.	10.7	10.7	78.6
10	Using GeoGebra software distracts my concern from the subject matter.	67.9	3.5	28.6
11	GeoGebra software makes the teacher and me very lazy and careless.	64.3	7.1	28.6
12	The environment of the class becomes noisy while the teacher uses GeoGebra software.	60.7	10.7	28.6
13	I want to learn this software to make clear concepts in mathematics subject matter as much as possible.	10.7	3.6	85.7
14	Every school should use GeoGebra software to teach mathematics in an effective way.	14.3	10.7	75.0
15	The basic and secondary school curriculum should include GeoGebra software in mathematics teaching.	17.9	3.5	78.6
16	I will explain GeoGebra software to all who have curiosity.	14.3	10.7	75.0

Source: Field Study (2022).

Table 3 shows the results of student-teachers of the experimental group's perceptions toward the use of GeoGebra software in teaching and learning circle theorems and mathematics in general. The result shows that the student-teachers have positive perceptions about using GeoGebra software in teaching and learning circle theorems. The majority of the student-teachers (89.3%) indicated that they like to learn and study circle theorems by using GeoGebra software through the teacher. Most of the student-teachers (82.1%) mentioned that they got clear concepts while the teacher used GeoGebra software for teaching mathematics. Again, the majority of the student-teachers (85.7%) were of the view that they like to learn this software to make clear concepts in mathematics subject matter as much as possible. The majority of the student-teachers (71.4%) agreed that they

feel GeoGebra is an essential and important software for teaching mathematics, GeoGebra mostly encourages students and their friends to take paths and improve performance and they like to study circle theorems lessons using GeoGebra software. Similarly, more than (74%) of the student-teachers agreed that GeoGebra software made students more clear about any figure visualized through a teacher in circle theorems, the use of GeoGebra software in circle theorems topic enhances long time memorization of what the teacher taught, the GeoGebra software gives students meaningful information on the subject matter, every school should use GeoGebra software in mathematics teaching, and students will explain about GeoGebra software to all who have curiosity. Also, more than (60%) of the student-teachers disagreed that using GeoGebra software distract their concern on the subject matter, the environment of the class becomes noisy when teacher use GeoGebra software to teach and GeoGebra software make teacher and the students very lazy and careless.

4. Discussion

The major findings of this study are discussed here. The main finding of this study was that the student-teachers who were taught by using GeoGebra software had higher achievement scores than the student-teachers taught by using the traditional method of teaching circle theorems in CoE. This study is in line with Lamichane (2017) that, students taught by using GeoGebra software perform better than students taught by the traditional approach in mathematics. Also, it was revealed that the use of GeoGebra assisted student-teachers in understanding the concept of circle theorems and visualizing the theorems as applied in geometry. The findings again indicated that the student-teachers have a positive perception of the use of GeoGebra software in teaching and learning mathematics and geometry. Moreover, the perception of the student-teachers pointed out that GeoGebra software makes teaching and learning meaningful, active, and helps the students for a long-time memorization. The finding of this study is in agreement with the study by Barai (2017) that students had positive perceptions toward using GeoGebra. It was found that the use of GeoGebra software by the experiment group made them have strong motivation, encouragement, and more attentiveness in learning subject matter than the students in the control group. In all, the findings of this study indicated that the use of GeoGebra software in teaching circle theorems was very effective in the classroom. This study supported the study by Keong, Horani, and Daniel (2005) that using ICT in teaching and learning enhances and makes the concepts clear and meaningful in any subject matter. Also, Chalaune and Subedi (2022) in line with this study mentioned that blending mathematics teaching with ICT, particularly with GeoGebra software is an important and effective way for meaningful understanding of mathematical concepts. In addition, this study supported the research by Majerek (2014) that all students from any level of mathematical knowledge can be encouraged to study mathematics by using GeoGebra software.

5. Conclusions

The use of GeoGebra software in teaching mathematics, including circle theorems, improves student-teachers' performance in comparison to the traditional method of teaching. The use of GeoGebra software is important to make clear concepts about circle theorems and increases student-teachers' curiosity towards mathematics subject matter. GeoGebra software use in teaching is an essential and effective way to a meaningful understanding of mathematical concepts. Thus, the use of GeoGebra software is an effective tool to increase achievement; promote curiosity and creativity; make clear sense of concepts and encourage overall learning of students in mathematics. Finally, this study suggests that mathematics teachers need to use ICT tools including GeoGebra for effective teaching and learning.

Funding Statement

This research received no specific grant from any funding agency in the public, commercial, or not-for-profit sector.

Conflict of Interest Statement

The author declares no conflict of interest.

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John Mensah presently works as a mathematics education tutor at Foso College of Education, Ghana. He is currently offering a doctorate program in mathematics education at the University of Education, Winneba, Ghana. He completed his master's degree at the University of Education, Winneba, Ghana. He has research interests in the field of mathematics education, technology in teaching and learning mathematics, and continuous professional development.

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