

## GeoGebra software to Teach and Learn Circle Geometry: Academic Achievement of Grade 11 Students

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**Abstract:** *This paper contains information on a study which investigated the use of GeoGebra software in teaching and learning circle geometry enhancing Grade 11 learners' academic achievement in South Africa. The study employed a quantitative methodological research design that included non-equivalent (pre-test and post-test) quasi-experimental research. One hundred and seven (108) Grade 11 learners participated in the study. Sixty (60) learners were in the experimental while 48 learners participated as control group. The experimental group was taught with incorporated in the teaching and learning of circular geometry theorem using GeoGebra software. The control group was taught circle geometry by the teacher using traditional teaching methods (chalkboard, marker board and textbooks). The instruments used for the data collection for the study was pre and post-test on circle geometry theorem for Grade 11. The result of the study showed that between the experimental and control groups, that there were statistically significant differences after using GeoGebra software to teach. GeoGebra software's intervention appears to increase learners' academic performance in circle geometry when compared to learners who are taught using traditional methods. The study recommends that teachers should integrate GeoGebra software in their teaching especially in circle geometry.*

### INTRODUCTION

Geometry is a branch of mathematics with a wide range of applications in daily life. Furthermore, geometry is an important part of the mathematics curriculum that can be explored using technology. As well, geometry is crucial to the study of other branches of mathematics (Adelabu, 2018). According to Choudhury and Das (2012) geometry is a combining theme to the entire mathematics curriculum and as such is a rich foundation of visualization for arithmetical, algebraic, and statistical concepts.

Circle geometry is a theoretical aspect of geometry concept that requires proof of the theorem. A circle can be drawn with any center and radius. Circles can be seen all around the universe, from

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ripples to moonlight. When a flat surface is impacted by a force that works evenly in all directions, circles frequently develop in nature. This aspect of geometry (circle) has been difficult for teachers and learners both to teach and to learn. The factors contributing to this are abstract geometry, learning methods still dominated using algorithms and formulas, students' inadequate spatial abilities, and geometric language (Murni & Jehadus, 2019). As a result, learners were unable to construct, visualise, and justify the circle geometry. Therefore, most learners, even teachers memorised the theoretical aspect of geometry which has been a problem in teaching and learning the concept (Tay & Wonkyi, 2018).

Research studies show that this theoretical aspect of geometry (circle) is being taught using the conventional method. That is making use of chalkboard or marker board and learning methods still dominated using algorithms and formulas (Akaazua, Bolaji, Kajuru, Mu, Musa, & Bala, 2017; Tay & Wonkyi, 2018). Due to the conventional method of teaching the content the learners were not motivated and encouraged to learn. Since teacher dominates the classroom and learners become listeners. This type of method did not give room for discussion and interaction in the classroom. According to Mollakuqe, Rexhepi, and Iseni (2021) the conventional system is antiquated, and it is both ambiguous and unappealing to newer generations in this 21<sup>st</sup> century. Although, some students build and practice accuracy on their own in the traditional approach, but the figures in circle geometry are difficult to understand. As a result, there is a significant likelihood of failure. Therefore, circle geometry poses a great challenge to learners especially in the mathematics examination. As a result, learners encounter challenges in proving and applying the theorems to answer questions on circle geometry which also resulted in low performance in this aspect of geometry and mathematics in general (Van Putten, Stols & Howie, 2014). This paper reports the use of GeoGebra software in teaching and learning circle geometry enhancing Grade 11 learners' academic achievement in South Africa.

The South African Department of Education (DoE) developed a new curriculum in 2003 that includes four core areas in mathematics: number and number relationships, functions and algebra, shape, space and measurement, and data handling and probability (Moore-Russo, et al. 2010). The shape, space, and measurement content (Geometry) band has been difficult for learners and teachers since the new curriculum was introduced, according to the study. The final examination report [National Senior Certificate, (NSC)] revealed that students were unable to do basic lower-level mathematics. To help the students to overcome these obstacles, a suitable intervention is required (Department of Basic Education [DBE], 2015). Under the Department of Education's jurisdiction, the DBE aims to improve learning environments by adopting learner-centered teaching methods and providing schools with technology. According to the National Council of Teachers of Mathematics, technology influences and enhances learners' learning (NCTM). As a result, technology is critical in the teaching and learning of geometry. Many concepts in circular geometry need students to visually study items and compare them to previous encounters with similar objects in order to establish their attributes. Furthermore, learners who are able to "touch-

see-do" and interact with the objects of their learning can acquire circle geometry in a more innovative and successful way (Guzman, 2008; Tay, 2003). Despite the adoption of a learner-centered approach and the use of technology, many mathematics teachers continue to teach circle geometry using a textbook and chalkboard (traditional method), which discourages and demotivates students. Many students scored poorly in this area on the final exam, resulting in poor academic performance in mathematics. Several research investigations on GeoGebra's role in the teaching and learning process have shown that it has a substantial impact on students' mathematics achievement. However, in South Africa, particularly in the Eastern Cape province, circle geometry research is sparse. As a result, it is a case study of a selected secondary school in the OR Tambo district of South Africa's Eastern Cape province. Hence, the academic achievement of Grade 11 students utilizing GeoGebra software to teach and learn circle geometry is examined in this research. The aim is that GeoGebra will enhance learning and improve learners' academic achievement. The research question for this study is:

- What is the significant difference between academic achievement of learners taught circle geometry theorems by GeoGebra software and learners taught by traditional method?

## LITERATURE REVIEW

Mathematics is a science that everybody can see and apply to gain meaning in someone's life on occasion. In schools, mathematics is a significant topic, and employing technology to teach math courses is essential. Technology is the most effective way to give students information about their capacity to solve factual problems (Tezer & Cumhuri, 2017). Geometry is an important area of mathematics that is studied in conjunction with other subjects. Geometry is a unified theme that runs across the whole mathematics curriculum, and it provides a strong basis for visualizing arithmetical, algebraic, and statistical concepts (Choudhury & Das, 2012). When learning geometry, geometrical instruments are crucial. These instruments evolved from tangible objects as a compass and ruler to technology tools as computers, handheld graphing calculators, and iPads (Hollebrands, Stohl & Lee, 2011). Geometry is often associated with the study of abstract concepts such as non-dimensional points and lines. Only imagination can create these objects. Geometry is a visual subject; thus, it is hard to conceive thinking geometrically without drawing a picture or utilizing a range of pictures to describe an abstract geometric concept. Learners frequently struggle to understand how different geometric objects are represented. Furthermore, learners may find it challenging to interpret geometric objects representations (Hollebrands, Stohl & Lee, 2011).

In Euclidean geometry, a circle is an example of plane geometry. The circle is a shape that is been used frequently in daily lives: wheels, dinner plates, cups, and bottle caps are all circles. Learning about circles is a necessary element of understanding geometry. A circle is a simple figure encircled by a curved line, each point of which is equidistant from a central point (Hussin, et al. 2018). Circle geometry is also called circle theorem is a sub-topic in geometry subject. It is abstract in nature and difficult to teach for the teachers and to learn for the learners.

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## Technology Integration in Geometry Classroom

To motivate and encourage learners in learning circle geometry, in this 21<sup>st</sup> century teachers are encouraged to integration technology in the teaching of the content. According to the principles and standards for school mathematics documents released by NCTM (2000), technology is very vital in teaching and learning mathematics; the use of technology influences the mathematics that is taught, and it enhances the learners' learning. According to Clark-Wilson, and Mostert (2016), technology makes it easier for teachers to provide lesson resources with exact mathematical content and illustrations. Furthermore, it provides learners with the opportunity to be drawn to mathematical ideas and experiences in novel ways.

Integrating technology in teaching and learning geometry requires technological learning environments such as Dynamic Geometry Environment (DGE). DGEs are geometry technology tools that have been utilized in education to help learners move beyond the specifics of a single drawing to generalizations across figures and shapes (Hollebrands, Stohl & Lee, 2011). The use of technology, such as interactive geometry software, allows learners and instructors to construct figurative, functional, and relational samples, resulting in higher-level thinking, better problem-solving skills, and a better understanding and reasoning about two-dimensional shapes in mathematics teaching (Battista, 2002; Bokosmaty, Mavilidi & Paas, 2017). DGEs give learners with diverse geometrical talents and degrees of knowledge with new learning opportunities and possible interaction with geometrical tasks and activities (Hollebrands, 2007). The employment of tools for depicting and virtual manipulatives is beneficial for communicating ideas and thoughts that are difficult to describe, talk about, or write about otherwise (Anthony & Walshaw, 2009). Learners have a sense of control in the setting, therefore there is no fear or anxiety among them if someone makes a mistake while learning.

In a technology setting, learners build self-confidence in solving mathematical issues, which motivates and encourages them to learn even when they are having difficulty (Naidoo & Govender, 2014). For extremely tough geometry assignments, dynamic geometry systems provide a novel technique of teaching. GeoGebra is used as the DGE technological learning environment in this study.

## GeoGebra – The Learning Environment in Teaching and Learning Geometry

GeoGebra provides several digital tools that enable users to develop mathematical relationships of practical situations, synthesise and personally manipulate diagrams using several representations and modelling tools. The GeoGebra learning environment promotes the use of various representations (graphs, equations as well as a table). The software could be used in a flipped classroom or for differentiated learning. It also increases the teachers' performance. The software was developed by Markus Hohenwarter in 2002 and it incorporates multiple mathematics trends into one single, open-source, and user-friendly software. The GeoGebra software screen is divided

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into numerous sections to represent mathematical objects in a different way. The software can be accessed on the website [www.geogebra.org](http://www.geogebra.org). The figure below depicts the GeoGebra software window with different sections

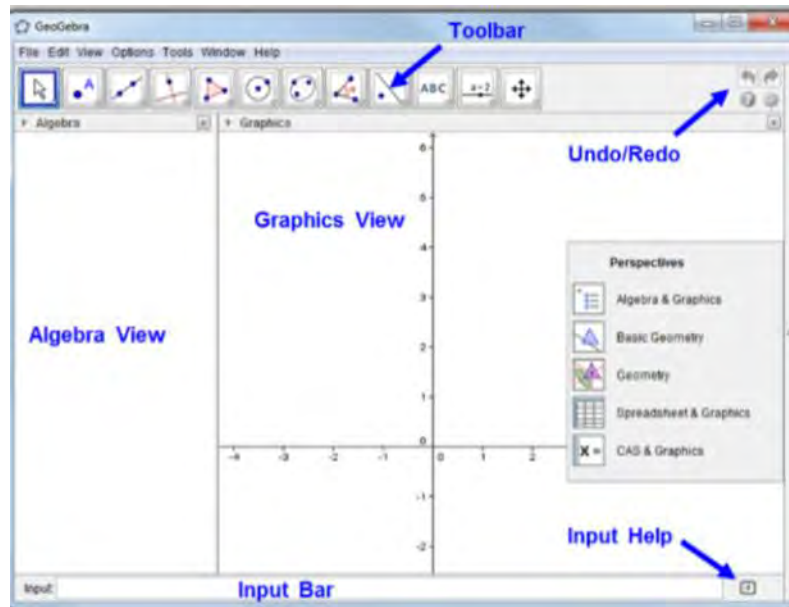


Figure 1: Different sections of GeoGebra software window (Source: [www.geogebra.org](http://www.geogebra.org))

GeoGebra gives learners with an immediate response mechanism, hence the program is considered as a motivator for them to learn. GeoGebra aids learners in the construction of knowledge as well as the solution of geometrical problems. The software's integration improves learners' procedural and conceptual knowledge of mathematics, making it easier for them to grasp abstract mathematical concepts. Furthermore, GeoGebra has a positive impact on learner learning outcomes in geometry, algebra, and calculus (Adelabu, 2018; Arbain & Shukor, 2014; Zulfadi & Zamri, 2017).

Murni and Jehadus (2019) find that GeoGebra aided realistic mathematics education can increase learners' knowledge of mathematical ideas in circle material in their study "learning circle with GeoGebra media focused to comprehending concepts." According to Badu-Domfeh (2020), including GeoGebra as a technological tool in teaching and learning increases learners' mathematical performance. The researcher goes on to say that including GeoGebra into the teaching and learning of circle theorems (circular geometry) encourages pupils to understand mathematics in general. Chimuka (2017) found that learners were more motivated to learn circle geometry when using GeoGebra rather than learning without technology in his study "the influence of integration of GeoGebra software in the teaching of circle geometry on Grade 11 learners' achievement." Further, Chimuka explains that the software enabled the learners to identify and name different circle geometry theorems.

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In addition, Sibiya (2019) agrees that learning circle geometry through technology (Geoboard) motivate learners to learn, increase their interest and confidence in learning geometry. Furthermore, Gamage and Charles-Ogan (2019) discover that learners taught with GeoGebra software performed better and were able to achieve more in circle geometry than learners taught circle geometry without GeoGebra. Moreover, Salifu (2020) claims that learners who were taught the circles theorem using GeoGebra achieved a significantly higher mean score than those who were taught using the traditional technique. According to Tay and Wonkyi (2018) high school learners who used GeoGebra to understand circle theorems had a statistically significant favourable effect. According to the findings of the aforesaid researcher, learners taught using the GeoGebra approach performed better than their peers who did not utilize GeoGebra to learn circle theorems. Tay and Wonkyi (2018) concluded that using GeoGebra method in the teaching made the classes more motivating, useful, and straightforward to understand.

## THEORETICAL FRAMEWORK

The ideas of constructivism concept of learning using technology were employed as the theoretical framework underpinning the study. Constructivist learning is defined by Cobb, Yackel, and Wood (1992) as an active construction and the representational view of the mind, in which learners adjust their own mental representations to construct. This contrasts with the belief that knowledge is passed down through the generations by the teacher. Learners generate knowledge and meaning based on their perceived experiences of the world, according to constructivism. The teacher is a facilitator in a constructivist classroom, and learners actively create information by interacting and interpreting concepts from social and individual experiences as well as past knowledge, which is said to improve learning and academic attitude (Abiatal & Howard, 2020).

Cognitive and social constructivism are distinguished by constructivists. Social constructivists believe that knowledge is created collaboratively in a socio-cultural environment, and that learning is facilitated through information sharing, negotiation, and dialogues (Mushipe & Ogbonnaya, 2019). As a result, social constructivists emphasize the importance of a learning environment that facilitates communication and collaboration with others. Learning is largely an individual affair for cognitive constructivists, hence pedagogical design should assist and satisfy the needs of individual learners to create knowledge. Despite the many definitions of constructivism resulting from the various theoretical perspectives of constructivism, the various theoretical perspectives all share the common characteristics of knowledge being constructed rather than passively absorbed and emphasizing a learner-centered instructional approach (Mushipe & Ogbonnaya, 2019). The teacher in a constructivist classroom offers learners with materials and activities to ensure that they are actively engaged and participate in the construction of their own knowledge. Therefore, the technology-based environments such as GeoGebra with visually fascinating

displays, together with resources for collaboration makes the environments to be more dynamic, powerful experiences for learners. In these regards, the environments are filled with motivations which encourage learners for effective constructions (Malabar & Pountney, 2002).

GeoGebra is used to develop learner's knowledge in circle geometry. In the GeoGebra environment, learners are actively involving in constructing different types of circle geometry representation. The environment motivates the learners to construct various circle geometry representation and enhances mathematics learning. Therefore, learners build knowledge of circle geometry and engage in higher-order thinking, as well as critical and creative thinking experiences in the environment. In this regards, GeoGebra software allows learners to construct their own interpretations while exploring and visualizing circle geometry, which helps them learn more effectively. In addition, learners are more engaged in developing a dynamic mathematical understanding of circular geometry and engagement inside the GeoGebra environment.

## METHODOLOGY

This study used a quantitative methodological research design using non-equivalent quasi-experimental research (pre-test and post-test). The non-equivalent quasi-experiments used the research control and experimental groups, but the participants were not randomly assigned to the groups. Without using a random selection process, the experimental and control groups were chosen. A pre-test and a post-test were given to both groups. Treatment was only given to the experimental group. The investigation was carried out in one secondary school in OR Tambo Inland District Eastern Cape Province, South Africa. One hundred and eight (108) Grade 11 learners participated in the study. Grade 11 mathematics learners were grouped into experimental and control group. Sixty (60) learners were in the experimental while 48 learners participated as control group. The school and participants of the study were chosen using convenience and purposive sampling methods.

During the experiment, both the groups (control and experimental) were taught circle geometry (circle theorem) for three weeks. The time allocated for each lesson was one hour. All the theorems of circle geometry were taught during this experiment. Before the experiment, the learners in both the experimental and control groups were given a test (pre-test) on the theorem of circle geometry to examine the level of achievement of the learners. The test consisted of four circle geometry questions from the past final examination questions. After the pre-test, the experimental group was taught circle geometry (circle theorem) using GeoGebra software, which was incorporated into the teaching and learning process. While the control group was taught circular geometry (circle theorem) by the mathematics teacher using traditional teaching methods (chalkboard, marker board and textbooks). In the experimental group, each of the participant was given laptop with installed GeoGebra software. The researcher taught the participants using Interactive Smartboard

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(ISB). Through the ISB, the researcher was able to introduce the GeoGebra software to the participants and how to use different tools in the environment. The experimental group participants were able to draw lines, construct circle and measure angles using GeoGebra software on their laptop. The understanding of how to use different GeoGebra software tools enable the participants to answer some of the circle theorem questions. The figure below shows the sample of the circle geometry theorem in GeoGebra software environment.

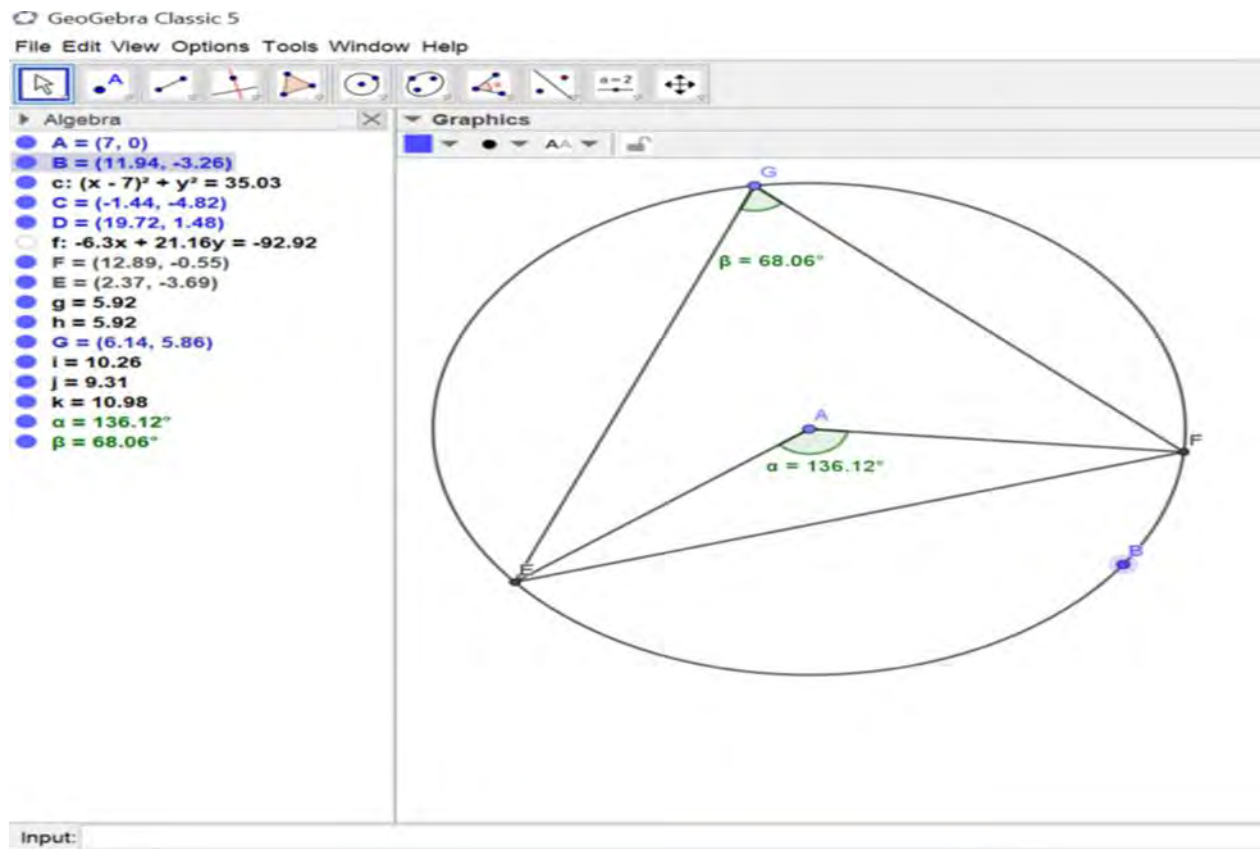


Figure 2: Sample of the circle geometry theorem in GeoGebra software environment [33].

After the teaching, the learners in both the experimental and control groups were given the same questions as post-test on circle geometry (circle theorem) to examine the level of achievement of the learners. The two tests (pre and post-test) were mark in line with the final examination marking memorandum. The results were analysed using inferential statistics with T-test of pre-test and post-test of both the experimental and control groups to determine the significant difference between the test scores of the two groups.

### The Validity and Reliability of the Instruments

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Validity is the ability of the instrument to measure what the researcher has designed it to measure. Instrument usage begins with ascertaining the worth of the instrument in relation to the extent of its validity. The face and content validity of the circle geometry theorem test was assessed. Two Grade 11 senior teachers validated the test. A pilot study was conducted with a non-participating Grade 11 learners to validate and test the reliability of the test.

The degree to which a test or other measurement technique delivers consistent results over time is known as reliability (Kothari, 2004). The test-retest reliability examines the consistency of responses across many instances of instrument use. As a result, in this study, test-retest reliability was utilized to assess reliability, which was determined by administering the same test twice to the same four Grade 11 learners picked from non-participating classes during a one-month period. The two scores were compared in order to assess the stability of the tests.

## RESULTS

To find the significant difference between academic achievement of learners taught circle geometry theorems by GeoGebra software and learners taught by traditional method.

The T-test, two-sample assuming equal variances is used to detect the significant difference between the test results of the experimental and control groups.

The significant difference between academic achievement of learners taught circle geometry theorems by GeoGebra software and learners taught by traditional method before the teaching.

The purpose of this pre-test is to determine the experimental and control groups' academic achievement in circle geometry theorems. The goal of this test is to determine the level of academic achievement of learners in circle geometry theorems before using GeoGebra in the experimental group and using traditional methods in the control group. Table 1 shows the t-Test - two-sample assuming equal variances of pre-test data for experimental and control groups.

Group	N	Mean	SD	T- value	DF	P (2 tailed)
Experimental	60	0.83	1.40	1.804	105	0.074
Control	47	0.36	1.23			

\*T-value significant at  $p < 0.05$ ; SD – Standard Deviation; \*DF – Degree of Freedom

Table 1: Two-sample t-test assuming equal variances of pre-test results for the experimental and control groups

Table 1 shows that the T-test revealed no significant difference in mean pre-test scores between the two groups, with  $t(105) = 1.804$ ,  $p = 0.074 > 0.05$ . This suggests that in both the experimental and control groups, there were no statistically significant differences. The symbol indicates that the two groups had similar academic performance at the start of the study.

The significant difference between academic achievement of learners taught circle geometry theorems by GeoGebra software and learners taught by traditional method after the teaching

This is used to compare the experimental and control groups' academic achievement on circular geometry theorems after the post-test. The goal of this test is to determine the level of academic achievement of learners in circle geometry theorems after using GeoGebra in the experimental group and using traditional methods in the control group. The T-test - two-sample assuming equal variances of post-test findings for experimental and control groups is shown in Table 2.

Group	N	Mean	SD	T- value	DF	P (2 tailed)
Experimental	60	11.33	9.82	4.783	105	0.000
Control	47	3.81	4.76			

\*T-value significant at  $p < 0.05$ ; SD – Standard Deviation; \*DF – Degree of Freedom

Table 2: T-test - two-sample assuming equal variances for experimental and control groups' post-test results

The T-test findings of the post-test results for the experimental and control groups were published in Table 2. The results demonstrate that there was a significant difference between the two groups' mean post-test scores, with  $t(105) = 4.783$ ,  $p = 0.000 < 0.05$ . This signifies that the difference between the experimental and control groups was statistically significant.

The signal denotes that the experimental group's learners outperformed the control group academically. Furthermore, it is also indicated that the intervention of GeoGebra improves the learner's academic achievement in learning circle geometry theorem than the learners in traditional method. Hence, using GeoGebra in learning circle geometry affects the academic achievement of learners positively.

## DISCUSSION

The results of the study revealed a significant difference in academic achievement in favour of learners who were taught GeoGebra. When compared to the control group of learners, GeoGebra software learners had a higher average test score. This finding could be explained by the fact that GeoGebra software allowed learners in the experimental group to develop and check the perfection of the circular geometry idea in the GeoGebra software's visual environment. Furthermore, being able to verify one's own work contributes significantly to academic success. Furthermore, because GeoGebra is a dynamic software, learners in the experimental group were able to re-evaluate their

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work, whereas those in the control group were unable to do so. Hence, GeoGebra software improves learners' visualisation instead of memorisation of the circle theorems. The findings of the study agree with other research studies (Arbain & Shukor, 2014; Badu-Domfeh 2020; Chimuka 2017; Murni & Jehadus, 2019; Salifu 2020; Tay & Wonkyi, 2018) where all discovered that learners who taught with GeoGebra attained a higher average test score compared to their counterpart using conventional method.

Learners in the experimental group are more engaged in developing a dynamic mathematical understanding of circular geometry and interaction in the GeoGebra software environment. As a result, the findings of this investigation support the constructivist viewpoint. The use of GeoGebra software tools in the teaching of circle geometry encourages active learning and helps learners learn (Isik, 2018). The findings as well encourage individual learning, lifelong learning, collaborative learning, and communication during the experiment. Furthermore, the technology tools ensure active learning and enable process evaluation and interaction, providing guidance, encourage the use of cognitive skills and skills development as well as encouraging activity-based learning (Isik, 2018). According to Prideaux (2007). adding active learning into the mathematics classroom encourages and engages learners in the learning process, resulting in improved comprehension of the concept. In addition, the GeoGebra software environment stimulates and motivates the learners to construct and develop their computer literacy skills (Malabar & Pountney, 2002).

## CONCLUSIONS AND RECOMMENDATIONS

The study concludes that using GeoGebra in circle geometry teaching improves learner's academic performance. GeoGebra environment is a dynamic environment where learner explored circle geometry. Using the software as manipulative materials helps learners understand circle geometry topics, allows them to share ideas among themselves and with the teacher, and improves memory. As a result, using technologies like GeoGebra in the teaching of circle geometry aids learners in developing positive attitudes about teaching and learning. Furthermore, learning in GeoGebra environment becomes more appealing as teachers have the option of largely replacing transmissive teaching with the constructivist method. Additionally, the software improves learners and teachers' technology literacy, which is a significant advantage.

Teachers should use technology, particularly GeoGebra, into the teaching and learning of mathematics, according to the study. The research can be done with learners in different grades (9 and 10) as well as other geometry and algebra ideas.

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