Examining the Effects of the use of Geogebra (Dynamic Software) on Students' Performance in Geometric Construction

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INTRODUCTION

Overview

This study looked at how using GeoGebra (dynamic software) affects students' proficiency in geometric construction. The background of the study, the problem statement, the research purpose, the study objectives, the research questions, and the research hypothesis are integral part of this chapter. Others include the significance of the study, the delimitation, the study limits, and organization of the study.

Background to the Study

Pupils' ability to see, develop, and interpret shape structures to related ideas is thought vital in the field of mathematics instruction, particularly in geometry (Narh-Kert & Sabtiwu, 2022; Armah, Cofie & Okpoti, 2018). The branch of mathematics that is most intimately related to our physical surroundings and the spaces we live in is geometry. Geometry, according to Adolphus (2011), is a branch of mathematics that explores various geometric forms, whether they are solid or flat. According to Tay and Wonkyi (2018), learning geometry in educational settings is believed to provide learners with a natural context for developing their reasoning and decision-making skills.

A number of geometry topics, including lines, angles, polygons, congruent and similar triangles, geometrical constructions (including loci), the circle theorem, 2D shapes and 3D objects, movement geometry, and coordinate geometry are included in the mathematics education curriculum for students (Narh-Kert & Sabtiwu, 2022). These geometry concepts constitute a chunk of mathematics curriculum in Ghanaian schools (from the basic to the university level). However, due to the over-reliance on traditional teaching methods used in many senior high school classrooms, most students in Ghana struggle to create, visualize, and identify geometrical concepts, despite the benefits geometry offers as a subject (Adolphus, 2011). The emphasis on memorizing and rote learning skills over critical thinking in traditional teaching methods often results in passive students who are incapable of analytical and rational thought (Emaikwu, 2012).

Accordingly, it has been reported that teaching strategies have a big impact on how students are motivated and respond to issues in class, which eventually impact on their learning results (Emaikwu, 2012). However, research has repeatedly shown that students frequently struggle to understand the fundamentals and variations involved in carrying out geometric transformations (Akay, 2011; Ada & Kurtuluş, 2010; Acquah & Alhassan, 2018). Generally, Senior High Schools students in Ghana experience several difficulties in geometry, particularly Geometric Construction, which causes their performance to continuously deteriorate (Acquah & Alhassan, 2018). The idea that students are passive consumers of knowledge is perpetuated by the traditional teacher-centered approach to instruction, which is characterized by lecturing and chalkboard-based teaching (Chimuka, 2017).

Geometry is taught and learned in ways that go beyond conventional methods (Mensah, Ansu, Karadaar, & Gurah, 2023). Many mathematical topics are now easier to understand and more accessible because of the integration of Information and Communication Technology (ICT) in education (Mensah et al., 2023; Lagura, 2022). As stated by Mijares (2022) and Lagura (2022), the effective use of ICT in teaching plays a crucial role

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in education and offers a number of advantages, including increased 3 student-engagement (White, 2012), expanded learning opportunities for students (Roberts, 2012), and encouragement of discovery-based learning (Tay & Wonkyi, 2018).

Numerous technological tools, such as GeoGebra (dynamic software), have been used in the teaching and learning of geometry (Armah et al., 2018).

GeoGebra is interactive geometry software that enables teachers and students to create lesson plans to promote a deep understanding of mathematics (Jia & Kwan, 2016). According to Bhagat and Chang (2011), it represents a cutting-edge method of incorporating technology into mathematics instruction. As dynamic geometric software, GeoGebra offers different learning opportunities by allowing active exploration and experimentation through symbolic links (Hohenwalter, 2006). An effective tool for improving learners' grasp of geometric construction is GeoGebra. It encourages student interest in mathematical inquiry, provides chances for the growth of creativity and critical thinking, and enhances experiential learning through problem-solving tasks in mathematics.

Numerous studies have documented how GeoGebra improves students' mathematics performance. For instance, GeoGebra software was successful in helping Erlina and Zakaria (2014) solve geometry-related issues. Students who used GeoGebra in an experimental group showed significant gains in their learning outcomes (Zengin, Furkan, & Kutluca, 2012). Researchers such as Abdul-Saha, Mohd-Ayub, and Ahmad-Tarmizi (2010) found that pupils whose teaching and learning was integrated with GeoGebra outperformed those were taught with conventional methods. According to Guven (2012), the experimental group outperformed the control group in terms of academic success and the acquisition of transformation geometry. This group employed GeoGebra as a teaching tool. 4

Williams et al.'s (2017) study also stressed the importance and power of GeoGebra in raising students' mathematics achievement. Although many studies have confirmed that GeoGebra has a good effect on student achievement, more research is required to confirm these results and determine the advantages of GeoGebra (Dynamic software) in improving students' performance in geometric building.

Statement of the Problem

The government of Ghana and many stakeholders in education including teachers and parents are concerned about students' poor performance in mathematics. It has been observed that non-elective mathematics students have negative attitudes towards mathematics, which has impacted on their in-depth understanding of geometry. Students who struggle in mathematics may respond with statements like, "You must be really smart" or "I'm really bad at mathematics." The majority of these students have likely held these negative views of themselves for a long time, whether as a result of ongoing arithmetic struggles or being told during in school that they lacked mathematical aptitude. As a result, when it comes to learning mathematics, individuals now feel low self-efficacy. These unfavorable perceptions are regrettable in light of the fact that mathematics is a scientific discipline with countless applications that can greatly advance people's intellectual and professional lives. The West African Examinations Council (WAEC) and the Ministry of Education report that the pass rates for core mathematics in the WASSCE were 65.71% in 2020, 54.11% in 2021, and 61.39% in 2022. This suggests that roughly 34.29 percent of students failed core mathematics in 2020, followed by 45.89 percent in 2021 and 38.61 percent in 2022. 5

For many students, geometry presents substantial difficulties as one area of mathematics. It is a fundamental area of mathematics that is essential to developing students' spatial reasoning and problem-solving abilities. Particularly, Geometric Construction stands out as a subject that many students find challenging. In support of this, Bwalya (2019) found that many students in their final exams were unable to provide adequate responses to questions about geometric construction. The majority of form three pupils at Osei Kyeretwie Senior High School, where the researcher teaches, were unable to solve geometric construction-related questions, according to a detailed study of students' answer booklets in the end-of-semester mathematics test. Even those who tried to answer the questions had only sporadic success.

With tools like GeoGebra becoming more common in mathematics classrooms, there has been a significant interest in incorporating technology into education in recent years (Sträßer & Lin, 2016). Students can dynamically explore and illustrate mathematical topics with GeoGebra, a dynamic mathematics program that smoothly blends geometry, algebra, spreadsheets, and graphing (Hohenwarter & Lavicza, 2018). Students design geometric shapes and work through difficulties using compasses, straightedges, and protractors in conventional geometric construction activities. Examiners have made the following recommendation. According to Bwalya (2019) and Ihechukwu and Chidi (2020), school administrators and teachers should make sure that candidates are exposed to hands-on learning activities to enable them bridge the gap between theory and practice. However, by incorporating GeoGebra into the classroom, students now have a digital substitute that enables them to carry out geometric designs on computer or tablet. This begs the question of whether or not the use of GeoGebra affects students' capacity to properly understand and apply geometric construction concepts. 6

A number of Ghanaian municipalities have recently performed research (Agyei & Benning, 2015; Asare & Atteh, 2022; Mensah, et al., 2023) on the usage of GeoGebra software in teaching and learning. For instance, Mensah et al.'s (2023) research on GeoGebra was carried out at Junior High Schools and Primary Schools within the Dormaa East Municipal, whereas Asare and Atteh's (2022) study focused on using GeoGebra software in teaching and learning mathematics at New Juaben Senior High School in the Koforidua municipality. These studies primarily focused on the application of GeoGebra in the general teaching of mathematics.

No research has been done at Senior High Schools in the Old Tafo Municipality despite the continually poor performance of students in mathematics, notably in Geometric Construction. As a result, there is a substantial research gap regarding GeoGebra's effect on students' performance in the area of Geometric Construction.

It is against this backdrop that this study sought to investigate the effects of GeoGebra's use as dynamic software on Senior High School students' performance in Geometric Construction within the Old Tafo Municipality in order to fill this gap in the literature. It specifically aims at finding out if integrating GeoGebra into geometry lessons improves students' geometric construction abilities, deepens their understanding of geometric concepts, and encourages a more intense interest in the topic. The study also looks into any potential issues or restrictions related to using GeoGebra to teach geometric construction. This research is crucial for advising educators and policymakers on how best to incorporate technology into mathematics instruction and to maximize instructional approaches to enhance students' geometric construction skills. 7

Purpose of the Study

The goal of the study is to determine how using GeoGebra (dynamic software) affects students' performance in Geometric Construction.

Objectives of the Study

The specific objectives of the study are the following:

1. To determine the challenges that Senior High School students face when tackling Geometric Construction.

2. To ascertain the students' views on the application of GeoGebra in the teaching and learning of Geometric Construction.

3. To assess the differences between the averages of students who received GeoGebra instruction compared to those who did not.

Research Questions

To direct the investigation, the following research questions were developed:

1. What challenges do Senior High School students have when tackling geometric Construction problems?

2. What do students think about using GeoGebra software to teach and learn about Geometric construction? 8

Research Hypothesis

The following hypotheses were considered:

1. H0: The performance of students who were taught with GeoGebra compared to those who were not does not significantly differ.

2. H1: Students who are taught with GeoGebra perform significantly better than those who are taught without GeoGebra.

Significance of the Study

Teachers could learn more about students' learning processes from the study's findings, particularly those that are connected to how the GeoGebra software is used in mathematics instruction. Senior High School students could be introduced to the benefits and effects of GeoGebra software on the teaching and learning of geometry. The use of mathematical software to streamline the teaching and learning processes could help teachers, school administrators, and curriculum writers overcome the challenges they have when teaching Geometric Construction in the classroom.

The study's findings will add to the body of knowledge already available on the advantages of technology in mathematics education, particularly in the context of Ghana. In order to inform the scope and focus of subsequent educational policies, it will also allow for an evaluation of how technology is used in educational practices. As a result, this study will significantly aid in the National Education Ministry's attempts to update curricula as well as educators' efforts to prepare future mathematics instructors. 9

Delimitation

The impact of GeoGebra Software (Dynamic software) on Geometric Construction performance was the main topic of this study. The study was conducted at Osei Kyeretwie SHS in the Old Tafo Municipality. In terms of content, the study focused on the challenges that students face when solving Geometric Construction problems and collected data on students' opinions on the use of GeoGebra software in the teaching and learning of Geometric Construction. It also contrasted the performance of students who received GeoGebra instruction with that of students who received conventional instruction.

Limitations of the Study

The study had some limitations, but, as much as possible the researcher made every attempt to reduce them and made sure they didn't affect the study's conclusions. Due to time and money constraints, the study was only conducted at Osei Kyeretwie SHS in the Old Tafo Municipality. The difficulty of obtaining prompt responses from the respondents is another typical issue with using the questionnaire approach for data collection. Given the purpose of the study, it was necessary to deliver the questionnaires to the students during arithmetic courses in order to collect them afterward. Given the potential for consultations among respondents, while completing the questionnaires, it would be challenging for the researcher to vouch for the lack of such consultations.

Organisation of the Rest of the Study

The five chapters of the research have been organized. The research is introduced, the main issue under inquiry is named, and pertinent questions are posed in the first chapter. The study's restrictions and delimitations are indicated, along with the general and 10 specific aims, significance of the research, and its constraints. This chapter is seen as being pertinent to the study since it places the research in a larger framework and supports the monitoring of deviations.

Chapter Two discusses relevant theories and ideas and presents both theoretical and empirical research on the effects of GeoGebra on students' academic achievement. The study methodology is the main topic of Chapter 3, which also covers the population, sample size, sampling method, and research approach. Additionally covered are data collecting, study validity and reliability, data analysis, and ethical issues.

The presentation and explanation of the research findings are the focus of the fourth chapter. It goes on to highlight the important results with regard to the study. The findings are reported in Chapter 5, along with conclusions, suggestions, and any other study constraints that need to be addressed. This has a lot of significance since it makes information that was previously unavailable available and so broadens the scope of our current knowledge.

LITERATURE REVIEW

Introduction

Theoretical framework, conceptual review, empirical review, and conceptual framework are all covered in this chapter. The concepts of mathematics education, integration of technology in mathematics, teaching and learning of geometric construction, difficulties students face in solving geometric construction problems, and students' opinions of GeoGebra software in the context of learning mathematics are all specifically covered in this chapter.

Theoretical Framework of the Study

The diffusion of innovation theory serves as the foundation for the study's theoretical framework. According to Rogers (1995), the diffusion of innovation is a theory that explains how, why, and how quickly a new technology spreads within a specific context, such as a group, community, organization, or country. In accordance with this hypothesis, certain people (known as innovators) decide to accept a new technology independently during the early phases of its introduction, regardless of the choices made by others within the social system. According to Rogers (1995), the order of adoption normally moves from innovators to early adopters, then the early majority, late majority, and finally laggards.

Diffusion is the process through which an innovation spreads over time within a social system through particular routes (Rogers, 2003). Rogers distinguished four key components of diffusion: (a) Innovation (the idea, practice, or object being adopted), (b) Time (the rate of innovation acceptance over time), (c) Communication channel (how the 12 innovation is introduced to or marketed to individuals), and (d) Social system (the entities, such as people, groups, organizations, or sub-systems involved in the adoption of the innovation and their mutual influence). Each of these four components is seen to be extremely important to the acceptance of new technologies.

Based on how quickly they acquire new technology, users are divided into different categories by Rogers' Diffusion Model. These groups consist of:

Innovation: The eager adoption of new technology, regardless of its intended use, by enthusiasts. Early Adopters: Pioneers that mix a love of technology with a desire to overcome large professional obstacles. Early Majority: Realists that put solving real-world business problems ahead of tools, despite being at ease with technology.

Conservatives or skeptics are similar in outlook to the early majority but less technologically savvy. People who are least inclined to accept new technologies are called laggards.

According to Rogers, the attitude of people towards the introduction of a new technology is a significant factor to process of its diffusion. Applicable in this study is the use of GeoGebra, which is the new technology (innovation) and its effects on students’ learning. Since Rogers uses the terms innovation and technology interchangeably, the diffusion of innovation framework seems particularly suited for the study of the diffusion of ICT. Rogers proposed features of innovations that helped in the innovation-diffusion process. These features include; relative advantage, compatibility, complexity, trialability, and observability. These attributes were applicable to this study in its effort to find out the implications of using the GeoGebra software to teach Geometry. 13

According to Rogers' (2003) theory, an innovation's relative advantage over current practices, compatibility with users' demands, trialability, and observability should all be higher, while its use should be simpler. Rogers' Innovation Diffusion Theory is largely regarded as a viable and reliable paradigm for studying the adoption process. This theory is valued because it makes an effort to understand the factors affecting innovation adoption and the process by which new innovations spread over time across social systems.

Conceptual Review

Mathematics Education in Ghana

The practice of teaching and studying mathematics, including the knowledge of the formulae and algorithms required for computations, is known as mathematics education (ME). It acts as a platform for enhancing mathematics teaching and learning strategies. Not just in Ghana, but, globally, mathematics is given a lot of prominence in educational curricula. It is seen as a significant subject because of its inherent worth and how it relates to other academic disciplines such as sciences (UK Essays, 2018; Jones, 2000). Owing to its relevance, educators (including teachers), students, and parents, have begun to pay urgent attention to the difficulties most students encounter when studying this subject. It is important to recognize that some teachers have challenges to teach mathematics, but such challenges are not insurmountable.

The Third Wave Project launched in 2008, according to Seah and Wong (2012), has increased the extensive research into what students value in successful mathematics study. This made it necessary to investigate, through global comparisons of educational assessments in mathematics, what students from less developed nations, like Ghana, who incessantly perform badly in the subject, value about the study of mathematics (Davis, 14

Carr, & Ernest, 2019). Given that it is thought to lay the groundwork for the study of other courses, mathematics is a subject that all students must study in both the Basic and Second Cycles of education. Although elective mathematics is an additional course that Second Cycle students might take, it is largely voluntary and dependent on the area of study that they have chosen.

All Second Cycle students take the core mathematics course, but there is also an additional course called elective mathematics that is largely optional and is dependent on whether a student chooses to study business, science, or the arts. This demonstrates how important mathematics is to a variety of academic disciplines in our educational system.

According to Mereku and Mereku (2015), students have relatively little exposure to calculators at the basic level of education, whereas calculator use is permitted during the teaching and learning of mathematics in the Second Cycle level of education. Given that mathematics is a less-complex subject at the basic level, the system presumes that students at this level should be able to conduct calculations without the need for calculators. According to Davis, Carr, and Ernest (2019), teachers of mathematics at the elementary level are often well-educated, suggesting that most courses are taught by primary school teachers.

The teachers of mathematics are, however, specialized at the Junior High School and Senior High School levels. The majority of mathematics instructors in Second Cycle institutions hold a bachelor's degree in education or a related degree in mathematics. However, it is normal to find teachers at the Second Cycle level who do not hold such credentials, yet they teach mathematics. This is typically owing to insufficient qualified teachers. 15

Training and education in Ghana's Senior and Primary schools, mathematics has traditionally been perceived as a difficult subject. The presentation of mathematics has not undergone any significant modifications, which has led to continually poor levels of student achievement in high school mathematics. The Junior High School level (grade 8 equivalents) Trends in International Mathematical and Science Study (TIMSS) results from 2003 and 2007 show examples of low-grade mathematical achievement throughout the nation. According to Mullis, Martin, and Foy (2008), Ghana's eighth graders were placed 46th out of 47 countries in 2007 and 43rd out of 44 countries in 2003. Senior High Schools (SHS) do not significantly better the situation. Due to students' poor performance in the Senior Secondary School Certificate Examination, the failure rate in mathematics has been persistently high for a long time.

In 2016, 38% of all pupils who took the test received an F9 grade, compared to 45% in 2015 and 32% in 2014. According to the figures, 122,450 applicants (42.73%) received grades A1 through C6, 106,024 (37%) received grades D7 through E8, and 58,070 (20.27%) received an F9 in mathematics.

Based on an examination of WASSCE scores for school candidates in 2018, Wendy Addy-Lamptey, Head of the National Office of WAEC, observed a fall in mathematics proficiency. In 2018, 38.15% of applicants received a grade C6 or higher in mathematics, down from 41.66% in 2017. Similar to this, results from the WASSCE 2019 showed that students performed similarly, with 65.31% of candidates earning grades A1–C6, 21.0% earning grades D7–E8, and 13.54% earning an F9 in mathematics (MoE, 2019). About 65.71% of the candidates in 2021, according to MoE (2021), excelled in mathematics. This suggests that mathematics was a failure for 34.29% of the 2021 WASSCE applicants. 16

The majority of Secondary School students that participate in science (physics, chemistry, and biology) and mathematics courses are considered to be unsuccessful, according to studies (Agyei & Voogt, 2012; Essibu, 2018). The dismal performance in mathematics is linked to a number of causes, despite the fact that there is a persistent demand for Engineers, Doctors, Accountants, Science and Mathematics teachers, as well as Agricultural officials. These problems include the lack of qualified instructors, a lack of instructional materials, and a shortage of mathematics educators in the majority of schools.

The government of Ghana has launched a number of programs to improve mathematics teaching, learning, and performance in recognition of the critical roles teachers play in fostering educational transformation and boosting student learning (Ampiah, Akyeampong & Leliveld, 2004).

Additionally, research carried out in various Sub-Saharan African nations by Ottevanger, van den Akker, and de Feiter (2007) gives light on the causes of students' poor mathematics performance. These include underfunded educational institutions, crammed classrooms, a curriculum that is irrelevant to students' daily lives, a shortage of skilled teachers, and inadequate teacher preparation courses.

According to Ampiah et al. (2004), mathematics pre-service and in-service programs primarily use teacher-centered learning strategies. To develop students' analytical thinking and their ability to apply knowledge to real-world issues, curriculum materials in this area advise teachers to start each lesson with a practical problem. These publications also support the use of computers and calculators for research into actual-world problems and problem-solving. The guidelines found in syllabi alone, however, are insufficient to achieve this teaching and learning focus (MoE, 2012). 17 The government of Ghana understands the need for various forms of support for mathematics educators.

According to the Ghana Information and Communication Technology for Accelerated Development (Ghana ICT4AD Policy paper, 2003), ICT literacy is seen as a driver for rapid development. As a result, Ghana incorporated ICT into the curriculum in September 2007 in accordance with the advice given in the ICT4AD document and the 2002 report of the Anamuah-Mensah National Education Review Committee.

The issue has remained in a tense manner year after year despite the wide range of interventions the government of Ghana has put in place to address the significant failure rates of students in mathematics. The only effective strategy to improve student learning in Science and Mathematics is to integrate ICT into classroom instruction (Keong et al., 2015). Research by Keong et al. (2015) and Voogt (2003) has shown that the use of ICT in mathematics instruction improves learning results because it fosters greater student participation, improved communication, and knowledge sharing. Additionally, ICT helps teachers give students quick and accurate feedback, allowing students to focus on developing techniques and interpretations of answers rather than spending a lot of time on hard computational tasks.

The constructivist pedagogical method, in which students use technology to explore and learn mathematical concepts by focusing on problem-solving rather than calculations connected to the problems, is also reported by Keong et al. (Voogt, 2013). 18

Technology in Teaching and Learning of Mathematics

Every sphere of human effort has steadily been impacted by technology, but education has been notably affected (Lagura, Rabang & Pascua, 2022; Lagura, 2022). The quality of teaching and learning has changed as a result of the integration of technology into education. Pannen (2014) asserts that when digital technology is included into teaching and learning, it enables innovation, acceleration, enrichment, and deepening of skill development within the context of learning experiences. It has had a big impact on teaching and learning, changing the roles that teachers and students have traditionally played. This transition from a teacher-centered to a learner-centered learning environment has put the emphasis on learning rather than teaching (Williams, Charles-Ogan, & Adesope, 2017).

The use of technology in teaching and learning has many benefits, including raising student engagement levels, expanding learning options for students, and fostering discovery-based learning (Roberts, 2012; Lagura, Rabang & Pascua, 2022). Higgins (2003) states that one of the main objectives of integrating ICTs (Information and Communication Technologies) in education is to improve teaching and learning methods and, as a result, raise educational standards. Technology improves students' attitudes about the subject and helps them understand concepts (Chang, 2004). Through activity-based learning, the use of technology in education helps pupils understand topics. Technology is a useful tool for assisting and modifying the teaching and learning process, particularly in mathematics, according to Abdul-Saha, Mohd-Ayub, and Ahmad-Tarmizi's (2010) report.

According to Grandgener (2008), technology helps individuals acquire flexibility in their mathematical thinking and strengthens their capacity for creativity. According to Nwoke and Okorie (2020), teachers should use technology to improve the educational opportunities for their students by choosing or developing mathematical projects that make good use of technology, such as graphing, visualization, and calculation. The incorporation of technology into mathematics instruction and learning increases student engagement and motivation, lessens the subject's abstract connotation, and develops their analytical and problem-solving abilities. The ability of students to conceptualize, construct, and interpret shape structures is crucial for connecting them to related topics in the teaching and learning of mathematics, particularly in geometry (Shadaan & Leong, 2014).

Gunga and Ricketts (2011) have observed that ICT devices give capable scope of visual portrayals which help teachers to draw students' attention to mathematical concepts. That is why ICT devices like computers, web-based applications, graphic calculators, dynamic mathematics/geometry software, are being used in Senior High School classrooms in advanced countries. Hence many studies have been done in those countries to evaluate the viability of technology in mathematics education (Skryabin, Zhang, Liu & Zhang 2015). A study by Amarin and Ghishan (2013) of the impact of educational technology on the learner interactions, for example, has shown that when educational technology is incorporated into conventional teaching practice, students' interest and motivation towards learning are increased. According to Amarin and Ghishan (2013), the incorporation of technology into lesson presentations turns the instruction into a constructivist learning process.

The way instructional information is delivered substantially influences the requirement to raise students' mathematics achievement (Pierce & Stacey, 2011). According to Chang and Lee (2010), well-structured instructional lessons allow students to develop a thorough comprehension of the ideas and theories relevant to solving mathematical problems. In order to improve students' arithmetic performance, a number of scholars have promoted the effective use of technology tools in the classroom (Jang, 2010; Cheung & Slavin, 2013;

Eyyam & Yaratan, 2014). These experts have urged educational institutions and mathematics teachers to include technological tools into the conventional classroom environment.

In conclusion, technological innovation is crucial to the teaching of mathematics and helps mathematics teachers engage students in the acquisition of mathematical concepts. However, paying close attention to pedagogy and lesson content is crucial for the integration of technology into mathematics learning and instruction. Technology improvements may require instructors to modify their strategies and plans in order to properly fulfill the demands of their students. By incorporating educational technologies into their teaching strategies, educators can offer students creative ways to support their learning. Students can participate in interactive learning environments, explore, discover, share, and collaborate with peers through the use of dynamic software and technology to reinforce their understanding.

Teaching and Learning of Geometric Construction

The study of the dimensions, shapes, and locations of 2-dimensional and 3-dimensional objects and figures is known as geometry. Geometry is regarded as a fundamental and important subject of mathematics (Kurumeh, Obarakpo, Odoh & Ikyereve, 2016). Due to the inclusion of these items in the classroom, geometry must be taught using a variety of representations, such as diagrams, schemes, drawings, and graphs. According to Stephen and Tchoshanov (2001), these representations act as contextual descriptions of geometrical notions or ideas and may aid cognition. Therefore, it is believed that using a variety of representations will help learners develop their geometrical notions.

Geometry has traditionally been taught and learned using a pencil and paper environment. According to Andraphanov (2015), geometry instruction begins in the Primary School and continues throughout all educational levels.

It is necessary to use a variety of activities when teaching geometry, with the objectives of the session influencing the choice of a particular activity. These exercises frequently have a significant impact on how well students understand geometric ideas. Diagrams are frequently used to teach geometry because they help with concept visualization and the explanation of underlying relationships. According to Schwartz and Heiser (2006), diagrams help students demonstrate their spatial reasoning. Thus, teachers must visually convey geometric drawings and guide their understanding of graphical or geometric relationships. The effects of geometric teaching and learning activities on students' comprehension have been the subject of numerous researches.

The development of learners' deductive reasoning abilities is a crucial goal of geometry instruction. In this context, Jones, Fujita, and Ding (2006) carried out a study that investigated geometry teaching methods, taking methods used in China and Japan into consideration. According to their research, learning geometry should include using modeling to apply geometric concepts, fostering deductive thinking, and using a problem-solving methodology in a variety of settings. They came to the conclusion that creating effective pedagogical models accompanied by thoughtfully created learning tasks and resources is essential for improving geometry instruction. The creation of geometric activities that aid geometry teaching and learning can also be accomplished through the use of games. Herbst, Gonzalez, and Macke's (2005) study which looked at how a teacher could prepare students to create meaningful geometric figures, served as an example of this. 53 pupils from two High School geometry classrooms participated in the "Guess My Quadrilateral" game that the writers had created. Quadrilateral knowledge among learners was to be evaluated through a game. Students were given a questionnaire before instruction. Over the course of three weeks, the researchers developed the game, concentrating on the area around unique quadrilaterals. Students were prompted by the game to carefully examine each quadrilateral, setting it apart from its neighbors. The results of the study demonstrated that as students talked about figure properties, they were able to draw these figures rather than just describe them. The authors came to the conclusion that students might use data from the game to assess the characteristics of the covered quadrilaterals.

Foster and Shah (2015) looked at how games could improve learning in a classroom setting in a different study. The study was carried out in a Senior High School and used a mixed-methods approach with experimental and control groups. It used the Play, Curricular Activity, Reflection, and Discussion (PCaRD) model as the teaching strategy. The PCaRD methodology was used to implement three games over the course of a year. Pre- and post-tests were used to measure academic progress. The PCaRD concept, according to the researchers, made it easier for pupils to understand geometry and helped teachers include games into their lesson plans. The ability of students to display comprehension when learning geometry depends on their ability to comprehend their own cognitive processes.

In research published in 2005, Moscucci, Piccione, Rinaldi, Simoni, and Marchini investigated the methods students used to understand geometrical ideas, concentrating on how pupils conceptualized isosceles triangles. The study, which recruited 105 children from six third-grade classrooms in Italy, sought to determine how students' views of isosceles triangles were affected by the orientation of a particular illustration. The researchers observed that students used a variety of naive measurement techniques in geometry, reflecting a variety of problem-solving approaches. Researchers discovered that shorter exercises helped pupils learn more efficiently.

Additionally, Marchett, Medici, Vighi, and Zaccomer (2005) looked into how students reasoned about the area and perimeter of geometric forms.

130 Italian fourth- and fifth-year primary school kids participated in the study, which examined competing notions about perimeter and area. Researchers found that pupils were cleverer at making area comparisons than perimeter comparisons while evaluating students' reasoning skills using two worksheets. As a result, students showed better problem-solving techniques when dealing with area-related difficulties, with their views of geometric forms frequently influencing those techniques. The researchers also noticed that rather than drawing parallels between different geometric shapes, children chose to work on particular geometric shapes.

All educational levels, including higher education, can benefit from geometry training, and activities and geometric representations are applicable to non-Euclidean geometry as well. In order to investigate how geometrical meanings could be generated through context and practices, Kaisari and Patronis (2010) looked at how college students built a model of elliptic geometry. The researchers believed that by reformulating Euclid's axioms and creating models for elliptic geometry, they would be able to identify pertinent connections between fundamental and sophisticated geometry. Over the course of a semester, students worked on building a model and conversed in teams, expressing their opinions and collaborating on various tasks. The study discovered that students were able to interact and affect their classmates' grasp of geometry, regardless of how they used geometrical principles.

In how learners comprehend and employ geometric concepts, circle geometry is crucial. There isn't much literature on this subject, though. Studies on circular geometry have concentrated on the creation of geometrical objects and shapes as well as the use of geometrical questions to develop learners' deductive reasoning.

In an effort to count the points at which a circle and a square meet, Canada and Blair (2006) carried out a study to look into these intersections. In order to generate mathematical arguments, hypotheses, and links between mathematical ideas, the study gave students and pre-service teachers assignments to complete. In order to complete the activities, participants had to build a six-point intersection and locate additional potential intersection points. Canada and Blair observed that even with sloppy circles and squares, students were still able to recognize potential 0, 1, 2, and 3 points of intersection. They came to the conclusion that when diagrams were created accurately, children could make precise discoveries and inferences about geometric ideas. Canada and Blair (2006) also noticed that based on the accuracy of students' drawings of 5-, 6-, and 7-point intersections, several conclusions were drawn. The researchers came to the conclusion that exact discoveries and conclusions on geometric ideas required accurate drawings.

In a study by Neel-Romine, Paul, and Shafer (2012), participants were tasked to define a circle and evaluate several definitions. Sixth-grade students were separated into groups and given the task of defining a circle. Their definitions were then tested using counterexamples. The purpose of the study was to assist pupils in investigating how to form a circle. Neel-Romine, Paul, and Shafer (2012) noted that students' initial definitions of a circle included terms like "round shape" and "looks like an orange or a coin." However, after participating in several exercises, students were able to give definitions that were more precise, such as "all diameters are the same length" and "a circle contains a diameter and a radius."

The study also showed that even with the use of pencils and paper clips, pupils had trouble defining the radius as equidistant. The authors came to the conclusion that students were able to accurately define a circle and articulate its properties after participating in a series of activities.

González and DeJarnette (2013) used problem-based instructional methods in a different study to help students improve their ability to reason about circles. In the study, 22 students took part in a variety of exercises, including a circle problem that was presented during a class that focused on solving problems. The goal of the class was to persuade pupils that the issue called for more than just mathematical calculations to be solved. Students were given the problem after they had mastered all the foundational mathematical ideas required to answer it, allowing them to formulate their own approaches without being restricted to certain theorems and ideas. The study found that almost all students applied several strategies by making use of important aspects of the challenge, such as diagrams. The Pythagorean theorem was applied, right angles were recognized, and dotted lines were used as guiding lines. González and DeJarnette (2013) observed that resolving the issue encouraged students to think critically, plan ahead, integrate various mathematical ideas and theorems, and reflect on the resolution.

In conclusion, geometry instructions are provided at all educational levels and use a variety of teaching strategies and tasks. Multiple representations, such as games and diagrams, can greatly help learners understand geometric ideas. Effective geometry instruction also includes developing students' deductive reasoning abilities and comprehending their cognitive processes. Despite being understudied, circle geometry offers chances to include students in insightful geometric investigations and problem-solving activities. Overall, creative pedagogical strategies and a focus on students' cognitive growth in the subject can enhance geometry learning.

Difficulties Students Faced in Solving Geometric Construction

Geometry is a crucial subject in education since it is intimately related to mathematics in many different contexts. Its importance is derived from its ability to develop critical abilities like problem-solving, conjecturing, deductive reasoning, intuition, imagery, logical argument, and evidence (Armah, Cofie, & Okpoti, 2017; Alex & Mammen, 2016). However, difficulties in the teaching and learning of geometry frequently result from a variety of issues, such as instructional strategies, geometric vocabulary, and visualization abilities (Noramini, 2006; Axsen, 2012).

Mason (2002) and Udo Usoro (2011) both cited the lack of accessing current instructional materials, gender differences, poor reasoning abilities, time restraints, flaws in the school curriculum, and students' difficulties developing mathematical proofs as additional factors contributing to these challenges. The efficiency of geometry instruction is hindered by all of these variables taken together. According to Adolphus (2011), students generally think of geometry as a challenging and daunting topic. When students work on geometry problems, this notion is more prominent (Seifi, Haghverdi, & Azismohamadi, 2012).

Students have trouble understanding the presented problems, choosing the best problem-solving techniques, creating mathematical models, and carrying out the proper mathematical procedures for addressing geometry problems (Haviger & Vojkuvkova, 2014).

Sulistiowati, Herman, and Jupri (2019) note that for students, particularly those at a low level (level 1), converting problems into mathematical models poses a great challenge. The inability to apply the proper mathematical principles, a lack of knowledge of appropriate strategies, and difficulties understanding the problems are other issues that students at this level face. The problem-solving process presents difficulties for pupils at the analysis and informal deduction levels.

The inability to translate problems into a mathematical model and improper use of mathematics were challenges faced by students at the analysis level. Computational errors and an inability to employ the proper mathematics were seen at the informal deduction level (Sulistiowati et al., 2019).

A research conducted by Juman, Mathavan, Ambegedara, and Udagedara (2022) revealed that students had more trouble learning geometry, because they couldn't draw diagrams for specific geometrical problems or use multiple theorems to solve a particular geometry problem. In addition, it was noted that learning geometry was influenced by students' language skills. Also, there were issues with remembering the theorems and applying them in appropriate circumstances, understanding the properties of congruent triangles, proving type geometrical questions rather than calculating type questions, creating geometrical diagrams for given problems, and understanding the properties of congruent triangles.

The students' disinterest in the Geometry component and their family circumstances also had an impact on their ability to study geometry. Additionally, the teaching experiments' findings showed that student-based learning strategies were superior to traditional ones for teaching geometry (Juman et al., 2022).

Idris (2006) claims that low performance among pupils is significantly attributed to a lack of understanding in learning geometry. Learning obstacles in geometry have been attributed to things like geometry language, visualizing skills, and poor instruction. Due to the inherent visual character of geometry, spatial visualization and geometric achievement have been linked. As the study of shape and space, geometry necessitates the ability to perceive; however, many students find it difficult to picture three-dimensional objects from a two-dimensional standpoint (Guven & Kosa, 2008).

Learning geometry can be difficult, and many students struggle to gain a sufficient comprehension of geometry principles, reasoning, and problem-solving techniques (Battista, 1999; Idris, 2006).

According to Chaudhary's (2019) study, pupils have trouble solving logical puzzles, proving geometrical theorems, and comprehending geometrical concepts. Time constraints and lack of interest are cited as the root causes of students' difficulties learning geometry, which eventually has a negative impact on performance. There is frequently not enough time in the classroom when teachers employ traditional teaching techniques.

Numerous issues that impede efficient geometry teaching and learning were discovered in a research Poudyal did in 2007 titled "Problems Faced by Lower Secondary Mathematics Teachers in Teaching Geometry." These problems included difficulties with the curriculum, textbooks, physical facilities, a lack of math labs, teaching-learning activities, materials, and procedures, as well as issues with how students were evaluated. Students' misunderstanding of geometry learning is also a result of the system's use of unqualified (untrained) teachers who teach mathematics. It is also observed that negative attitudes regarding geometry represent psychological issues.

A research titled "Difficulties Faced by Learning Geometry at the Lower Secondary Level" was undertaken by Chaudhary in 2014. The goal of this qualitative study, which used a descriptive survey approach as its foundation, was to pinpoint the challenges Lower Secondary pupils have when learning geometry. The study's findings pointed to problems like language discontinuity, poor comprehension of geometry concepts and figures, interpersonal problems, little interaction between teachers and students, low-class attendance, and difficulties comprehending mathematical language during mathematics instruction.

GeoGebra in Teaching Practice

From Secondary school to the Tertiary level, dynamic mathematics, conceptually and practically applied by GeoGebra is often used as a learning and teaching tool (Njiku, Mutarutinya, & Maniraho, 2020; Hohenwarter et al., 2007). Its inclusion in the school curriculum first concentrated on fundamental mathematical ideas but gradually broadened to include university-level courses in geometry, algebra, and calculus.

The main goal of GeoGebra, which is created for both teaching and learning, is to improve students' understanding of mathematical ideas. Its architecture facilitates proactive teaching and makes it useful for idea introduction, problem-solving, and the creation of mathematical experiments. This tool can be used in both in-person and online classroom settings (Hohenwarter et al., 2007). Users can download the latest version of the software from the official GeoGebra website, which also offers access to tutorials, the GeoGebra Wiki and the User Forum, related publications and information on nearby GeoGebra institutions (Sangwin, 2007). Users of GeoGebra, mostly teachers and students, use this environment to research, describe, and model mathematical concepts and relations (Hohenwarter & Jones, 2007). GeoGebra, which connects diverse representations, includes algebraic, geometrical, and calculus instructions. Markus and his team of programmers developed this software with the intention of making solving mathematical puzzles simpler. It provides several ways to represent and visualize mathematical concepts.

GeoGebra's dynamic nature makes it extremely valuable and ideal for learners at all educational levels. GeoGebra can be seen as a useful resource for students studying a variety of mathematical topics in numerous ways. It enables HTML exports, making it possible to create instructional materials for artistic graphics and learning aids, which in turn encourages greater class involvement, which is largely linked to dynamic worksheets (Hohenwarter et al., 2007; Bist, 2017).

Students in Middle and High school, as well as College students and educators, find GeoGebra to be helpful. The benefits of GeoGebra for College students learning and practicing calculus were explored by Machromah et al. (2019), who discovered that it considerably improved discourse. Another study by Haciomeroglu et al. (2009) showed that GeoGebra helped teachers become more familiar with the ideas in geometry, algebra, and calculus that are frequently taught at higher education institutions. Notably, the teachers were taught the value of representations, visualizations, and interactive worksheets (Haciomeroglu et al., 2009). The teachers' participation in the courses also improved their ability to deliver more modern and efficient teaching strategies. Instructing with GeoGebra helps educators experience less concern about technology-integrated learning. Teachers must update their instructional methods to better serve 21st-century learners, preferably by embracing the most recent technological developments. Escuder and Furner (2011) found in their study on the influence of GeoGebra on mathematics teachers' professional development that teachers got useful experience using the program, which improved their abilities to instruct pupils successfully. Overall, mathematics teachers had a favorable opinion of technology-enhanced learning, which raised their self-confidence in utilizing technology in the classroom.

GeoGebra provides teachers with a potential way to explore and practise mathematics and STEM-related disciplines (Science, Technology, Engineering, and Mathematics), in addition to easing their concerns and difficulties with digital literacy. It helps them improve their digital literacy skills, which include the capacity to find, evaluate, and present information clearly across a range of digital media. UNESCO defines digital skills as the capacity to use digital devices, communication apps, and networks to obtain and manage information. One of the fundamental competencies that educators should develop in students is digital competence (Redecker, 2017).

In summary, GeoGebra serves a dual purpose by not only allowing instructors to explore technological advancements and enhance their own skills but also enabling them to refine their teaching skills in mathematics and STEM-related subjects (Flehantov & Ovsiienko, 2019). This, in turn, can boost instructors' self-efficacy and their relationship with their profession and students. Exploring GeoGebra empowers teachers to enhance their pedagogical knowledge and skills thereby creating a more engaging and interactive learning environment in the classroom (Flehantov & Ovsiienko, 2019).

Verhoef et al.'s (2015) study showed that GeoGebra has a beneficial effect on instructors' professional development. The study concentrated on a four-year lesson study project carried out by teachers who were committed to exploring and learning derivatives using GeoGebra. The findings demonstrated how teachers from several Dutch schools used GeoGebra to investigate calculus and understand the interaction between conceptual embodiment and operational symbolism. Teachers examined the local behavior of a derivative graph by combining GeoGebra and derivative consolidation. The studies showed how teachers understood their students’ learning processes and were able to benefit from GeoGebra while learning mathematics.

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GeoGebra aids with the understanding of geometry through its graphical elements. Gaining expertise in geometry necessitates a number of factors, including command of the geometry language, visualization abilities, and effective training. If any of these factors are neglected, learning may be impeded (Idris, 2006). Learning challenges with geometric themes are influenced by deficiencies in these components. In their 2010 investigation of GeoGebra's impacts on geometry learning, Saha, Ayub, and Tarmizi found that it improved students' comprehension of geometry. In order to help students better understand geometric ideas, GeoGebra can offer various visualization levels.

(Figure 1).

Figure 1: Visualization of GeoGebra

Source: Ziatdinov and Valles (2022)

Although it is simple to obtain the graphs and identify their intersection areas, the solutions must first undergo algebraic verification (Ziatdinov and Valles, 2022). In this situation, GeoGebra helps students better understand symmetry, one of the key ideas buried in analytic geometry. GeoGebra allows for a constructivist approach and clearly illustrates point and line symmetries. GeoGebra is a useful tool for keeping students' attention in otherwise intimidating subjects since it offers real graphics for fundamental mathematical concepts and courses, such as symmetry. This is due to the fact that by using GeoGebra, learners are allowed to independently investigate the idea.

Analytic geometry significantly relies on graphics and images to assist students in exhibiting comprehension and thorough knowledge in a practical and applicable way. This is in line with the capabilities of GeoGebra.

Zengin, Furkan, and Kutluca (2011) looked at how GeoGebra affected teaching and learning in the area of trigonometry, a field of mathematics that includes algebra, geometry, and pictorial reasoning. Trigonometric functions and related issues involving their graphs, which are regarded as crucial in mathematics classrooms, can be explored using GeoGebra. They used a pre/post-test control group half-experimental design in their investigation, which revealed disparities in the outcomes. These results demonstrated that the constructivist teaching technique, when combined with computer-assisted training, is more effective than the constructivist teaching method alone (Zengin et al., 2011).

GeoGebra's efficacy in teaching and learning trigonometry, particularly by emphasizing the periodicity of trigonometric functions, was examined by Kepceoglu and Yavuz (2016). They wanted to compare how well traditional learning and blended learning affected students' comprehension of the periodicity of trigonometric functions. The study's findings showed that the functions in GeoGebra, which allow for different representations of the periodicity of trigonometric functions, were helpful in assisting the experimental group in obtaining accurate and almost perfect answers. Therefore, it was determined that the GeoGebra-assisted teaching strategy is preferable to the conventional approach for teaching calculus students about the graphs of trigonometric functions. As a result, the study's conclusions highlighted GeoGebra's usefulness as a teaching tool (Kepceoglu & Yavuz, 2016), emphasizing the necessity of using diverse representations in a variety of courses and subjects.

According to Pamungkas, Rahmawati, and Dinara (2020), who employed a quasi-experimental design approach to evaluate its efficacy, GeoGebra is useful for the study of spatial geometry in school. They discovered that GeoGebra has beneficial effects on the comprehension of space geometry, establishing it as an important tool for studying and teaching this subject. It improves the subject matter's theory-centered nature while also offering more effective learning techniques (Pamungkas et al., 2020). It is clear from the thorough analysis of the research on GeoGebra's application that this program has considerable benefits for mathematics instruction. Numerous studies have shown that GeoGebra, a sophisticated and dynamic mathematical software package, can help with a variety of calculations and jobs with varied degrees of complexity. For a variety of people, including students, instructors, researchers, scientists, and mathematics professionals, it offers several benefits. Users of all skill levels, from elementary school children to those in college and beyond, as well as their instructors, can access it because of its user-friendly design. As a result, GeoGebra is recognized as a useful tool for a variety of tasks, such as learning, teaching, and studying.

Students' Opinion on GeoGebra Software in Learning Mathematics

In GeoGebra, mathematical objects are divided into free objects and dependent objects. It is possible to package the building steps for dependent objects that are specified by an explicit construction, be it algebraic or geometric. Once a tool has been defined, a new button will show up on the toolbar and the user will have access to the function name. These devices can work with geometrical objects like circles, lines, and points and are essentially functions. The usage of tools in GeoGebra is fascinating because it enables the design of geometrical functions, which highlights an important mathematical concept called encapsulation or compression. These features allow for the organic growth of the software, much as how mathematical domains naturally grow during regular teaching. GeoGebra is regarded as a user-friendly mathematics program for geometry, algebra, and calculus coursework, according to Wulandari (2015). Similarly, in Wulandari's study, students see GeoGebra as a piece of mathematics software that aids in the comprehension of abstract mathematical concepts. Additionally, GeoGebra helps students learn the concept of straight-line graphs more thoroughly. Thanks to its unique and varied visual representations. GeoGebra is useful for both students and teachers since it can be used to design interactive lessons that let students explore a variety of abstract mathematical ideas. Furthermore, GeoGebra encourages learners to dive deeper into their study of mathematics, according to Preiner (2008).

According to Dikovic's 2009 study, using GeoGebra enables students to investigate different function types and make links between symbolic and visual representations. In their 2013 study on the learning of circles, Shadaan and Eu discovered that integrating GeoGebra into the classroom increased students' critical thinking, inventiveness, and capacity for logical inference. According to Chimuka's (2017) research, learners thought GeoGebra's integration helped them focus more on mathematical ideas and made computations easier. Both Kim and Md-Ali (2017) and Azizul and Din (2016) discovered that giving students the chance to utilize GeoGebra while learning and interacting with classmates had a favorable impact on their interest in learning mathematics. Students were able to apply mathematics to their daily lives by using this dynamic software to foster critical thinking and linkages between concepts in shape and space.

In their 2016 study, Nocar and Zdrahal looked at three different approaches to teaching geometry, including paper-and-pencil graphing, CAS Maxima, and GeoGebra Dynamic Geometry Software (DGS). According to the findings, DGS improved students' conceptual and practical understanding of limit functions.

The Ubiquitous Geometry (UG) system was created by Hwang et al. (2015) for the purpose of teaching geometry, and students were enthusiastic about learning geometry on a computer and using the UG system. Children between the ages of 5 and 6 were used in a study by Seloraji and Kwan Eu (2017), which found that GeoGebra improved the children's arithmetic abilities.

2017 research by Fiallo and Gutierrez investigated the impact of dynamic geometry software on students' acquisition of trigonometry and found that it increased students' understanding of the subject. Using the GeoGebra program, which was discovered to be simple to use and successful in improving students' grasp of geometry, Azzizul and Din (2016) created mathematics teaching resources. Students preferred utilizing GeoGebra to learn about and comprehend angles in geometry, according to Boo and Leong's (2016) experience with teaching and learning activities involving the program. In a survey using the Geometry Sketchpad program, Dhayanti et al. (2018) found that it helped students develop and master their mathematical knowledge while improving their critical and creative thinking.

Empirical Review

GeoGebra has been used in numerous studies to improve students' skills in geometric construction. By Bakar et al. (2015), Ocal (2017), Saputra and Fahrizal (2019), Uwurukundo et al. (2022), and Velichova (2011), several advantages of adopting GeoGebra have been noted. These advantages include how simple it is for learners to use independently, the appealing animations and graphics, and the availability of straightforward exercises. In particular, it helps students explore, visualize, and build mathematical concepts, which strengthens their mathematical skills (Azizah et al., 2021; Shadaan & Leong, 2013; Tamam & Dasari, 2021). GeoGebra has been demonstrated to be a useful tool for raising the quality of learning.

According to the University of Wisconsin System (2022), GeoGebra's various features are approved for use within digital learning environments, enabling users to quickly solve mathematics problems, graph functions and equations, perform statistics and calculus, combine interactive geometry, and save and share results (Dahal et al., 2019; Hamzah & Hidayat, 2022).

GeoGebra was used as a tool by Ghanaian instructors in a study by Mensah, Ansu, Karadar, and Gurah (2023) to enhance mathematics instruction and learning. The study, which used a quantitative approach, found that instructors think GeoGebra may significantly improve mathematics instruction and learning in the classroom, demonstrating a readiness among teachers to incorporate information and communication technology (ICT) into their lesson plans.

Research on the adoption of GeoGebra in the teaching and learning of geometry among mathematics education students and in-service teachers was done by Narh-Kert and Sabtiwu in 2022. Based on action research, they discovered that both student performance and enthusiasm in learning and teaching geometry had statistically significant improvements. It was discovered that GeoGebra made lessons more applicable and simple to comprehend. The study recommends using GeoGebra in the instruction and study of geometry. GeoGebra was used by Azucena, Gacayan, Tabat, Cuanan, and Pentang (2022) to increase student confidence and algebra learning. A GeoGebra group and a control group were part in their quasi-experimental research design. According to the study, GeoGebra significantly accelerated learning, increased student confidence in algebra, and addressed their least-mastered skills. Algebra and other mathematics subject areas should be taught and learned using GeoGebra, according to the study.

Ihechukwu and Chidi (2020) looked into how Geogebra Software affected students' geometry performance and discovered that it had a positive impact on students' geometry performance regardless of gender. The study suggested implementing GeoGebra software in Secondary schools to aid in the teaching of mathematics.

According to Singh (2019), who investigated how utilizing GeoGebra in geometry lessons affected students' achievement, there was a large achievement gap between the experimental group (taught using GeoGebra) and the control group (taught using conventional methods). The study recommended encouraging the use of GeoGebra to enhance Secondary geometry instruction. In their 2016 study of GeoGebra's effectiveness in educating students about the periodicity of trigonometric functions, Kepceoglu and Yavuz concluded that computer-assisted mathematics instruction was superior to conventional techniques in terms of student learning.

Arbain and Shukor (2015) conducted a quasi-experimental study to evaluate the impact of GeoGebra software on Malaysian students' mathematics achievement. Results showed that when utilizing GeoGebra, students had an excellent opinion of the software and improved learning results. Bhagat and Chang (2015), looked at how GeoGebra affected the mathematical proficiency of ninth-grade pupils as they learned geometry. GeoGebra was determined to be useful for teaching and studying geometry in Middle school by the study.

In research to evaluate GeoGebra's impact on students' conceptual and procedural knowledge of limit functions, Hutkemri and Zarkria (2014) discovered that students' comprehension of the subject had greatly improved.

Zegin, Furkan, and Kuttaca (2012) conducted research on GeoGebra's effects on students' trigonometry achievement and came to the conclusion that it helped students learn and comprehend trigonometry more effectively.

GeoGebra was used to create symmetry-related teaching resources by Akkaya, Tatar, and Kagizmanli in 2011. Dogan and Icel discovered that GeoGebra improved students' understanding of and motivation for learning about triangles.

Based on a case study by Reis (2010), effective mathematics instruction and long-term learning depend on the implementation of GeoGebra in the classroom.

GeoGebra improved student performance and conceptual acquisition of coordinate geometry, particularly among students with high visual-spatial ability (HV), according to Saha, Ayub, and Tarmini's (2010) research.

GeoGebra materials were found to be more effective than conventional techniques by Zerrin and Sebnam (2010) in teaching the concept of parabola.

In a quasi-experimental study, Dogan (2010) discovered that computer-based exercises using the GeoGebra program boosted students' motivation and helped them retain knowledge. Saha, Ayub, and Tarmini (2010) discovered that GeoGebra significantly increased mathematical accomplishment compared to conventional teaching techniques when used to teach coordinate geometry to children with good visual-spatial aptitude.

Collectively, these studies highlight GeoGebra's efficacy and beneficial effects on mathematics teaching and student learning across a range of mathematical themes and educational levels.

Conceptual Framework

Based on the thorough literature study, a conceptual framework was created. According to Brunswick (2009), the conceptual framework is a diagrammatic description of the variables and how they interact to fulfill the study's objectives. The use of GeoGebra in instruction was one of the independent factors that were used in the study. The study's dependent variable was how well students did academically in geometric construction. Thus, the framework illustrates how GeoGebra software has an impact on students' academic achievement in geometric construction.. Figure 2 shows the conceptual framework of the study.

Teaching using GeoGebra

Student’s performance in Geometry

Figure 2: Conceptual Framework of the Study

Source: Author’s construct, 2023

To assess the impact of GeoGebra on raising students' academic achievement in geometric construction, the conceptual framework was modified. According to Simbolon and Siahaan (2020), geometry software is frequently used as a tool to generate, show, or represent abstract mathematical problems that cannot be addressed manually. On the other hand, Pamungkas, Fadhilah, and Hasenda (2019) highlighted that GeoGebra can be used to display and demonstrate mathematical concepts, particularly in geometry and algebra. Because of GeoGebra's potential in mathematics education, and because it enables students to employ algebraic and geometrical functions simultaneously with interactive dynamics that improve their cognitive capacities, its inclusion in the school curriculum is advised (Zetriuslita & Endang, 2020).

Kusumah (2003) listed a number of advantages of using GeoGebra in math education and said that it is best for learning concepts that need high accuracy, repetition of ideas or principles, and exact chart completion. In addition, Kusumah (2003) asserted that the development of computer-assisted learning is ideally suited for integration into the study of mathematical ideas, particularly those requiring the transformation of geometry, calculus, statistics, and function graphs. Increased use of GeoGebra in mathematics instruction, according to Simbolon and Siahaan, is necessary for effective instruction and lasting learning that improves students' academic achievement.

METHODOLOGY

Introduction

This chapter covers research methodologies with the goal of determining the appropriate approach to respond to the posed research questions to aid in attaining the research's goals and objectives. The study area, research design, target population, sample size and sampling method, data collection instruments, instrument validity and reliability, data analysis, and ethical considerations are all specifically covered in this chapter.

Study Area

The study was conducted in the Old Tafo Municipality. By Legislative Instrument 2293, which went into effect on November 16, 2017, the Old Tafo Municipal Assembly was created to carry out the duties outlined in Section 10 of the Local Government Act, 1993 (Act 462), as amended by Sections 12 and 13 of the Local Governance Act, 2016 (Act 936) of 2017. The administrative center is located in Old Tafo, Kumasi (Ghana Statistical Service, 2021).

The municipality is in the region's center, bordered to the north, south, and east by the Kumasi Metropolitan Assembly, to the west by the Suame Municipal Assembly, and by sister assemblies Kwabre East Municipality and Afigya Kwabre North. It covers a total land area of about 31.13 square kilometers. It is elevated 250 to 300 meters above sea level and situated between latitude and longitude (GSS, 2021). 0 6.42 N 0 6.45 N 0 1.35 W 0 1.37 W. According to the 2010 Population and Housing Census, 193,040 people lived there as of 2021, with a growth rate of 3.91. 12,869 people live in each square kilometer, with a gender ratio of 91.4. The municipality has a sixty-six percent (66%) Akan population which constitutes the ethnic majority. The presence of various ethnic groups, including the Mole Dagbamba (26.01%), Ewes (4.72%), and Ga-Dangme and other ethnic minorities (3.27%), suffice to say that Old Tafo is regarded as cosmopolitan.

The municipality is influenced by all three major religions: Native Tradition, Christianity, and Islam. Religiously, there are some variations in how they practise (PHC 2010). There are over 30 communities in the municipality, totaling about 55,000 homes. Old Tafo, Ahenbronum, Nhyiaeso, Santan, Adompom, Pankrono, and Adabraka are some of the larger settlements (GSS, 2021).

For effective and efficient management, the municipal education system is overseen by the Ghana Education Service and is divided into three (3) circuits. According to the Old Tafo Assembly of 2021, there are 46 public educational institutions in the municipality, including kindergarten (12), primary (16), JHS (15), and SHS (3). There are currently 814 teachers working in public schools in the municipality, and they are all qualified individuals. There are currently 25,234 students enrolled in public and private schools, with 14,192 females and 11,042 males. Infrastructure has been kept up-to-date and adequate as required for the delivery of fundamental educational standards. Poor infrastructure conditions include lighting, electricity, and sanitization, among others. The availability of libraries and other essential educational resources and facilities is inadequate (Old Tafo Assembly, 2021).

Research Paradigm

The philosophical issues of existence, knowing and worth, have a considerable impact on the research design from a literary perspective (Christou et al., 2008). As a result, since they influence the choice of research instruments, such philosophical issues as ontology, epistemology, axiology, and methodology assumptions need to be addressed clearly (Christou et al., 2008). Positivism and interpretivism are the two subcategories of epistemology, which deal with how people decide what is right (Streubert & Carpenter, 1999). The positivist approach to knowing is used in this study.

Since the current study places a greater emphasis on numerical data, the positivist approach was chosen for the investigation. Because they were acquired utilizing an objective epistemology, the study's findings can be trusted and used to direct additional research (Pham, 2018). According to interpretivism, people rather than inanimate objects are the source of meaning (Alharahsheh & Pius, 2020; Saunders, Lewis & Thorntill, 2019).

They contend that social science must be distinguished from natural science because it is impossible to study people and their social circumstances in the same way that physical phenomena can (Alharahsheh & Pius, 2020). As a result, it is advised that results from a small sample be thoroughly examined before being applied to a larger population.

Research Approach

According to Rajasekar, Philominathan, and Chinnathambi (2013), a research methodology is a logical and systematic method used to gather newly discovered and helpful information on an area of study. According to positivism and interpretivism's opposing epistemological concepts, research methodologies have traditionally been characterized as either quantitative or qualitative depending on the subject in question. There are two main ways to research, according to Fellows and Liu (2003): qualitative and quantitative approaches. Denzin and Lincoln believe that research methodologies can be divided into qualitative, quantitative, and multi-method categories. In stating that there are three main methods, Creswell (2003) agrees with Denzin and Lincoln. He names a third strategy, the mixed-method strategy, which Denzin and Lincoln had previously referred to as multi-methodology.

The quantitative research approach was used in this investigation. According to a deductive and objective point of view, the quantitative research approach is defined by concrete information such as counts, weight, mass, and other physical measurements (Fellows & Liu, 2003). According to Boateng (2014), the quantitative method is used to quantify variation in order to assess the severity of a problem or the existence of a relationship between different components of a phenomenon. In order to understand a certain event, it typically entails the analysis of frequencies and various observable factors (Phoya, 2012).

According to Phoya, the benefit of the quantitative approach is that it collects data on a large number of respondents' responses to a small number of questions, allowing for statistical aggregation of the data, comparisons, and generalization of the findings.

Additionally, the quantitative approach has the benefit of allowing for precise statements and enabling the researcher to draw conclusions with a known level of confidence regarding their scope (Weiss, 1998). The quantitative method, which primarily uses checklists and questionnaires as data-collecting methods, focuses on numerical measurements. Experimental research, correlational research, and survey research are a few instances of quantitative designs.

Research Design

The research design serves as a road map for carrying out the study and links its objectives with its practical application (Bloomfield & Fisher, 2019). The descriptive survey design and quasi-experimental design were the research techniques used in this study. A quasi-experimental design is an empirical study that does not randomly assign participants to groups but instead examines the causal impact of an intervention on a target population (Creswell, 2014). Quasi-experimental research mimics experimental research but lacks the traits of actual experimental research, claim Harris, McGregor, Perencevich, Furuno, Zhu, Peterson, and Finkelstein (2006).

Participants aren't randomly assigned to conditions or orders of conditions while the independent variable is changed. The participants were non-randomly divided into the treatment (experimental) and control groups according to the research design. The researcher was able to explore the cause-and-effect relationship by incorporating the GeoGebra software into teaching and learning to enhance students' performance in geometric construction through the use of a quasi-experimental approach.

Responses to research questions one and two were gathered using a descriptive survey methodology. The descriptive design accurately describes predictions, facts, and event characteristics (Asenahabi, 2019). The descriptive survey approach was chosen because it allows for the quick and efficient gathering of data from a large sample of respondents, which is appropriate considering the objective of the research. As Osei Kyeretwie Senior High School students are the primary focus of the study, the descriptive survey approach was also used to generalize the study's findings to these students. A descriptive survey research technique, according to Pandey and Pandey (2021), entails studying a portion of the population (via questionnaires or direct observation) in order to draw conclusions about how the rest of the population behaves or exhibits relationships.

Population

It was necessary to identify or define the target demographic from which the sample was taken because the research design depends on replies from respondents from whom information will be requested. According to Sekaran (2000), a population is any collection of individuals, occasions, or objects that the researchers are interested in learning more about. Students at Osei Kyeretwie SHS in the Old Tafo Municipality made up the study's target population.

1,500 students made up the population that could be accessed. Particularly, individuals were chosen from the second-year general arts, business, and home economics courses. Due to the researcher's extensive teaching experience in the Old Tafo Municipality and familiarity with the academic setting, the municipality was chosen for the study. Students in their second year were selected since they had one more year to finish their curriculum and no imminent pressure to sit for the WASSCE.

Sample Size and Sampling Technique

According to Avoke (2005), samples often represent a portion of the overall population that is of interest to the researcher. A multi-stage sampling strategy was used in this investigation. The procedure required splitting the population into strata A and B using a stratified sampling technique. Those studying business and a portion of general arts made up Strata A (the control group), while those studying home economics and a portion of general arts made up Strata B (the experimental group). Purposive sampling was used to choose the second-year general arts, business, and home economics courses.

General Arts (2Arts 4-6) and Business (2B2) were chosen specifically for the study as the control group, while General Arts (2Arts 8-10) and Home Economics (2HEcons 1-3) were picked specifically for the study as the experimental group. To make sure that the chosen students had the traits that would best answer the research questions, purposeful sampling was used. The study covered each and every student in the general arts, business, and home economics departments that were sampled.

790 individuals made up the sample size for this study, which was chosen from a limited population of 1,500 students. This corresponds to around 52.7% or 53% of the accessible student body at Osei Kyeretwie SHS. The population size of 1,500 students was used to determine the sample size. The breakdown of the sample size for the study is shown in Table 1 in great depth.

Table 1: Sample Size for Selected Control and experimental groups Control Group (Business) Experimental Group (General Arts)

Class	**Target population**	**Sample size**	**Class**	**Target population**	**Sample size**
2B2	50	50	2Arts 8-10	200	200
2Arts4-6	180	180	2HEcons 1-3	360	360
Total	**230**	**230**	**Total**	**560**	**560**

Questionnaire

Well-structured, closed-ended questionnaires were created to elicit information from the students in order to fulfil the study's goals. The research questions posed in the study were related to the questionnaire. Because they are simple for respondents to complete and for researchers to assess the data, close-ended questionnaires were utilized (Gay, 1996). The questionnaire, which was separated into three portions, based on the research objectives, primarily consisted of dichotomous response and rating scale items.

Section A provided background information about the respondents. Section B covered the challenges Senior High School students face when solving geometric construction problems, and Section C covered the students' opinions on the use of GeoGebra software in teaching and learning geometric construction. The researcher personally handed out the questionnaires to the chosen students, and they were then collected at the scheduled time to reduce poor response rates. It should be stated that the survey gave participants enough of time to properly analyze the questions and give truthful responses. This method made data collecting extremely efficient and improved the generalizability of the findings across a larger population.

Pre-test and Post-test Questions

Before and after the experiment, pre-test and post-test questions were given to the chosen class. There were 3 items for the pre-test questions and 5 items for the post-test to measure students' understanding of the subject. The questions for both the pre-test 51 and post-test were created, typed, and copied by the researcher to guarantee the security, validity, and reliability of the test items. For each task, students were told to present all of their work and not black out or erase any writing. After then, both sets of scripts were marked, recorded, and analysed.

Validity and Reliability of the Instrument

In this study, emphasis was placed on instrument validity, which refers to how well an instrument assesses the structures it was designed to test (Kumar, 1999). Instrument validity is concerned with establishing if an instrument appears to measure what it is meant to measure. Consequently, a thorough evaluation of the questionnaire items during the preparation process was required to ensure the validity of research instruments.

The researcher conducted a pilot study at Ahzaria Islamic SHS, which led to the reorganization of questions for the main study, to see if the instruments would fulfil their intended aims. We looked for any potential ambiguity in the test questions from the pre-test and post-test. To resolve any concerns with clarity or ambiguity, the questionnaire was also discussed with the supervisor.

Data Analysis

For the study, quantitative data were gathered through the distribution of questionnaires. The information received from the teacher questionnaire survey underwent a data cleaning step after the data collection phase. Any mistakes made in filling out the questionnaires were fixed, and the information was then coded. Then, the coded data were entered into the Windows version of SPSS program, 23.0.

A 95% level of confidence and a 5% level of significance were used to assess the data. Several statistical indicators, including mean, standard deviation, skewness, and kurtosis, were used to summarize the data. A paired t-test was also performed to compare the geometric construction performance of students taught using GeoGebra software with those taught using the traditional technique.

Ethics in Data Collection

Ethics serve as norms that distinguish between acceptable and unacceptable behaviour (Miller, 2009), play a vital role in research. In Western societies, the paramount ethical concern is the individual's right to privacy. Certain aspects of a research situation or characteristics of individual participants may render them easily identifiable, making it impossible to conceal their identities without distorting the research. Therefore, informed consent must be based on a realistic understanding of the practical limitations of anonymity and confidentiality.

By purposefully excluding alternatives for information like names and phone numbers from the questionnaires, the researcher in this study upheld the standard of anonymity for the included respondents. As a result, the

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respondents' right to privacy was often upheld, and the researcher used caution while determining whether to record sensitive material.

Furthermore, regardless of whether an explicit promise had been made, the identities and data collected were handled with confidentiality. The researcher placed a prologue on the questionnaire assuring adequate procedures to preserve respondents' data in order to ensure the anonymity of the students. With this confidence, respondents were more willing to open up and talk about delicate topics pertaining to the use of the GeoGebra software. Individuals not directly involved in the study were not given access to any identified information.

Additionally, there was no coercion used to force students to take part in the study. The research techniques and associated risks were clearly disclosed to the potential responders, and the questionnaire was only supplied after each participant had given their agreement to participate. Due to the researcher's ethical study practices and lack of coercion, the responses were accurate, the response rate was high, and the data was collected on time. 54

RESULTS AND DISCUSSION

Overview

This chapter presents the study's findings with an emphasis on the opinions expressed by second-year General Arts, Business, and Home Economics students in the Old Tafo Municipality. The findings are particularly pertinent to Senior High School students' difficulties with Geometric Construction problems, their opinions on the use of GeoGebra software in the teaching and learning of geometric construction, and the effects of GeoGebra-based Geometric Construction instruction on SHS students' academic performance.

Analysis and Results

Response Rate

The identified students were given a total of 790 questionnaires, 560 were given to the experimental group and 230 to the control group. 660 of the 790 questionnaires that were distributed were actually returned. As a result, an 83.5% response rate was used as the basis for the study's analysis. This response rate was thought to be sufficient for inferring study conclusions. A response rate of 50.0% is deemed adequate, 60.0% is good, and 70.0% is very good, according to Mulusa (1998). As a result, the 83.5% response rate was deemed to be extremely good for supplying the necessary data for data analysis.

Demographic Characteristics of Respondents

From the students, a variety of demographic data was acquired. In this study, the 55

respondents' demographics, including gender, age range, and living situation, were analysed. Table 2 provides a tabular summary of the demographic information. **Variable**	**Category**	**Frequency (N)**	**Percentage (%)**
Gender	Male	228	30.0
Female		533	70.0
Age group (years)	16-18 years	343	45.1
19 years and above		337	44.3
Living status	Mother only	190	25.0
Both parent		533	70.0
Other relatives		38	5.0

According to Table 3, the respondents generally agreed that they had trouble envisioning the procedures necessary to solve geometric construction problems. This statement had a mean score of 3.80 and a standard deviation of 1.123. A mean of 3.75 and a standard deviation of 1.375 indicate that respondents also stated that they frequently made blunders or errors when attempting to design geometric figures. With a mean score of 3.70 and a standard deviation of 1.188, the students also acknowledged that they found it challenging to precisely measure and mark angles, lengths, and other geometric aspects during construction.

A mean score of 3.45 and a standard deviation of 1.565 were obtained from the respondents, who also acknowledged that it was difficult for them to identify and choose acceptable tools and procedures for creating geometrical shapes. However, with a mean score of 3.35 and a standard deviation of 1.196, the respondents acknowledged that they had trouble grasping the guidelines and requirements for geometric constructing problems.

With a mean score of 2.50 and a standard deviation of 1.363, however, the majority of respondents disputed that they thought geometric construction was less significant or useful than other mathematical topics. The respondents disagreed that they found it difficult to apply various geometric construction methods, such as compass and straightedge constructions, with a mean score of 2.35 and a standard deviation of 1.156. Additionally, the respondents disagreed with the idea that the teacher did not offer advice and assistance in order to get beyond obstacles in geometric construction, as shown by the statement's mean of 2.35 and standard deviation of 1.315.

The results of this study show that students have trouble solving geometric construction. Students have difficulties visualizing the steps involved in geometric construction, 58