UNIVERSITY OF EDUCATION, WINNEBA

EFFECT OF GEOBOARD SOFTWARE ON JUNIOR HIGH SCHOOL PUPILS' ACADEMIC ACHIEVEMENT IN AREA AND PERIMETER OF PLANE FIGURES

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DECLARATION

Student's Declaration

I, **Kingsford Bondzie,** declare that this thesis, with the exception of quotation and references contained in published works which have all been identified and duly acknowledged, is entirely my original work, and it has not been submitted, either in part or whole, for another degree elsewhere.

Signature……………………………..

Date……………………………..……..

Supervisors' Declaration

We hereby declare that the preparation and presentation of this work were supervised in accordance with the guidelines on the supervision of thesis as laid down by the University of Education, Winneba

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DEDICATION

I dedicate this work to my family for their love and support.

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GLOSSARY

ANCOVA	Analysis of Covariance
BECE	Basic Education Certificate Examination
STEM	Science, Technology, Engineering and Mathematics
JHS	Junior High School
SPSS	Statistical Package for the Social Sciences
TIMSS	Trends in International Mathematics and Science Study
WAEC	West African Examination Council
CCP	Common Core Programme
NaCCA	National Council for Curriculum and Assessment

ABSTRACT

The purpose of the study was to investigate the effect of Geobaord software on basic seven (7) pupils' academic achievement in area and perimeter of plane figures. The study used a quasi-experimental non-equivalent pre-test post-test research design. The study made use of cluster sampling technique to select basic seven (7) classes from two different schools within the Effutu Municipality. The sample size for the study was 109 pupils. The instruments used were pre-test and post-tests with an intraclass correlation coefficient of 0.875. The pre-test scores were used to establish that pupils in the two schools had similar or equivalent abilities in area and perimeter of plane figures before the intervention. The post-test scores were used to determine the differences in academic achievement between pupils who were taught area and perimeter with the use of the Geoboard software and pupils who were taught area and perimeter without Geoboard software. The pupils who were taught using the Geoboard software performed better than their peers who were taught the concepts of area and perimeter without the use of the software. The study also found that the use of Geoboard software in teaching and learning increased the interest of pupils to learn area and perimeter of plane figures. Based on the findings, it was recommended that integrating the use of Geoboard software into the teaching and learning of mathematics will help improve pupils' understanding of mathematics and make mathematics interesting to learn in Effutu Municipality.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter discusses the background to the study, problem statement, purpose of the study, objectives of the study, research questions, research hypothesis, significance of the study, limitations, and delimitations.

1.1 Background to the Study

Technology has become an integral part of our daily lives, and the field of education has not been left behind. With the advancement of technology, there has been a significant transformation in how education is delivered and received (Duffy, 2022). Digital technology has provided new tools and opportunities for both pupils and teachers to enhance the teaching and learning experience (Cavanaugh & Jacquemin, 2015; Heick, 2022).

According to Eyyam and Yaratan (2014), one of the areas in which digital technology has made a significant impact in education is mathematics. Mathematics can be a challenging subject for many pupils, but digital technology has made it more accessible and engaging. Mathematics software such as Geogebra, Mathway, and Photomath have changed the way pupils learn and practice mathematical concepts, providing them with interactive and visual tools to better understand complex ideas.

Geoboards are mathematical manipulatives consisting of a square or rectangular board with a grid of pegs and rubber bands. They are commonly used in mathematics education to teach concepts related to geometry, measurement, and algebraic thinking. In recent years, digital versions of geoboards have become increasingly popular, with geoboard software being used in classrooms and homes around the world. The use of geoboard software in mathematics education has been the subject of numerous research studies, with many studies indicating that geoboard software can be an effective tool for enhancing pupil learning and engagement (Carneiro et al., 2021; Johnson, 2018; Matengu, 2018). One advantage of geoboard software is that it allows pupils to explore geometric concepts in a dynamic and interactive way, and to easily manipulate and experiment with geometric shapes and figures. Geoboard software can also provide immediate feedback to pupils, allowing them to see the results of their actions in real-time, and can be used to support collaborative learning and communication among pupils (Carneiro et al., 2021).

Despite the use of software in mathematics education, many pupils still struggle with the subject (Hewson, 2019). Mathematics is a complex subject that requires a deep understanding of fundamental concepts and the ability to apply them in various contexts. However, literature shows that many pupils struggle with the subject (Martin, 2018; Nelson & Powell, 2018; Senyefia, 2017; Wein et al., 2011).

Mathematics is a crucial topic for the technical and methodical growth of every state (Krushna, 2020; Lakshmi & Kundarapu, 2018). Its impact on children's lives is significant, as it has become a crucial aspect of existence that is essential for technological and scientific advancement (Fatima, 2017; Pellissier, 2023; Suratno, 2016; Taylor, 2013). Mathematics is valuable as a tool for developing one's personality, reasoning skills, and mental faculties, making it a significant contributor to global general and primary education (Yığ, 2022).

The common core mathematics curriculum (CCP) focuses on developing pupils' mathematical literacy, problem-solving skills, and creative thinking, as well as equipping them with the confidence and skills to participate in society as responsible citizens (Ministry of Education [MoE], 2020). The common core programme (CCP) mathematics curriculum has been designed to meet the demands of life. Specifically, the curriculum is planned to assist the learner to:

a) Recognise that mathematics permeates the world around us
b) Appreciate the usefulness, power and beauty of mathematics
c) Enjoy mathematics and develop patience and persistence when solving problems
d) Understand and be able to use the language, symbols and notations of mathematics
e) Develop mathematical curiosity and use inductive and deductive reasoning when solving problems.
f) Become confident in using mathematics to analyse and solve problems both in school and in real-life situations
g) Develop the knowledge, skills and attitudes necessary to pursue further studies in mathematics develop abstract, logical and critical thinking abilities to reflect critically upon their work and the works of other (Ministry of Education, 2020)

Geometry is a significant field of mathematics that deals with points, lines, figures, space, and three-dimensional objects, as well as their interrelationships (Biber et al., 2013). Heilbron (2023) define geometry as "the area of mathematics related to the study of points and figures, and their properties." It is concerned with the study of shapes and spatial relationships of objects, and is taught from basic school to higher levels of education in

Ghana. The study of shapes and their properties helps us understand mathematics as an integral part of our everyday experiences and usage. For instance, symmetry, which is a fundamental aspect of geometry, is evident in the patterns found in nature and shapes, and this helps us to conceptualize and shape our world (Ginsburg & Oppenzato, 2017; Knuchel, 2004). A proper understanding of the concepts of shapes, particularly plane figures, and their properties lays a solid foundation for studying mathematical topics such as mensuration, vectors, fractions, statistics, and mechanics (Jones & Tzekaki, 2016)

Measurement, shape and space concepts in geometry offer opportunities to teachers practice and help pupils understand the concept in various patterns. Reasoning skills in pupil learning have transformed from a procedural to a conceptual approach and from basic to abstract learning (Moore, 2013; Suh & Moyer-Packenham, 2007). Learning activities with visualisation in geometry requires many approaches which are more effective for understanding the lesson. Many teachers believe that the virtual manipulative technique is one of the methods to teach geometrical concepts effectively. It helps pupils develop their conceptual understanding of mathematical ideas in multiple ways (Dahlan & Wibisono, 2021). Many researchers believe that virtual and physical manipulative use is effective in their instruction. Each manipulative type has its unique effectiveness in pupils' learning of geometrical concepts.

Several African studies on geometry have looked into various elements of teaching and learning in this subject. Ogunyomi (2021) used technology, especially the Geometer's Sketchpad programme, to improve geometry education in Nigerian secondary schools. According to the study, using technology increased pupils' knowledge of geometry ideas as well as their academic achievement on geometry activities. Again, Nasiru Muhammad and Maccido (2023) studied the influence of visual aids on geometry instruction in Nigerian elementary schools. The study discovered that using visual aids such as geometric shapes and diagrams increased pupils' grasp of geometry concepts and academic achievement on geometry activities. Also, Reddy et al. (2016) Mamali (2015) examined the geometry academic achievement of Grade 9 pupils in South Africa. According to the study, pupils' low geometry academic achievement was driven by a lack of teacher training, insufficient teaching resources, and limited access to technology. In addition, Gobebo, Tereza Gebriel (2016) investigated the link between Ethiopian children' mathematical achievement and motivation in geometry and their instructors' and parents' participation. The study discovered that pupils' enthusiasm in geometry was connected to their mathematical success, and that teacher and parent participation was critical in boosting pupils' motivation and accomplishment. Lastly, Kundema (2016) explored the benefits and drawbacks of using technology to teach and study geometry in Tanzanian secondary schools. The study discovered that the use of technology, notably GeoGebra software, had the ability to improve pupils' grasp of geometry topics, but that constraints such as limited infrastructure and teacher training hampered effective technology implementation in the classroom.

Overall, these studies have contributed to our understanding of geometry education in Africa, highlighting both successes and challenges in this field. The studies suggest that the use of technology and visual aids can improve pupils' understanding and academic achievement in geometry and its related concepts, but that challenges such as inadequate instructional materials, limited access to technology, and inadequate teacher training can hinder the effective implementation of new teaching strategies.

Gender has been shown to play a role in the learning and academic achievement of mathematics, including geometry. Research studies have revealed differences in the ways that boys and girls approach geometry problems, with boys tending to rely more on spatial reasoning and girls on verbal reasoning (Lauer et al., 2019). This difference in approach may lead to differences in achievement and attitudes towards geometry (Kivkovich & Chis, 2016). One study found that girls in middle school were less likely than boys to enroll in geometry courses, despite their comparable academic achievement on mathematics achievement tests (Armstrong, 2014). Another study showed that girls had lower self-efficacy beliefs in geometry than boys, which may affect their motivation and persistence in learning the subject (Watt et al., 2012). The use of visual aids and manipulatives in geometry instruction has been shown to benefit both boys and girls, but may be particularly helpful for girls who may struggle with spatial reasoning (Markey, 2009). Interactive geometry software has also been found to improve girls' achievement and interest in the subject (Fabarebo et al., 2023). Some studies have looked into the influence of gender on perceived difficult geometry topics in mathematics and accomplishment. Mutai (2016), for example, stated that the gender of pupils had an influence on mathematics learning in favour of men. Fabiyi (2017), on the other hand, did a study in Nigeria to see if the quantity of geometry ideas rated as challenging changed between male and female senior high school pupils. The study included 500 senior secondary school pupils and discovered that gender had a substantial influence on geometric concept learning in favour of female pupils.

In Ghana, geometric concept such as plane figures is a fundamental component of the mathematics curriculum, taught at both the junior and senior high school levels.

Nonetheless, there are issues with plane figures teaching and learning in the nation, such as a shortage of instructional resources, insufficient teacher training, and restricted access to technology. For example, Kabutey (2016) discovered that insufficient instructional resources and restricted teacher training were important problems impeding successful implementation of the geometry in Ghanaian junior high schools. Moreover, Zunurain et al. (2021) emphasised the necessity for additional manipulatives in geometry instruction to assist pupils better comprehend the topic.

Basic school pupils have consistently shown poor command of questions relating to mathematics on the Basic Education Certificates Examination. This verifies the claim that pupils' academic achievement in Geometry is particularly concerning (Kwadwo & Asomani, 2021) and has contributed considerably to the low academic achievement in the Basic Education Certificates Examination for around ten years. According to the conclusions of the chief examiner in 2010, 2011, 2012, 2014, 2015, 2017 & 2018 for the Basic Education Certificate Examination, a good percentage of basic school pupils repeatedly demonstrated insufficient control of geometry and its related items in the mathematics examination.

1.2 Statement of the Problem

In the learning of mathematics, it is expected that junior high school learners develop a strong foundation in basic arithmetic concepts such as addition, subtraction, multiplication, and division (Bryant, 2014); access to clear and concise explanations of key geometric concepts, such as space and shape, measurement, position and transformation (Atta & Bonyah, 2023; Auliya & Munasiah, 2019; Cesaria & Herman, 2019); use of visual aids, such as graphs and diagrams, to help pupils understand abstract concepts (Fang, 2023). Again, as part of their education, pupils are expected to develop strong spatial awareness and geometrical intuition, which enables them to visualize and manipulate geometric objects with ease. They are also to gain knowledge and understanding of geometrical properties and theorems, and be able to apply this knowledge to solve real-world problems. The ability to use these concepts and principles effectively is crucial in many fields, including architecture, engineering, and physics (Jones et al., 2006). Again, In Ghana, the expectation of learning mathematics at the junior high school level is similar to that of other countries. The Ghanaian national curriculum for mathematics at the junior high school level, in particular, strives to enhance pupils' mathematical knowledge, skills, and attitudes so that they can solve issues in everyday life and pursue further study in mathematics and related subjects(Adomako, 2019; Asante, 2017; Kwaku & Anderson, 2018; Ministry of Education, 2020).

However, academic achievement in geometry at the basic level in Ghana has been consistently poor, as reflected in the unsatisfactory results of the Ghanaian Basic Education Certificate Examination (BECE) mathematics in (2010, 2011, 2012, 2013, 2014, 2015, 2017 & 2018). Again, Ghanaian pupils' academic achievement in mathematics also indicated that, algebra and geometry were the weak content areas (Anamuah Mensah & Mereku, 2005; Butakor et al., 2017).

In an attempt to curb this problem, several measures have been made to address the poor academic achievement of mathematics by various governments. In 1987, the Ministry of Education restructured the educational system, which included an increased focus on mathematics, Science Technology, Social Sciences and technical skills (Biney et al., 2015). As part of the educational reforms, the Ghanaian Government implemented various measures to promote the teaching and learning of mathematics including the Science, Technology, Mathematics, Innovation and Education (STMIE) clinics. The STMIE clinics were designed to provide Junior High School (JHS) pupils with the opportunity to create products and models using local materials for exhibition purposes (Akyeampong, 2014). Again, in 2018, the Ministry of Education in Ghana released the Education Strategic Plan for the period of 2018-2030, which prioritized the need for improved quality of teaching and learning in STEM at all levels (Ministry of Education, 2018). Recently, The Ministry of Education (MoE) through NaCCA introduced the kindergarten-primary standards-based school curriculum and common core programme (CCP) for basic seven (7) to basic nine (9) (Ministry of Education, 2020). The introduction of these curriculum was to change the method of teaching and learning from a teacher-centered to learner-centered. A change that is expected to improve pupils' performance.

Despite the implementation of various educational interventions, including the STEM policy and the introduction of the new standard-based curriculum and Common Core Programme (CPP), basic school pupils in Ghana continue to face significant challenges in Mathematics. These initiatives were designed to enhance the quality of mathematics education and improve pupils' academic performance. However, their impact appears limited, as pupils' performance in Mathematics remains unsatisfactory (Amankwah-Amoah, 2016). This persistent issue is particularly evident in the chief examiners' reports for the Basic Education Certificate Examination (BECE) across multiple years—specifically 2010, 2011, 2012, 2013, 2014, 2015, 2017, and 2018. These reports have consistently highlighted that a large number of basic school pupils struggle with Geometry and related mathematical concepts. The reports identify several key areas of weakness, including:

1. Insufficient knowledge about properties of parallelograms and isosceles triangles
2. Difficulty in understanding the properties of congruent triangles
3. Challenges in constructing geometrical diagrams for a given problem
4. Insufficient knowledge in applying the Pythagorean theorem
5. Inability to find area and perimeter of geometric shapes
6. Difficulty with spatial reasoning and visualization
7. Problems with interpreting and solving word problems involving geometry
8. Lack of understanding in applying geometric theorems beyond the Pythagorean
9. Inaccuracies in performing geometric constructions

Overall, these findings suggest that many basic school pupils need additional support to master geometry and measurement related topics.

Evidence in literature reveals that Junior High School pupils in the Effutu Municipality performed below the mathematics national minimum standard in Geometry and measurement related areas (Mills & Mereku, 2016).

Table 1.1 shows the results of Junior High School pupils in the Effutu Municipality performance on the mathematics national minimum standard. The table provides an overview of the specific standards within five key content domains that pupils find most challenging to attain.

Table 1.1: Standards Most Pupils Find Difficult to Attain in Each of the Five Content Domains

Content domain	Standards specified by syllabus objective	Percent reaching standard	Difficulty ranking
Number operations and Algebra	1. Identify and use the appropriate operations (including combinations of operations) to solve word problems involving numbers and quantities, and explain methods and reasoning.	47.55	5
	2. Write common fractions which are multiples of halves, fourths, fifths, and tenths as percentages and convert it to its simplest form (and vice versa).	32.46	1
	3. Compare and order common rational numbers expressed as (common fractions, decimals and percentages).	47.37	4
	4. Add and subtract fractions where the denominator of one is a factor of the other.	49.22	7
	5. Carry out short multiplication and division of numbers involving decimals.	42.81	3
Measures, Shape and Space	6. Bisect a given line segment and an angle and measure the result.	49.99	8
	7. Find the perimeter and area of simple shapes drawn in square grid or draw such shapes when given the perimeter and area.	37.89	2
Problem Solving Applications	8. Perform simple computation using the calculator as well as use it to check answers.	48.49	6

Source: (Mills & Mereku, 2016)

Results from Table 1.1 are data obtained on pupils' academic achievement on the Ghanaian junior high school mathematics national minimum standards in the Effutu Municipality. show that a number of the standards have not been achieved by majority of

JHS 2 pupils (Mills & Mereku, 2016). From the results, about 47.55% of pupils could solve simple word problems with a majority (52.45%) not achieving standard 1. On standard 2, 32.46% of the pupils could write and convert, to its simplest form, common fractions as percentages. 47.37%, 49.22% and 42.81% of pupils could compare and order common rational numbers expressed as fractions, decimals and percentages, add and subtract fractions, and perform short multiplication and division of numbers involving decimals respectively. Furthermore, only about 49.99% could bisect and measure a line segment and an angle, 37.89% could find the perimeter and area of simple shapes leaving a majority (62.11%) who could not. These results show that a large number of pupils are yet to grasp some of the minimum content standards that every pupil is expected to acquire upon completing JHS, including measures, space and shape as indicated by results in table 1. Data from the table indicates that finding the perimeter and area of simple shapes drawn in square grid or drawing such shapes when given the perimeter and area is second most difficult standard for junior high school pupils in the Effutu municipality.

Furthermore, Yen's (2021) investigation revealed a persistent pattern of difficulties encountered by junior high school pupils residing in the Effutu Municipality when it comes to mathematics. This research sheds light on the enduring nature of these challenges, suggesting a need for targeted interventions and support mechanisms to address the underlying issues hindering pupils' mathematical proficiency within this community. The findings from Yen's research reveal that, on average, pupils in the Effutu Municipality only marginally pass mathematics, with an average pass rate of 59.5% between 2016 and 2019. This implies that, typically, 40.5% of pupils in the Effutu Municipality fall short in mathematics.

Table 1.2: Effutu Pupils Mathematics Performance in Basic Education Certificate Examination (2016-2019)

Year	Pass rate (%)	Failure rate (%)
2016	60.5	39.5
2017	58.2	41.8
2018	60.8	39.2
2019	58.6	41.4

Source: Effutu Municipal Examination Unit of Ghana Education Service (2016-2019) as cited in Yeng (2021)

Data provided in Table 1.2 indicates that junior high school pupils in the Effutu Municipality encounter difficulties with mathematics exams, as evidenced by a mean pass rate of 59.5% and an average of 40.5% failing. Except for 2016 and 2018, during which a relatively higher proportion of candidates passed, approximately half of the candidates presented for the examination in the other years achieved only an average level of success. The substantial number of pupils failing indicates that mathematics performance in the municipality has not reached an optimal level, emphasizing the necessity for interventions to enhance mathematics education.

It is crucial that pupils' difficulty in finding area and perimeter at the basic level is given importance as one of the most significant effects is that it can limit one's ability to pursue specific vocations or courses. STEM (science, technology, engineering, and mathematics) fields require a strong measurement foundation, and not developing measurement skills can limit one's opportunities in these professions (National Research Council, 2011). Furthermore, a lack of measurement understanding can impair one's capacity to comprehend and cope with essential real-world issues. Measurement technician, metrology and engineer for example, all require knowledge of area and perimeter. People who lack this awareness may struggle to make informed decisions on critical issues (Kamin, 2016). In addition to these practical implications, pupils' inability to grasp measurement concepts may have psychological consequences. According to research, pupils who struggle with mathematics may suffer worry, irritation, and a sense of failure (Luu-Thi et al., 2021). This can lead to a lack of confidence and a reluctance to engage in more challenging academic areas in the future.

On the subject of area and perimeter, studies have been conduct such as (Anwar et al., 2016; Stone, 1994; Winarti et al., 2012) which look at the mathematical relationship between area and perimeter; Espejo and Deters (2011) examined the use of real object in teaching area and perimeter; Machaba (2016) investigated the misconceptions of area and perimeter among middle school pupils; Satsangi and Bouck (2015) and (Cass et al., 2003) examined the effect of virtual manipulatives and physical manipulatives on pupils with learning disabilities in area teaching area and perimeter; and Yeo (2008) examined the pedagogical content knowledge of teachers in teaching area and perimeter. Santsangi and Bouck's study had a relatively low sample size with 3 pupils with learning disabilities. In Ghana, several studies have been conducted on the teaching of geometry and its related concepts. Aboagye et al. (2021) examined factors influencing the perceived difficulties in studying geometry; Armah and Kissi (2019) investigated the use of the Van Hiele theory in teaching strategies used by college of education geometry tutors; examined the achievement and mastery of Geometry of pre-service teachers in college of education in Bambila; (Kakraba, 2020) investigated the effect of mastery-based learning approach on pre-service mathematics teachers academic achievement in volta region. A review of literature shows that not much in terms of research has been done on area and perimeter of plane figures, specifically on the use of virtual manipulatives such as geoboard software in teaching the concept area and perimeter at the junior high school level. In terms of the Effutu Municipality, no research has been conducted on the concept of area and perimeter. As a result, more research into using Geoboard software as a teaching and learning aid is needed to understand better how they might be used to increase pupil learning and engagement in teaching and learning of area and perimeter. Hence, the problem to be addressed in this study is to investigate the effect of geoboard software on junior high school pupils' academic achievement perimeter and area in Effutu Municipality. The study specifically seeks to determine whether using geoboard software as a teaching tool will increase pupils' academic achievement in solving perimeter and area problems.

1.3 Purpose of the Study

The purpose of this study was to investigate the effect of Geoboard software on junior high school pupils' academic achievement on plane figures in the Effutu Municipality.

1.4 Research Objectives

The Objectives of the study are to:

1. Find the level of academic achievement of pupils on areas and perimeters of a plane figures.
2. Establish the difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught area and perimeter of plane figures without Geoboard software.

3. Establish the difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught area and perimeter of plane figures without Geoboard software at the Van Hieles' levels of Geometric Thinking.
4. Find out the difference in academic achievement between male and female pupils taught area and perimeter with Geoboard software.

1.5 Research Questions

The research question that underpinned the study is as follows:

1. What is the level of academic achievement of pupils on areas and perimeters of plane figures?
2. What is the difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught area and perimeter of plane figures without Geoboard software.
3. What is the difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught area and perimeter of plane figures without Geoboard software at the Van Hieles' levels of Geometric Thinking.
4. What is the difference in academic achievement between male and female pupils taught area and perimeter with Geoboard software.

1.6 Hypotheses

The following null hypotheses was tested in the study:

H_{o1}: There is no statistically significant difference in the academic achievement between pupils taught area and perimeter of plane figures using Geoboard software and pupils taught area and perimeter of plane figures without Geoboard software.

H_{a1}: There is a statistically significant difference in the academic achievement between pupils taught area and perimeter of plane figures using Geoboard software and pupils taught area and perimeter of plane figures without Geoboard software.

H_{o2}: There is no statistically significant difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught area and perimeter without Geoboard software at the Van Hieles' Levels of Geometric Thinking.

H_{a2}: There is a statistically significant difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught area and perimeter without Geoboard software at the Van Hieles' Levels of Geometric Thinking.

H_{o3}: There is no statistically significant difference in the academic achievement of male and female pupils taught area and perimeter using Geoboard software.

H_{a3}: There is no statistically significant difference in the academic achievement of male and female pupils taught area and perimeter using Geoboard software.

1.7 Significance of the study

The findings of this study will contribute to practice, literature and policy-making. In terms of practice, the integration of geoboard software into the geometry and measurement strand of the Common Core Programme (CCP) can assist educators, specifically mathematics teachers in Effutu in Ghana, teaching these concepts and enable pupils to gain a better understanding of area and perimeter as well other geometric concepts. Additionally, this approach can help pupils connect school mathematics to their everyday experiences, highlighting the relevance of math in their lives. By demonstrating the importance of virtual manipulatives in teaching mathematics, the study's results can enhance pupils' interest in mathematics.

Again, in terms of literature, this study is important because it addresses a gap in the literature on the integration of Geoboard software in teaching area and perimeter and other geometric concepts.

Finally, in terms policy-making, training session will be organised by GES, the Effutu Municipal Directorate, and NaCCA to teach innovative approaches to addressing challenging topics in the curriculum. This training will also serve as an opportunity to raise awareness among stakeholders about the importance of integrating virtual manipulatives in mathematics education.

1.8 Delimitation of the Study

This study was restricted to junior high schools in the Effutu Municipality, Central Region of Ghana. The study is focused on plane figures which is a concept in geometry and measurement strand from common core programme (CCP) mathematics curriculum for basic seven (7) specifically focused on area and perimeter. Also, quantitative methods will be used to obtain data on learners' progress when the experiment was being conducted. Therefore, the conclusions of the study are not to be extended beyond the subject matter of the study.

1.9 Limitations of the Study

This study utilized a quasi-experimental design, characterized by the deliberate assignment of participants into groups that are not randomly selected. Specifically, the utilization of unequal groups designated as control and experimental raises concerns regarding potential errors in data analysis. The absence of randomization in the selection of study constituents may introduce biases, thereby compromising the validity and reliability of the findings.

1.10 Organisation of the Study

The thesis consists of five chapters. Chapter One presents the background to the study, the statement of the problem, the purpose of the study, research questions, and the significance of the study, delimitation and limitations of the study and the organisation of the study. Chapter Two reviews the related literature. Chapter Three discusses the methodology while Chapter Four presents the analyses of the data collected. The thesis ends with Chapter Five, where the summary, conclusions and recommendations are presented.

1.11 Chapter Summary

This chapter gave an overall background which provided focus and direction for the study. The chapter first presented interactive software as innovative tool in the teaching and learning of geometry. The problem of the study was then presented which underscored the need for conducting the study. The chapter went further to state the purpose of the study and the specific objectives of the study. This was followed by the research question and hypotheses. The significance of the study was then discussed. The limitation encountered during the course of conducting the study was discussed and the delimitation was also presented. The last section, which is the organisation of the study was then presented before the summary of the chapter.

CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.0 Overview

This chapter delves into various pieces of literature, all of which are framed by the following themes: integration of digital technology in Ghanaian education, impact of digital technology integration on pupils' learning, enhancing mathematics teaching through the use of digital technology, Geometry instruction and learning, the concept of Area and Perimeter teaching and learning Area and Perimeter, interactive Geometry software in Mathematics education, manipulative instruction in Mathematics, pupils' academic achievement in Areas and Perimeters of Plane Figures, and influence of gender in Geometry. Finally, the chapter concludes with a presentation of the theoretical framework for the study, followed by a summary and empirical review in the last section.

2.1 Integration of Digital Technology in Ghanaian Education

The government of Ghana has shown a strong commitment to providing meaningful educational opportunities to all children, regardless of their location, gender, or disability. Ghana's longstanding free education policy has resulted in high enrolment rates and reduced traditional barriers to education. With the support of stakeholders such as the World Bank and FCDO, the government of Ghana is now focusing on further reforming its education system to improve learning outcomes, tackle issues relating to access to learning, learning inequality, gender and disability and also support teacher capacity improvements (Tahi, 2021).

One of the key strategies for achieving these goals is the integration of information and communication technology (ICT) in education. ICT is defined as "any device or application that allows users to access, manage, integrate, evaluate, create or communicate information (Mogea & Salaki, 2016). ICT can include computers, tablets, smartphones, interactive whiteboards, digital cameras, software applications, internet platforms, online courses, etc. ICT can be used for various purposes in education, such as instruction, assessment, administration, communication, collaboration, research, etc.

The use of ICT in education in Ghana was championed by the government of Ghana and implemented through its 2003 ICT for Accelerated Development (ICT4AD) policy (Kubuga et al., 2021). The policy aimed to transform Ghana into an information-rich and knowledge-based society and economy through the development and deployment of ICTs within all sectors of the economy (National Information Technology Agency, 2003)). The policy also recognized the role of ICTs in enhancing the quality and relevance of education and training at all levels. The policy outlined several objectives for ICT integration in education, such as: providing ICT infrastructure and equipment to all educational institutions, developing ICT literacy and skills among teachers and pupils, developing ICT-based curricula and content for all subjects, promoting ICT-based pedagogy and learning methods, enhancing access to educational resources and opportunities through ICTs, supporting educational management and administration through ICTs, encouraging research and innovation in ICTs for education, and establishing partnerships and collaboration among stakeholders for ICTs for education.

To operationalize the policy objectives, the government of Ghana initiated several projects and programmes to integrate ICTs in education at various levels. Some of these include:

The Basic School Computerization Project in Ghana, initiated in 2015, sought to equip public primary and junior high schools with computers, internet access, and training for teachers and pupils in basic computer skills (Natia & Alhassan, 2015). The Senior High School Connectivity Project, launched in 2016, extended similar provisions to public senior high schools, emphasizing advanced computer skills and digital content development. The One Laptop Per Child Project targeted rural and deprived areas, aiming to provide low-cost laptops to enhance learning opportunities, accompanied by training for both teachers and pupils. The iCampus Project focused on establishing online learning platforms for tertiary institutions in Ghana, involving the development of online courses and content. Lastly, the e-Learning Project aimed to offer online learning opportunities for out-of-school youth and adults, focusing on literacy and numeracy skills through the development of relevant online courses and content. All these initiatives were collaborative efforts between the Ministry of Education and the Ministry of Communications in Ghana (Natia & Alhassan, 2015).

2.2 Impact of Digital Technology Integration on Pupil Learning

The integration of technology in education in Ghana has had a positive impact on pupil learning. Research has shown that the use of technology in the classroom can improve pupil engagement, motivation, and achievement (Farjon et al., 2019). One study conducted in Ghana found that the use of multimedia resources such as videos, animations, and interactive simulations improved pupils' understanding of science concepts (Azumah et al., 2023). Another study found that the use of mobile phones in the classroom improved pupils' reading comprehension and writing skills (Farjon et al., 2019). However, there are also challenges associated with the integration of technology in education in Ghana. One of the main challenges is the lack of infrastructure and resources, such as reliable internet connectivity and electricity, which can limit the use of technology in schools (Farjon et al., 2019).

2.3 Enhancing Mathematics Teaching Through the Use of Digital Technology

The emergence of digital technology and its innovative advancements have revolutionized the landscape of learning and teaching, necessitating a transformation in individual and societal capabilities. According to Butcher (2015), the essence of incorporating new technologies in education lies in their ability to shape how we learn and practice mathematics. In the context of mathematics instruction, the integration of Information and Communication Technologies (ICTs) offers teachers the means to align with instructional goals and provides learners ample opportunities for comprehensive development.

Numerous studies have explored the implications of using digital technology in the classroom. In a particular study conducted by Ross and Bruce (2009), the interactive programme "Critical Learning Instructional Paths Support" (CLIPS) was employed in Grades 9 and 10classrooms to enhance understanding of fractions. This programme aimed to provide pupils with independent lessons, including video presentations and assigned readings, followed by quizzes and other activities. The results revealed that pupils benefited most when the digital learning tool was introduced during instructional lessons, suggesting that technology integration during instruction provides pupils with the necessary support for effective learning.

Dincer (2015) conducted a meta-analysis on the influence of Computer-Assisted Instruction (CAI) on college pupils' performance. Their findings indicated a general positive effect when pupils were exposed to computer-assisted instruction. The analysis further demonstrated that CAI packages specifically designed for a particular course had a more significant impact on pupils' academic achievement compared to general CAI packages. Additionally, consistent and continuous utilization of technology throughout the course, rather than as a one-time occurrence, yielded higher gains. The study also explored the provision of feedback within CAI packages and found no evidence supporting the hypothesis that providing feedback led to a significant improvement in pupils' performance. The study noted that pupils tended to briefly view the feedback on the screen before proceeding, highlighting the challenge of encouraging pupils to use the CAI package as intended by the instructor.

In contrast to the study conducted by Dincer (2015), which focused on exploring various technological packages, Sibiya (2019) took a more specific approach and investigated the Geobaord programme. Unlike Dincer, who examined different digital technologies, the present study referred to exclusively examined the utilisation of Geobaord as a digital technology. This narrower focus allows for a more in-depth analysis of the benefits, challenges, and outcomes associated with the implementation of Geobaord in educational settings. By concentrating solely on Geobaord, the researchers can provide more detailed insights into the specific features, instructional strategies, and pupil outcomes associated with this particular digital tool.

Walters et al. (2018) observed that digital technology devices provide impactful visual representations that engage pupils and facilitate their comprehension of mathematical concepts. This is why developed countries incorporate various digital technology devices, such as computers, web-based applications, graphic calculators, and dynamic mathematics/geometry software, into high school classrooms. Consequently, numerous studies in these countries have evaluated the effectiveness of digital technology in mathematics education, as highlighted by (Skryabin et al., 2015). Amarin and Ghishan (2013) conducted a study on the influence of educational technology on learner interactions and found that integrating technology into traditional teaching practices enhances pupils' interest and motivation to learn. The authors emphasized that incorporating technology into lesson presentations aligns with a constructivist approach to learning.

The drive to improve pupils' achievement in mathematics is often associated with how instructional content is delivered (Pierce & Stacey, 2011). Permatasari et al. (2022) stressed the importance of well-structured instructional lessons that enable learners to develop a comprehensive understanding of concepts and theories relevant to mathematical problem-solving. Several researchers have advocated for the integration of digital technology tools in the classroom as an effective way to enhance pupils' academic achievement in mathematics (Hähkiöniemi & Francisco, 2019; Permatasari et al., 2022; Piper & Malmont, 2009; Yoshida & Jackson, 2011). They suggest that educational institutions and mathematics instructors embrace the incorporation of technological resources in traditional classroom settings.

As demonstrated in the preceding discussion, the field of mathematics instruction relies heavily on the symbiotic relationship between technological innovation and pedagogical expertise, acting as a catalyst for mathematics teachers to engage pupils and foster a profound understanding of mathematical concepts (Khouyibaba, 2010). However, harnessing the potential of digital technology in mathematics education requires a thoughtful balance between pedagogy and content, necessitating a unique approach to integrating technology within the learning and teaching process. These technology-infused educational environments empower educators to adapt their methods and strategies to effectively address the diverse needs of their pupils. By seamlessly integrating educational tools into their teaching practices, educators unlock innovative opportunities that support and enhance pupils' learning journeys.

2.4 Geometry Instruction and Learning

Teaching geometry encompasses various activities, and the choice of a particular activity depends on the lesson objectives, as it significantly impacts how pupils learn geometry. One commonly employed method for learning geometry is through the use of diagrams. Diagrams serve as powerful tools for illustrating concepts and conveying spatial relationships. Lowrie et al. (2019) argued that diagrams aid in pupils' demonstration of spatial reasoning. Therefore, incorporating diagrams in geometry instruction involves the teacher visually representing geometric drawings and assisting pupils in recognizing graphical and geometric relationships within the diagrams.

Numerous studies have investigated the effects of geometric teaching and learning activities on pupils' learning outcomes. Yerushalmy et al., (1990) conducted a study examining the impact of high school pupils' use of diagrams in geometry. They employed an inquiry-based approach using "Geometric Supposers" from 1984 to 1988. The researchers identified three factors that hinder pupils when examining and interpreting diagrams: the specificity of geometric diagrams, frequent confusion arising from non-standard diagrams, and the potential for different visualizations of a single diagram. Data were collected from pupils who learned with "The Supposer" and those who did not, from various senior high schools. The findings revealed that pupils who used "The Supposer" integrated diagrams more effectively in their work. The researchers concluded that these pupils demonstrated a better understanding of geometric diagrams compared to those who did not use them.

In another study by Goldsmith et al. (2016), the significance of spatial reasoning in learning geometry was explored. The researchers aimed to investigate the relationship between learners' actions, visualizations, and how these were articulated. They utilized Microworld Matchsticks, a tool designed to help pupils develop mathematical meanings by establishing connections between their actions and the symbolic representations they constructed. The study involved a case study of two pupils. The results indicated that visualizations assisted pupils in establishing relationships between spatial and practical scenarios. Additionally, visualizations helped pupils establish algebraic relationships based on diagrammatic representations.

Developing deductive reasoning skills in pupils is a vital objective in teaching geometry. Jones et al., (2006) conducted a study comparing teaching approaches in geometry between China and Japan. They suggested that geometry instruction should incorporate modelling to apply geometric concepts, deductive reasoning, and problem-solving approaches in various contexts. The researchers concluded that improving the teaching of geometry requires the development of effective pedagogical models supported by well-designed learning tasks and tools.

Games offer another avenue for creating geometric activities that facilitate teaching and learning in geometry. Herbst et al., (2005) demonstrated this through a study investigating how teachers can lay the foundation for pupils to meaningfully define a figure. The authors involved 53 pupils from two high school geometry classes in a game called "Guess My Quadrilateral." The game aimed to assess pupils' prior knowledge of quadrilaterals. Before the instruction, pupils completed a questionnaire. Over three weeks, the researchers planned and implemented the game-based instruction, which focused on a neighbourhood of special quadrilaterals. The game required pupils to carefully examine each quadrilateral and differentiate it from its neighbouring shapes. Analysis of pupil responses indicated that as pupils discussed the properties of figures, they were able to draw the figures instead of merely describing them. The authors concluded that pupils utilized the information obtained from the game to assess the properties of the discussed quadrilaterals.

These studies highlight the importance of employing various teaching and learning activities in geometry instruction, such as diagrams, visualizations, deductive reasoning, and games. By utilizing these approaches, educators can enhance pupils' understanding and engagement in geometry, fostering a deeper grasp of geometric concepts.

In another notable investigation by Foster and Shah (2015), the potential of games in enhancing learning within an educational setting was examined. The researchers employed the Play, Curricular Activity, Reflection, Discussion (PCaRD) model as the teaching strategy. The study was conducted at a senior high school and employed a mixed-methods approach, utilizing experimental and control groups. Over the course of one year, three games were implemented using the PCaRD model. Pre- and post-tests were administered to measure achievement gains. The findings indicated that the PCaRD model significantly contributed to pupils' learning of geometry. Foster and Shah (2015) further emphasized that the PCaRD model facilitated teachers in effectively incorporating games into their teaching strategies.

Understanding pupils' thought processes is also crucial in assessing their comprehension and ability to demonstrate understanding when learning geometry. Dağlı, and Halat (2016) conducted a study to investigate the strategies employed by pupils in understanding geometrical concepts, specifically focusing on isosceles triangles. The study involved 105 pupils from six third-grade classrooms in Italy. The researchers explored how the orientation of a particular drawing influenced pupils' perception of isosceles triangles. The findings revealed that pupils utilized various naive methods of measurement in geometry when developing solutions. The researchers further reported that pupils showed improved learning outcomes when engaged in short activities. Similarly, Gunhan (2014) investigated pupils' thinking processes concerning the area and perimeter of geometric figures. This study included 130 primary school pupils in their fourth and fifth years in Italy. It specifically examined conflicting ideas surrounding perimeter and area. The researchers employed two worksheets to evaluate pupils' reasoning skills. The findings highlighted that pupils were more adept at making comparisons between areas than perimeters. Consequently, when attempting problems involving areas, pupils employed more appropriate strategies. The researchers also noted that pupils could be misled by their visual perceptions of geometric figures and that pupils tended to prefer working on individual geometric shapes rather than comparing them.

Geometry instruction is a fundamental component across all levels of education. Even at the university level, the use of geometric visualizations and activities remains relevant, including in the realm of non-Euclidean geometry. An illuminating study conducted by Kaisari and Patronis (2010) investigated how university pupils constructed models of elliptic geometry. The objective of the study was to explore how geometrical meanings can be developed through contextualization and practical applications. The researchers hypothesized that the reformulation of Euclid's axioms and the development of models for elliptic geometry would reveal pertinent relationships between basic and higher-level geometry. Throughout a semester, pupils were assigned specific tasks related to elliptic geometry and engaged in team discussions to express their views and interact with one another regarding various tasks. The study unveiled that regardless of the specific approach pupils employed in understanding geometrical concepts, they were able to effectively interact and influence their peers' understanding.

2.5 The Concept of Area and Perimeter

Area is defined as 'the amount of surface of a region' by Danielson (2005, p.67), and perimeter is defined as 'the distance around the territory'. She claims that in the lower grades, pupils are only taught to define area as the product of length and breadth (A = l b), which is utterly unrelated to the concept of covering surface. Children's success in understanding area is not independent of the resources they are provided to depict area during problem-solving, according to Bond and Parkinson (2010). Learners require objects or resources such as bricks and cuttings that they can fit, fold, match, and count so that they can work concretely to gain a conceptual knowledge of area and perimeter (Destina et al., 2012). This means that the formula length breadth is insufficient for pupils to grasp the idea of area and perimeter.

Again, in geometry, "area" is a fundamental concept that quantifies the amount of space occupied by a two-dimensional shape or surface (Muir, 2007). It provides a measure of the size or extent of a region, allowing for comparisons and calculations within the field.

Area is typically expressed in square units, such as square meters (m^2), square centimetres (cm^2), or square inches (in^2), depending on the system of measurement being used.

The calculation of area depends on the specific shape or region under consideration. Different geometric shapes have their own formulas for determining their areas. For example, the area of a rectangle can be found by multiplying its length (l) by its width (w), using the formula $A = l \times w$ (Muir, 2007). Similarly, for a square with equal sides, its area is given by squaring the length of one side (s), as expressed by the formula $A = s^2$ (Muir, 2007).

In the case of triangles, their areas can be calculated using the formula $A = 0.5 \times$ base $\times$ height, where the base represents the length of the triangle's base and the height is the perpendicular distance from the base to the opposite vertex (Muir, 2007). Circles have their own unique formula for area calculation, given by $A = \pi r^2$, where π (pi) is a mathematical constant approximately equal to 3.14159 and r represents the radius of the circle (Muir, 2007).

For irregular polygons, determining their area may involve dividing them into simpler shapes and summing up their individual areas. For example, the area of a trapezoid can be found using the formula $A = 0.5 \times (b_1 + b_2) \times h$, where b_1 and b_2 denote the lengths of the parallel bases, and h represents the height (Muir, 2007).

In geometry, the term "perimeter" refers to the measurement of the total length of the boundary of a two-dimensional shape or figure. It provides information about the distance around the outer edge of the shape, much like tracing the outline with a pen or pencil. The perimeter is a crucial metric as it aids in determining the size, enclosure, or containment of a shape (Stone, 1994).

The calculation of the perimeter depends on the specific shape being considered. Various geometric shapes have their formulas for calculating their perimeters. Understanding these formulas allows for accurate measurements and calculations. One common shape is the rectangle. To find the perimeter of a rectangle, one must add the lengths of all four sides. If the length of the rectangle is represented by 'l' and the width by 'w,' the formula for the perimeter, denoted as 'P,' is given by $P = 2l + 2w$ ((Inoue & Kimura, 1987).

In the case of a square, all four sides are equal in length. To calculate the perimeter, one can multiply the length of one side, represented by 's,' by 4. Hence, the formula for the perimeter of a square is $P = 4s$ (Inoue & Kimura, 1987)

A triangle is another fundamental shape in geometry. The perimeter of a triangle is determined by adding the lengths of its three sides. If the lengths of the three sides are denoted as 'a,' 'b,' and 'c,' the formula for the perimeter, denoted as 'P,' is given by $P = a + b + c$ (Inoue & Kimura, 1987)

In the case of a circle, the perimeter is more commonly referred to as its "circumference." The circumference is calculated using the formula $C = 2\pi r$, where 'π' (pi) is a mathematical constant approximately equal to 3.14159, and 'r' represents the radius of the circle (Inoue & Kimura, 1987).

For irregular polygons, the perimeter can be calculated by summing the lengths of all their sides. In the case of polygons with equal side lengths, such as an equilateral triangle or a regular pentagon, the perimeter can be found by multiplying the length of one side by the number of sides (Inoue & Kimura, 1987).

The concept of perimeter has practical applications in measurement. For instance, it is useful in determining the amount of fencing required for a yard, as the perimeter of the yard corresponds to the length of the fence needed. Similarly, when designing borders or paths, understanding the perimeter helps in accurately measuring the required materials. Moreover, in industries such as construction and architecture, determining the perimeter is essential for establishing the outlines and dimensions of various objects or structures (Inoue & Kimura, 1987).

The perimeter provides valuable information about the overall size or boundary of a shape. By measuring the perimeter, one can assess the space occupied by a shape within a two-dimensional plane. It serves as a fundamental aspect of geometric calculations and is a key component in solving problems related to measurement and shape analysis (Zhao & Wang, 2010).

2.6 Teaching and Learning Area and Perimeter

The study of area and perimeter in geometry holds significant importance in shaping pupils' comprehension and application of geometric concepts. Although the existing literature on specific aspects of area and perimeter is limited, some research has delved into exploring the construction of geometric shapes and objects, as well as utilizing geometric problems to enhance pupils' reasoning abilities and understanding of area and perimeter. One of such study conducted by Bouck et al. (2015) sought to investigate the effect of using a virtual manipulative through the National Library of Virtual Manipulatives – polyominoes (i.e., tiles) – as a tool to help teachers present a unit on area and perimeter. The results suggest instruction with virtual manipulatives improved the understanding of area and perimeter by middle school pupils with learning disabilities. The pupils performed better on the post-test in terms of number of problems correct and number of problems attempted than on the pre-test.

Bouck et al. (2015) utilized a multiple baseline design to investigate how manipulative instruction affected the problem-solving academic achievement of middle and high school pupils diagnosed with learning disabilities in mathematics. The researchers employed a combination of modelling, prompting/guided practice, and independent practice along with manipulative training to teach the pupils how to solve perimeter and area problems. The data analysis indicated that the pupils quickly acquired these problem-solving skills and were able to maintain them for two months. Additionally, they were able to transfer these skills to solving problems using paper and pencil. This research contributes to the existing knowledge by demonstrating that the use of tangible manipulatives promotes the long-term retention of skills.

This research sheds light on the significant role of integrating virtual manipulatives into the instructional approach for teaching area and perimeter to pupils with learning disabilities. It emphasizes the critical need for educators to pay meticulous attention to detail and ensure accuracy when delving into geometric concepts, particularly within the realm of area and perimeter.

By incorporating virtual manipulatives into the teaching process, pupils with learning disabilities are provided with an invaluable opportunity to enhance their mathematical abilities. These digital tools enable pupils to interact with visual and interactive representations of geometric shapes, thereby facilitating a deeper understanding of the fundamental principles underlying geometric phenomena.

The utilization of virtual manipulatives not only promotes active engagement and participation but also offers a multi-sensory learning experience for pupils. By manipulating virtual objects, pupils can explore various scenarios, manipulate dimensions, and observe the resulting changes in area and perimeter. This hands-on approach fosters a more comprehensive grasp of the abstract concepts involved in geometry, bridging the gap between theory and application.

Furthermore, virtual manipulatives provide a flexible and adaptable learning environment, allowing for personalized instruction that caters to the unique needs of pupils with learning disabilities. These digital tools can be customized to offer scaffolded support, guiding pupils through step-by-step problem-solving processes, and providing immediate feedback to reinforce their understanding.

In a study conducted by Yeo (2008), the influence of a teacher's mathematics pedagogical content knowledge (MPCK) on the instruction of area and perimeter to Grade 4 pupils was examined. Regarding the understanding of area, the pupils tended to perceive it as a formula rather than comprehending it as the amount of space enclosed by a two-dimensional figure. John facilitated the pupils' exploration of area through various examples and activities involving rectangles and squares. The pupils discovered that rectangles and squares with the same perimeter could have different areas.

The study emphasized the teaching of composite figures primarily composed of rectangles and squares, in alignment with the Grade 4 syllabus. Pupils utilized cut-outs of rectangles and squares to construct composite figures and measured their dimensions. John facilitated class discussions to address solutions and encouraged the exploration of different ways to find the area of composite figures through subdivisions. However, time limitations restricted further investigation in this area.

In terms of perimeter, John ensured that pupils were able to explicitly define it at the beginning of the lessons. The teacher also presented examples of L-shaped figures where the lengths were not explicitly given, challenging the pupils to employ reasoning skills and deduce missing lengths. Homework assignments involving composite figures with unspecified lengths were given to provide additional opportunities for practising perimeter calculations.

Overall, the research paper underscores the development of area and perimeter concepts within the lessons and identifies the significance of the teacher's content knowledge (CK) and pedagogical content knowledge (PCK) in facilitating pupil understanding of these concepts.

Freire et al. (2018) conducted a study focusing on the importance of teaching resources in Mathematics Learning, specifically in the context of plane geometry and the calculation of area and perimeter using geoboards. The study included a workshop designed to teach the concept of area and perimeter to pupils. The researchers employed a qualitative approach and utilized questionnaires, interviews, and observations as data collection instruments. Interviews were conducted with both teachers and pupils, while questionnaires were administered to 30 pupils to gather their perspectives on their learning experiences with area and perimeter.

The main objective of the workshop was to help pupils develop a deeper understanding of the concept of area and perimeter in geometry, emphasizing that it required more than mere numerical calculations. The workshop was conducted after the pupils had already covered the necessary mathematical concepts needed to comprehend area and perimeter. It provided pupils with the opportunity to develop their strategies and approaches, allowing them to go beyond applying specific theorems and concepts to solve area and perimeter problems.

The findings of the study revealed that 100% of the pupils agreed with the use of geoboards in geometry, as it facilitated the calculation of area and perimeter. The researchers noted that engaging in the task of solving area and perimeter problems enabled learners to analyse the problems, develop strategies, and make connections between the geoboards and the concepts of area and perimeter.

In conclusion, the study highlighted the significance of well-designed resources such as geoboards in enabling pupils to construct their mathematical knowledge. By providing a hands-on and interactive learning experience, these resources contribute to a deeper understanding of area and perimeter concepts in geometry. The study emphasized the value of incorporating such teaching resources to enhance mathematics instruction and pupil learning outcomes.

2.7 Interactive Geometry Software in Mathematics Education

Interactive Geometry Software (IGS) refers to computer programmes that provide users with an interactive environment to draw, measure, and explore geometric figures. These software tools enable users to manipulate and calculate variables of geometric figures, as well as establish relationships between them (Hollebrands, 2007). By allowing users to alter the orientation and appearance of geometric figures while preserving mathematical relationships, IGS enriches visual representations and aids pupils in understanding mathematical concepts and problem-solving strategies.

The visualization aspect of geometric reasoning is crucial in mathematics education (Mulligan, 2015), and IGS facilitates this process. Through IGS, pupils can manipulate points and components of geometric figures, observing the resulting changes in relationships and properties of the figures. This dynamic aspect enhances pupils' understanding and allows for a more interactive and engaging learning experience.

Several interactive geometry software (IGS) environments are available for educational purposes, including Geoboard, GeoGebra, Cabri 3D, and Geometer's Sketchpad. Among these, Cabri 3D, developed in 2004 by the French company Cabrilog, focuses on exploring three-dimensional geometric figures (Mackrell, 2011). As a commercial product designed for use in geometry and trigonometry, one of its significant advantages is the ability to animate geometric figures, offering a dynamic representation that surpasses traditional static drawings. The software allows users to establish relationships between points on a geometric figure and provides robust graphing and display functions, which enable connections between geometry and algebra, fostering a deeper understanding of mathematical concepts (Mackrell, 2011). Cabri 3D is compatible with multiple operating systems, including Windows, Mac OS, Android, iOS, and Linux, making it accessible to a broad audience.

The use of interactive geometry software like Cabri 3D enhances mathematics education by providing pupils with powerful tools to visualize, explore, and analyse geometric figures (Suparman, 2021). Its dynamic nature promotes active learning and deepens pupils' understanding of mathematical concepts in both two-dimensional and three-dimensional geometry (Suparman, 2021). Another software widely used in mathematics education is Geometer's Sketchpad, a commercial interactive tool that delves into various aspects of geometry and other mathematical areas. This software incorporates traditional Euclidean tools for geometric constructions, enabling users to construct figures such as pentagons or decagons, just as they would with a compass and ruler. One key advantage of Geometer's Sketchpad is its ability to perform transformations that may be challenging with conventional tools (Kgatshe, 2017). Users can easily manipulate objects, perform translations, rotations, reflections, and even animate geometric figures, bringing geometry to life and providing a deeper understanding of concepts while enhancing pupils' visualization skills.

Furthermore, Geometer's Sketchpad allows users to create and explore a wide range of objects that can be utilized to solve complex mathematical problems. The software facilitates the determination of midpoints and midsegments of objects, aiding in the exploration of geometric properties and relationships. However, it is important to note that Geometer's Sketchpad requires a paid license, which can limit its accessibility for pupils and teachers, as not all educational institutions or individuals may have the necessary resources to acquire the software. As a result, alternative free or open-source software options may be sought to ensure equitable access to geometry education tools. Despite this potential limitation, Geometer's Sketchpad remains a powerful tool for teaching and learning geometry (Kgatshe, 2017). Its interactive features, versatility in geometric constructions, and ability to perform transformations and animations contribute to a comprehensive and engaging learning experience that, when combined with effective pedagogical strategies, can enhance pupils' mathematical understanding, problem-solving skills, and geometric reasoning abilities (Kgatshe, 2017).

Geoboard, on the other hand, is an innovative open web application specifically designed for mathematics learning. This powerful tool can be accessed through the website https://apps.mathlearningcenter.org/geoboard/ and is also available as an application for iOS devices, as well as a convenient Chrome extension. Geoboard consolidates elements of various dynamic representations, providing pupils with a rich variety of computational tools for modeling and simulations (Carneiro et al., 2021). Its extensive range of features enables pupils to explore mathematical concepts interactively and visually, from geometric shapes to determining area and perimeter, offering a wide array of resources to support learning across multiple mathematical topics. Geoboard stands out as an exceptional mathematics learning tool due to its user-friendly interface, which effortlessly guides pupils and teachers through the application's functionalities, whether they are working independently or engaging in collaborative activities (Carneiro et al., 2021).

One of the notable strengths of Geoboard is its intuitive design and ease of navigation. Pupils can navigate the application seamlessly, accessing various tools and features without unnecessary complexities or confusion (Carneiro et al., 2021). The clear layout and logical organization of Geoboard's interface contribute to a smooth user experience, allowing pupils to focus on the mathematical concepts at hand. Teachers also find Geoboard's user-friendly interface advantageous for facilitating effective classroom instruction, allowing them to spend minimal time explaining the application's mechanics and more time guiding and supporting pupils' mathematical inquiries (Carneiro et al., 2021). Geoboard's platform extends its benefits beyond individual use and is well-suited for collaborative activities, enabling pupils to work together to explore mathematical ideas and solve problems collectively. The intuitive interface fosters effective communication and teamwork as pupils manipulate geometric shapes, investigate relationships, and analyse data (Mainali, Bhesh Raj, 2020). Geoboard's commitment to user-friendliness enhances the overall mathematics education experience for both pupils and educators alike. Additionally, Geoboard's web-based nature makes it highly accessible to users worldwide. By simply accessing the website, users can tap into a wealth of mathematical resources, regardless of their geographical location. This global accessibility promotes inclusive learning opportunities and allows pupils and educators to leverage the benefits of Geoboard's dynamic representations and computational tools.

Figure 2.1 shows the interface of the *Geoboard* web application.

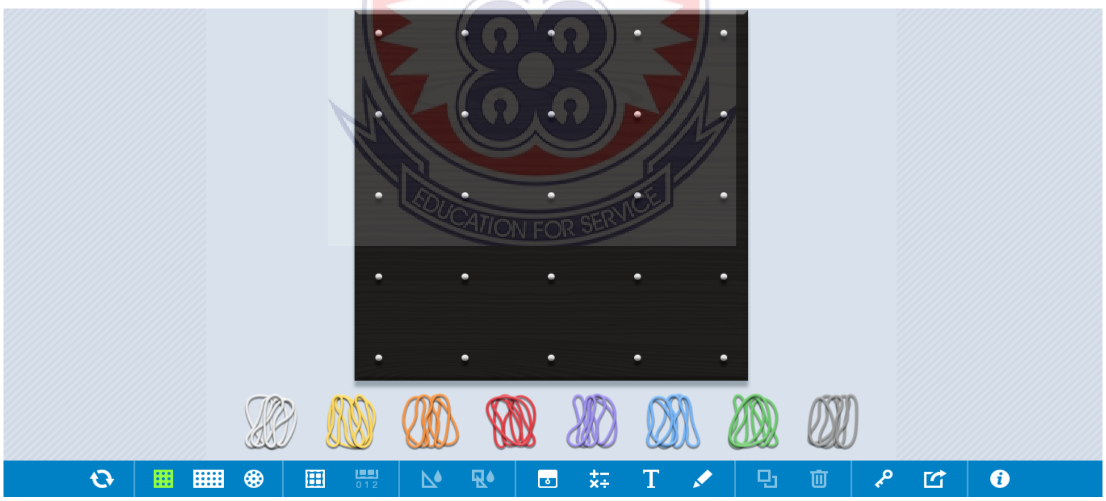

Figure 2.1; Geoboard application interface

Source: https://apps.mathlearningcenter.org/geoboard/

Figure 2.1 shows a digital geoboard with different coloured bands at the bottom. The board has a grid of pegs, and the bands can likely be stretched across the pegs to create various shapes or patterns.

There have been a number of studies that have focused on integrating IGS in mathematics teaching and learning. Strausova and Hasek (2013) conducted a study to investigate visual proofs with the use of IGS. The researchers suggested that diagrams play a vital role in helping learners conceptualised various mathematical properties. They also suggested that a geometric property or theorem can be proven using a diagram. Strausova and Hasek (2013) asserted pupils appreciate geometric proofs rather than the use of only words. Karaibryamov et al. (2012) as cited by (Badu Domfeh, 2020) also investigated courses optimisation in geometry with the use of the IGS. The researchers used a new method with the aid of IGS to teach geometry in at the tertiary level. The effective ways in which courses in geometry can be taught. Karaibryamov et al. (2012) reported that the use IGS helped optimised the teaching process by ensuring that there was enough time for drawing, generalise a large of problems and help form creative way of reasoning.

Ertekin et al. (2014) also investigated the effect of Cabri 3D on pupils' geometric ability in Geometry. The purpose of the study was to determine if the pupils could properly write out the equation of a given plane and draw a graph of the plane. Another objective of the study was to determine if pupils could find the normal vector of a given plane. The study comprised of 78 pupils grouped into two groups. The two groups were the experimental group and the control group. Pupils in the experimental group were taught with the Cabri 3D while pupils in the control group were taught without the Cabri 3D. The study found that pupils that were taught with the Cabri 3D were more successful in identifying identify special plane and the corresponding normal vector. The pupils taught with Cabr 3D were also more successful in drawing out corresponding diagrams for the special planes.

Another study was conducted by Donevska-Todorova (2015) to focused on pupils' understanding of the scalar product. The study sought to use IGS in a dynamic geometry environment to aid pupils understanding of dot product. The sample used in the study comprised of 12th-grade pupils learning in a dynamic geometry environment (DGE). The findings of the study showed that that IGS helped pupils to acquire a deeper understanding of dot product. Donevska-Todorova (2015) argued that the use of a number of diagrammatic representations helped pupils to gain more insight about a particular mathematical concept.

Bakar et al. (2015) investigate the effects of using Dynamic Mathematics Software (Geoboard) on pupils' academic achievement compared to the regular instruction without using technology for a Geometry topic. The analysis showed that pupils who were exposed to GeoGebra achieved significantly better test scores as compared to the group which followed the class without using any technology. However, the delayed post-test showed a different finding. The results from this study suggest that the integration of mathematical software in the teaching and learning of geometry is beneficial and the use of it should be continued.

From the prior discussion of the IGS and the literature available, the appropriate use of IGS holds a significant advantage in mathematics education. The succeeding section gives an empirical review of the use of *Geoboard* in mathematics education.

2.8 Manipulative Instruction in Mathematics

Manipulatives are physical objects that facilitate the understanding and exploration of abstract mathematical properties, concepts, or processes (Bouck & Flanagan, 2010; Moyer et al., 2002). They serve as instructional tools and can be categorized into two main types: concrete and virtual. Concrete manipulatives offer the advantage of being affordable and independent of external power sources. These include pattern blocks, algebra tiles, fraction strips, and geoboards, among others. On the other hand, virtual manipulatives are closely associated with computer technology and rely on software programmes and/or Internet accessibility (Bouck & Flanagan, 2010; Moyer et al., 2002).

Concrete manipulative instruction has been recognized as an effective pedagogical approach for pupils facing challenges in mathematics, aiding their comprehension of various mathematical concepts such as computation (Bartolini & Martignone, 2020), place value (Rodríguez et al., 2021), fractions (Morano et al., 2020) and word problem solving (Borghi et al., 2011). Existing literature extensively addresses the use of concrete manipulative instruction in relation to numbers and operations, particularly within lower grade levels of the mathematics curriculum. However, as pupils' progress in their academic journey, there is a noticeable shift in curriculum focus (CCSSI, 2010; NCTM, 2000), with greater attention given to algebraic and geometric principles in secondary education.

The available research on concrete manipulatives for pupils with learning difficulties, particularly those pertaining to mathematical concepts, contrasts greatly with the limited literature investigating the effectiveness of virtual manipulatives among elementary and secondary pupils. Although no studies specifically measuring the impact of virtual manipulatives were identified, three published studies were discovered that focused on elementary pupils identified with learning difficulties. Moyer-Packenham, Ulmer, and Anderson (2012) and Reimer and Moyer (2005) employed group designs to explore the use of virtual manipulatives in fraction-solving tasks for elementary pupils with learning difficulties, and both studies reported positive outcomes favouring the utilization of virtual manipulatives. Additionally, Bouck et al., (2013) examined the application of virtual manipulatives for acquiring single- and double-digit subtraction skills among three elementary-aged pupils diagnosed with autism spectrum disorder. When compared to concrete manipulatives, the authors observed improved skill acquisition when virtual manipulatives were employed to solve subtraction problems for each of the pupils.

Several studies present several justifications for the potential suitability of virtual manipulatives over concrete manipulatives when used by pupils with learning difficulties. One prevailing theory supporting this claim emphasizes the perceived impact of cognitive load on learners when employing concrete manipulatives to solve complex problems (Kaput, 1989; Suh & Moyer, 2008). Concrete manipulatives, as currently designed, offer limited structural guidance in their usage. Consequently, pupils experience a substantial cognitive load when manipulating numerous physical objects in a sequential manner. According to cognitive load theory, this process of managing multiple procedural actions with physical objects often hinders pupils' ability to connect these manipulations with the underlying mathematical concepts being taught (Suh & Moyer, 2008).

In contrast, virtual manipulatives provide users with enhanced organization on the screen, presenting each manipulative and its associated procedural steps in a more structured manner (Bouck et al., 2013). Virtual manipulatives incorporate built-in constraints that alleviate much of the cognitive load experienced by pupils during mathematical problem-solving (Moyer et al., 2005; Suh & Moyer, 2008). However, the benefits of virtual manipulatives for pupils with learning difficulties remain speculative due to the limited research conducted thus far on their use in this specific context.

2.9 Pupils' Academic Achievement in Areas and Perimeters of Plane Figures

Understanding the notions of area and perimeter is critical in the subject of mathematics education (Richit et al., 2021). These ideas are fundamental in many real-world applications, including architecture, engineering, and physics. Pupils must be able to comprehend and manipulate areas and perimeters in order to succeed in higher mathematical and scientific disciplines.

Previous study on pupils' understanding of area and perimeter has consistently found that many pupils struggle to discern between these two-rectangle metrics and fail to appreciate their intrinsic links (Sanfeliz, 2023). For example, a study of Grade 10 pupils' conceptual grasp of area and perimeter indicated that pupils answered only 50% of the evaluation questions correctly on average. When specifically challenged to describe area and perimeter, 67% of pupils were unable to do so, while a stunning 90% were unable to do so (Machaba, 2016).

Abadi and Amir (2022) investigated the challenges elementary school pupils face in solving problems related to the perimeter and area of plane figures, categorized by their proficiency levels. The findings revealed that pupils with low ability had verbal difficulties not adhering to instructions, those with moderate ability encountered conceptual issues in decision-making, and principle difficulties were observed in their improper use of units. High-ability pupils faced challenges in formula application, leading to inaccuracies. Overall, the study identified elementary pupils' struggles in solving perimeter and area problems, attributing them to verbal obstacles and insufficient conceptual understanding.

Again, evaluating other studies, experts frequently point out two key variables that contribute to pupils' trouble grasping the concepts of area and perimeter: an overemphasis on formulas and their premature introduction (Walton & Randolph, 2017). Pupils are more likely to mix up the formulas if they are exposed to and rely on procedural formulas for calculating area and perimeter without first developing a solid conceptual understanding of these concepts (Walton & Randolph, 2017).

Furthermore, Sanfeliz (2023) stressed that remembering formulas without understanding the underlying concepts makes it difficult for pupils to generalize operations. This shows that a lack of understanding of the underlying links between area and perimeter can obstruct not only comprehension of surface area and volume, but also application of this information to other geometry and algebra disciplines.

The consequences of this conceptual misunderstanding go beyond simple math errors when tackling area and perimeter problems. In reality, pupils frequently develop errors regarding area and perimeter, which are more troublesome since they are based on poor conceptual understanding and are difficult to address with basic instruction (Machaba, 2016). For example, Livy et al. (2012) discovered that some pupils wrongly believe that as the perimeter of a rectangle rises, so does the area. Although this hypothesis may hold true on occasion, it is critical for pupils to participate in actual learning experiences that question such assumptions, allowing them to restructure their thinking (Machaba, 2017).

According to Simpson and Haltiwanger (2017) to aid pupils in rearranging their thinking, it is critical to present them with compelling learning experiences that allow them to examine the complicated relationships between area and perimeter inside a single arithmetic problem that requires high cognitive load. Simply presenting a rectangle, outlining the links between perimeter and area, and demonstrating several techniques for solving area and perimeter problems is insufficient. Even contextualizing the subject using examples such as the perimeter and size of a basketball court may not offer pupils with a tangible comprehension of the underlying concepts (Kaplinsky, 2017). What is required is a more authentic and hands-on experience.

Offering pupils opportunities and tools to physically modify and rearrange the areas and perimeters of rectangles is one effective way to help them reorganize their thinking (Machaba, 2016). Pupils can gain a better understanding of how changes in length and breadth affect both the area and perimeter by actively reshaping and modifying these geometric forms. This hands-on inquiry enables pupils to visually and kinaesthetically grasp the dynamic nature of fundamental mathematical concepts, resulting in a more meaningful and long-lasting understanding.

2.10 Influence of Gender in Geometry

Geometry, as a vital component of mathematics education, has long been associated with gender disparities, with males traditionally seen as excelling in spatial reasoning and geometric thinking (Kundu & Ghose, 2016). This prevailing perception has resulted in underrepresentation and limited opportunities for female pupils in geometry-related fields. Understanding the influence of gender on pupils' engagement, performance, and attitudes towards geometry is crucial for promoting gender equity and inclusivity in mathematics education (Leder, 2019).

Historically, the idea that males possess innate spatial abilities and excel in geometric thinking has influenced societal expectations and educational practices (Bartlett & Camba, 2023). This belief has created an environment that implicitly discourages female pupils from actively pursuing and excelling in geometry (Quattlebaum, 2020). Stereotypes suggesting that girls are naturally less inclined towards spatial reasoning or that geometry is not as relevant to their future pursuits have perpetuated a gendered division within mathematics education.

Several research studies have explored the influence of gender on pupils' experiences and outcomes in geometry. Research on the use of Geoboard and Geometer's Sketchpad in teaching geometry has shown mixed results. Seloraji (2017) and Bakar (2015) found that the use of Geoboard significantly improved pupils' academic achievement in geometrical reflection and mathematics, respectively. However, Bakar (2009) found no significant difference in mathematical academic achievement between the use of Geoboard and traditional teaching methods. Bakar (2015) also found that the use of Geoboard had no significant effect on pupils' mathematics academic achievement based on their spatial visualization abilities. These findings suggest that the impact of these software tools on pupil academic achievement may vary depending on the specific topic and the software used.

2.11 Theoretical Framework

A theoretical framework as stated by Lederman and Lederman (2015) comprises the theories presented by experts in the relevant field, providing a conceptual structure that researchers utilize for data analysis and result interpretation. Grant and Osanloo (2014) emphasizes that the theoretical framework serves as the supporting structure for a research study's theory. In the context of a thesis, the theoretical framework synthesizes ideas from prominent figures in the research field, relating them to the proposed study and guiding the understanding of these theories for data comprehension. In this study, the theoretical framework is constructed around the Van Hieles' theory of geometry thinking (Van Hiele, 1957).

2.11.1 Constructivism Theory

Constructivism posits that learners must actively construct their own understanding from their experiences (Bada & Olusegun, 2015). This aligns with Piaget's learning theory, which suggests that students develop and adapt their mental frameworks, or schemas, when they encounter new information. Piaget also emphasized that effective learning occurs when a student experiences cognitive conflict and must adjust their thinking to incorporate new knowledge (Piaget, 1972). However, this learning is most effective when the new information aligns with the student's cognitive development stage.

John Dewey also advocated for active student involvement in the learning process, emphasizing the importance of continuous observation and assessment to adapt instruction to meet students' needs and interests. Building on these ideas, Jerome Bruner argued that lessons should be structured to facilitate understanding.

Furthermore, Vygotsky highlighted the importance of communication in learning, whether through interaction with others or self-dialogue (Kozulin, 2022). Social interaction plays a crucial role in learning, as discussing concepts and ideas helps students deepen their comprehension (Hansen, 2011). By encouraging students to share their learning with peers or to reflect in writing after a lesson, communication becomes integral to the learning process.

The constructivist theory is further supported by research on scaffolding, which involves providing initial support when introducing new concepts, gradually removing this assistance as students gain confidence and proficiency, guiding them toward independent learning (Schaper et al., 2022).

Incorporating a constructivist approach in teaching can enhance student motivation by requiring active participation, offering appropriately challenging instruction, providing necessary support, and encouraging social interaction. This approach can be effectively supported by both computer-aided instruction and traditional teaching methods.

2.11.2 Van Hieles' Theory of Geometry Thinking

The Van Hieles theory outlines the development of geometric reasoning, providing a framework created by Dutch educators Pierre Van Hiele and Dina Van-Geldorf (Villiers, 2010). This pedagogical theory focuses on understanding the challenges pupils face in learning geometry. Historically, geometry curriculum lacked clear definition, but the work of Van Hiele and Van Hiele-Geldof has influenced geometry instruction and curriculum design. Originating in 1959, their five-level hierarchy of Geometric Thought gained attention globally, notably in the Soviet Union. In recent years, it has become a significant factor in shaping the American geometry curriculum. The model's key feature is a progression through five levels, namely visualization, analysis, abstraction, deduction, and rigor, describing the evolution of thinking processes in geometric contexts rather than measuring knowledge quantity (Trimurtini et al., 2021).

2.11.2.2 Level 0: Visualization

At level 0 of geometric thinking, individuals primarily focus on the visual aspects of shapes, recognizing and naming them based on overall appearance rather than specific properties (Swoboda & Vighi, 2016). This level involves a gestalt approach, where shapes are identified by their global characteristics. While individuals at this level may engage in measurements and discuss shape properties, the defining factor is the visual resemblance of a shape – for example, a square is considered a square because it visually looks like one.

However, this reliance on appearance can lead to misconceptions, as a rotated square may not be perceived as such by a level 0 thinker. Sorting and classifying shapes are common activities at this level, with individuals grouping shapes based on their perceived similarities. The outcomes of thinking at level 0 are classifications or groupings of shapes that appear to be alike.

2.11.2.3 Level 1: Analysis

At level 1 of geometric thinking, the focus shifts from individual shapes to classes of shapes (Clements, 2003). Individuals operating at the analysis level can consider entire classes of shapes rather than specific ones. This involves discussing properties that define a class, such as rectangles having four sides, opposite sides parallel, equal side lengths, right angles, and congruent diagonals. By concentrating on a class, irrelevant features like size or orientation become less significant. At this stage, learners recognize that shapes within a class share common properties, allowing for the generalization of ideas from individual shapes to the entire class. For example, understanding that all cubes have six congruent faces, each being a square. While level 1 thinkers can list properties of specific shapes like squares, rectangles, and parallelograms, they may not yet grasp the hierarchical relationships between these classes. Defining a shape at this level involves listing known properties, and the outcomes of thinking at level 1 are the identified properties of shapes (Libusha, 2019).

2.11.2.4 Level 2: Abstraction

At level 2 of geometric thinking, the focus shifts to understanding the properties of shapes independently of specific objects, allowing for the development of relationships among these properties (Libusha, 2019). Learners engage in "if-then" reasoning, classifying shapes based on minimal characteristics. For instance, recognizing that a shape with four right angles is a rectangle, and if it is also a square, it must be a rectangle. This level involves following informal deductive arguments about shapes and their properties, acknowledging the compelling nature of logical reasoning. While the "proofs" may be more intuitive than rigorously deductive, there's a limited understanding of the formal deductive system's axiomatic structure. The outcomes of thinking at level 2 include identifying relationships among properties of geometric objects (Libusha, 2019).

2.11.2.5 Level 3: Deduction

At level 3 of geometric thinking, learners focus on understanding relationships among properties of geometric objects (Libusha, 2019). They move beyond examining shape properties, forming conjectures and evaluating their correctness. This involves analysing informal arguments, leading to an appreciation for structured systems with axioms, definitions, theorems, and postulates. Level 3 thinkers recognize the importance of a logical system grounded in minimal assumptions for deriving geometric truths. They work with abstract statements, drawing conclusions based on logic rather than intuition (Libusha, 2019). This level aligns with the traditional high school geometric course, where pupils not only observe facts but also appreciate the need for deductive proof. The outcome is the creation of deductive axiomatic systems for geometry.

2.11.2.6 Level 4: Rigor

At level 4 of geometric thinking, the focus is on deductive axiomatic systems for geometry (ArnalBailera & Manero, 2024). This represents the pinnacle of the van Hiele's hierarchy, where attention is directed not only to deductions within a system but to the axiomatic systems themselves. At this level, there is a heightened appreciation for the distinctions and relationships between various axiomatic systems. Typically reached by college mathematics majors studying geometry as a branch of mathematical science, the outcomes of thinking at level 4 involve making comparisons and contrasts among different axiomatic systems of geometry.

2.12 Conceptual Framework

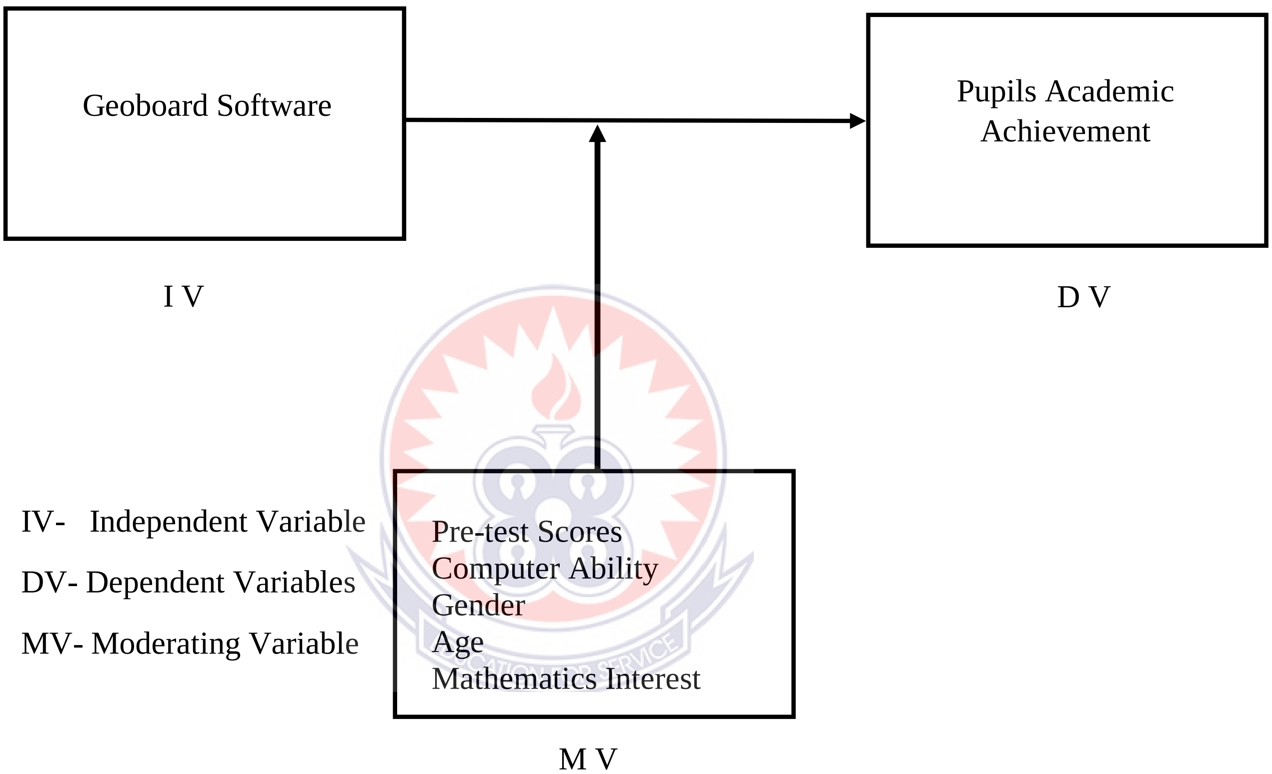

Figure 2.2: Researcher Constructed Framework.

Figure 2.2 presents a conceptual framework that explores the relationship between the use of Geoboard Software and pupils' academic achievement. In this model, the Geoboard Software serves as the independent variable, implying that it is the primary factor being examined for its potential impact on pupils' academic achievement. The dependent variable, pupils' academic achievement, is the outcome the study aims to measure, indicating how effectively pupils learn and perform academically when using the software.

The framework also introduces several moderating variables which are pre-test scores, computer ability, gender, age, and mathematics interest which could influence the strength or direction of the relationship between the Geoboard Software and academic achievement. These moderating variables suggest that the effect of the software on academic outcomes may vary depending on pupils' prior knowledge, skills, demographic characteristics, and interest in mathematics. Overall, the framework provides a structured approach to understanding the potential impact of Geoboard software on pupils' academic achievement in Area and Perimeter of Plane Figures, while accounting for individual differences that may affect the results.

2.13 Chapter Summary

The present study reviewed literature that shows various studies that have provided many insights into the use of technology (particularly interactive software) in the teaching and learning of geometric concepts such as area and perimeter. While there has been much attention on the teaching and learning of geometry in general, there has been little focus on the use of interactive software to learn area and perimeter in particular. Studies involving the use of computer programmes have focused on pupils' ability to identify geometric objects and improving pupils' spatial and deductive reasoning skills when solving a problem in geometry. Therefore, there is no explicit focus given to pupils' knowledge and skills in area and perimeter concepts or using interactive software to improve the teaching and learning of these concepts. This makes the present study is unique because of its attention on junior high school pupils in Ghana and on pupils' achievement in area and perimeter.

CHAPTER THREE

METHODOLOGY

3.0 Overview

This chapter describes the methodology that will be used to conduct the study. These are the following: research design, population, sample size and sampling technique, research instruments, validity, pilot study, reliability, data collection procedures, and data analysis techniques.

3.1 Research Philosophy

A research philosophy, as defined by Moser and Korstjens (2018), refers to a specific viewpoint on how to obtain, examine, and utilize information about a phenomenon. The present study adopted a positivist research approach, which posits that consistent results can be obtained by different researchers using the same statistical tools and research procedures when analysing large samples, thereby enabling generalisation that transcends specific contexts (Schreier, 2018). In the realm of positive psychology, quantitative research techniques are favoured (Kivunja & Kuyini, 2017). According to Williams (2020), positivism emphasizes the importance of quantifiable observations that can be subjected to statistical analysis. It aligns with the empiricist perspective that knowledge is derived from human experience and perceives the world as consisting of distinct, observable factors and events that interact predictably and regularly (Tholen, 2015).

Positivist researchers prefer quantitative approaches over qualitative ones, as they are considered more reliable and representative. They employ methods such as social surveys, systematic questionnaires, and official statistics to gain a general understanding of society and identify social patterns, such as the correlation between educational attainment and social status. Rather than focusing on specific individuals, this sociological approach seeks to discern broader trends and patterns.

Positivism, as a philosophical standpoint, asserts that reliable information is derived solely from observation (the senses) and measurement (Burton Jones & Lee, 2017). In positivist research, the role of the researcher is limited to gathering and impartially analysing data. The outcomes of such investigations often manifest as observable and quantitative results. Positivism aligns with the empiricist belief that knowledge is derived from human experience. It views the world as consisting of distinct, observable elements and occurrences that interact predictably and regularly.

Moreover, positivist research does not account for human interests, and the researcher maintains a separate position from the study. According to Azungah (2018), positivist studies typically follow a deductive approach, whereas inductive research methods are more closely associated with the phenomenological school of thought. Positivism emphasizes the primacy of factual evidence, while phenomenology considers meaning and acknowledges the role of human interest (Eberle, 2014).

Researchers adopting a positivist stance strive for impartiality in their investigations, as they are not personally invested in the findings. Independent researchers minimize their interaction with the subjects, aiming to rely solely on objective evidence. In other words, investigations rooted in the positivist paradigm assume an external and objective universe, relying exclusively on factual observations.

Objectivism, as embraced by positivists, serves as their epistemological framework. According to Salmieri (2016), objectivism refers to the belief in an objective world that can be progressively understood through the accumulation of detailed knowledge. Critical realism, a scientific school of thought, provides the most comprehensive explanation of the relationship between objectivist ontology and epistemology. Positivism approaches the world in an objective manner, aiming to uncover the complete truth about objective reality. Its foundations lie in the deterministic, mechanistic, methodical, and empiricist aspects of scientific inquiry. Given its nature as a scientific philosophy, positivism serves as the underlying basis for this research study.

The choice to adopt the positivism paradigm for this study is grounded in the pursuit of rigorous scientific inquiry and the pursuit of objective understanding. Positivism provides a robust framework for examining causal relationships between the integration of Geoboard software and junior high school pupils' academic achievement in area and perimeter of plane figures. Positivism prioritizes objectivity, crucial in educational research when assessing interventions like the Geoboard software. It emphasizes minimizing bias and subjective interpretation, ensuring our findings are based on empirical evidence rather than personal opinions.

Additionally, positivism values replicability and generalizability, ensuring the study's results can be replicated by others and applied to similar educational settings and populations. This commitment strengthens the robustness and external validity of the study, contributing to broader knowledge in the field. In essence, by embracing the positivism paradigm, the study aims to conduct a scientifically rigorous investigation into the effects of Geoboard software on pupils' academic achievement.

3.2 Research Approach

The study employed a quantitative approach, which involves quantifying data through collection and analysis, as described by Bryman (Watson, 2015). Martin and

Bridgmon (2012) defines quantitative research as a method that focuses on numerical data and applies statistical analysis. It utilizes formal, objective, rigorous, deductive, and systematic approaches to generate and enhance knowledge for problem-solving (Albers, 2017). Quantitative research designs, whether experimental or non-experimental, aim to obtain precise and reliable measurements (Farhady, 2013b). This approach involves systematically observing and describing quantifiable or numerical traits, features, or quantities of things or events in order to identify correlations between an independent (predictor) variable and a dependent (outcome) variable within a population (Bloomfield & Fisher, 2019).

Quantitative research employs statistics to address questions such as who, what, when, where, how much, how many, and how, in order to explain events through the collection of comprehensive numerical data. It relies on factual evidence, logical reasoning, and an unbiased perspective. It involves selecting a specific research topic, formulating focused questions, gathering quantifiable data from participants, analysing the data using statistical techniques, and conducting the investigation impartially and objectively. While quantitative research considers human interactions, interpersonal relationships, and individual values, meanings, beliefs, thoughts, and feelings, it aims to manipulate variables and control natural phenomena (Creswell, 2012).

Quantitative research emerged as a means of generating new knowledge, particularly in the natural sciences, where it was used to investigate natural events (Goertzen, 2017). Variables in quantitative research are elements that can be manipulated or altered during an experiment (Mohajan, 2020), and the method focuses on quantifying and analysing these variables to obtain outcomes. It is characterized by objectivity, scientific rigor, experimentation, and a positivistic approach. This method is particularly suitable for highly organized research designs that can be implemented effectively. Even complex events can be broken down and assigned numerical values. Researchers must maintain complete objectivity, avoiding personal involvement, values, or biases in their research (Creswell, 2012).

Quantitative research employs numerical data and measurement to investigate phenomena and their interactions. It aims to provide explanations by examining correlations between quantifiable factors, and its methods are used to predict and control phenomena (Yilmaz, 2013). Researchers in quantitative research select their research topics, formulate focused questions, collect quantifiable participant data, interpret the data using statistical analysis, and conduct the study in an objective manner.

Currently, quantitative data, which offer high research quality and validity, are utilized in the publication of two-thirds of research articles. Quantitative approaches are particularly necessary when examining data from large samples (Yilmaz, 2013). Martin and Bridgmon (2012b) asserts that statistical, mathematical, or computational tools are employed in quantitative research to ensure accurate results. Various fields, including business studies, natural sciences, mathematical sciences, and social sciences, have increasingly utilized quantitative research. Closed-ended questionnaires are commonly employed to gather data for quantitative studies, and the resulting data is presented numerically, including statistics, percentages, and graphs. The study develops and applies models based on theories, hypotheses, and mathematical frameworks to achieve the intended outcomes. Pandey and Pandey (2021) define a research hypothesis as an experimentally testable assertion derived from a clearly stated relationship between independent and dependent variables.

In quantitative research, researchers follow the scientific method, starting with a specific theory and hypothesis, conducting research processes, and striving to collect rich, accurate, deep, and reliable data (Bergin, 2018). They seek quantitative correlations between variables to test and validate their research hypotheses, maintaining an objective perspective. Creswell (2012) notes that the results of quantitative research can be prescriptive, explanatory, and confirmatory, aiming to develop and apply mathematical models, theories, and statements or hypotheses about phenomena.

The decision to adopt a quantitative approach is rooted in the study's adherence to the positivism paradigm, which inherently aligns with quantitative methods. Furthermore, the research employs quantitative instruments, including pre-test and post-test assessments, for data collection.

3.3 Research Design

The study employed a quasi-experimental design. A quasi-experiment is an empirical research design that does not randomly assign participants to groups and assesses the causal impact of an intervention (treatment) on a target population (Creswell, 2014). In this study, the participants were divided into two groups (experimental and control group) in a non-random manner as part of the research design. This design allowed the researcher to investigate the causes and effects of using Geoboard application in teaching and learning to raise pupils' academic achievement levels (Creswell, 2014). According to Miller et al. (2020), quasi-experimental designs shares similarities with the traditional experimental design or randomized controlled trial, but it lacks the element of random assignment to treatment or control groups. Therefore, this study employed a quasi-experimental design of non-equivalent comparison groups because intact classes with an unequal number of pupils were used.

A quasi-experiment is an empirical interventional study used to estimate the causal impact of an intervention on a target population without random assignment (Sullivan Bolyai & Bova, 2013). While quasi-experimental research shares similarities with traditional experimental designs or randomized controlled trials, it specifically lacks random assignment to treatment or control groups. Instead, quasi-experimental designs typically allow the researcher to control the assignment to the treatment condition using some criterion other than random assignment. However, quasi-experiments are subject to concerns regarding internal validity, as the treatment and control groups may not be comparable at the outset. This means that convincingly demonstrating a causal link between the treatment condition and observed outcomes may be challenging, particularly when confounding variables cannot be controlled or accounted for.

The term "quasi" means "resembling," indicating that quasi-experimental research resembles experimental research but is not a true experimental design (Creswell & Piano-Clark, 2017). In quasi-experimental research, although the independent variable is manipulated, participants are not randomly assigned to specific conditions or orders of conditions. This manipulation of the independent variable before measuring the dependent variable helps address the issue of directionality. However, since participants are not randomly assigned, it is likely that there are other differences between the conditions, and thus, quasi-experimental research does not eliminate the problem of confounding variables. In terms of internal validity, quasi-experiments generally fall somewhere between correlational studies and true experiments. Quasi-experiments are commonly conducted in field settings where random assignment is difficult or impossible, often to evaluate the effectiveness of a treatment or educational intervention. However, when participants are not randomly assigned to conditions, the resulting groups are likely to be dissimilar in some ways, making them non-equivalent. A non-equivalent groups design is a between-subjects design in which participants have not been randomly assigned to conditions (Creswell, 2014).

In this study, a quasi-experimental design (non-equivalent groups) was employed to examine the effect of integrating Geoboard application in teaching and learning area and perimeter of plane figures for Junior High School pupils. Teaching lessons were planned and taught to two non-equivalent groups of pupils. The researcher using non-equivalent groups design take steps to ensure that their groups are as similar as possible, as recommended by Krishnan (2023).

3.4 Study Area

The study was conducted in the Effutu municipality. The Effutu Municipality located in Ghana's Central Region, spans 95 square kilometres with 14 settlements around its administrative capital, Winneba. Boasting a population of 68,597 and a rich cultural heritage, it was established in 2007 with active participation in Ghana's administrative landscape. The low-lying terrain, two rivers which are Ayensu and Gyahadze and the Muni Lagoon offer opportunities for irrigation, aquaculture, and eco-tourism. The municipality experiences a dry-equatorial climate with coastal savannah grasslands, suitable for agriculture. Spatial development plans include intensive irrigation, fishing, eco-tourism, technology parks, and education initiatives. Governed by a municipal assembly and emphasizing representation through zonal councils, Winneba is significant for its historical and cultural importance. Economic activities such as fishing, farming, services, manufacturing, salt mining, and agro-processing contribute to the vibrant local economy (Ministry of Food and Agriculture, 2022).

The Municipality is made up of three circuits for the purposes of education management. There is a total of 247 educational institutions in the Municipality; of which 74 (30%) are public institutions and 173 (70%) are private institutions. The Municipality has 78 pre-schools (24 public and 54 private), 77 Primary Schools (26 Public and 51 Private) and 47 Junior High Schools (22 Public and 25 Private). The Winneba Senior High School is the only public second cycle institution. There are three (3) private Senior High Schools and two (2) Technical and Vocational Institutions in the Municipality. There is one major tertiary institution; the University of Education, Winneba which has its main campus in Winneba with Campuses at Kumasi, Mampong and Ajumako. The Perez University formerly the Pan African University though located in the Gomoa East Municipality (i.e. Pomadze), its impact is more felt in the Municipality. There is also the National Sports College of Winneba where sports personnel (Football, Sportsmen and Women) receive advanced training in their specialized fields and disciplines. In addition, there is the Police Staff and Command College. Other Specialized Institutions include the hearing-Impaired School – University Practice (UNIPRA) South School and Fr. John Mentally Derailed School under the Don Bosco Girls Primary School (Effutu Municipal Assembly, 2019).

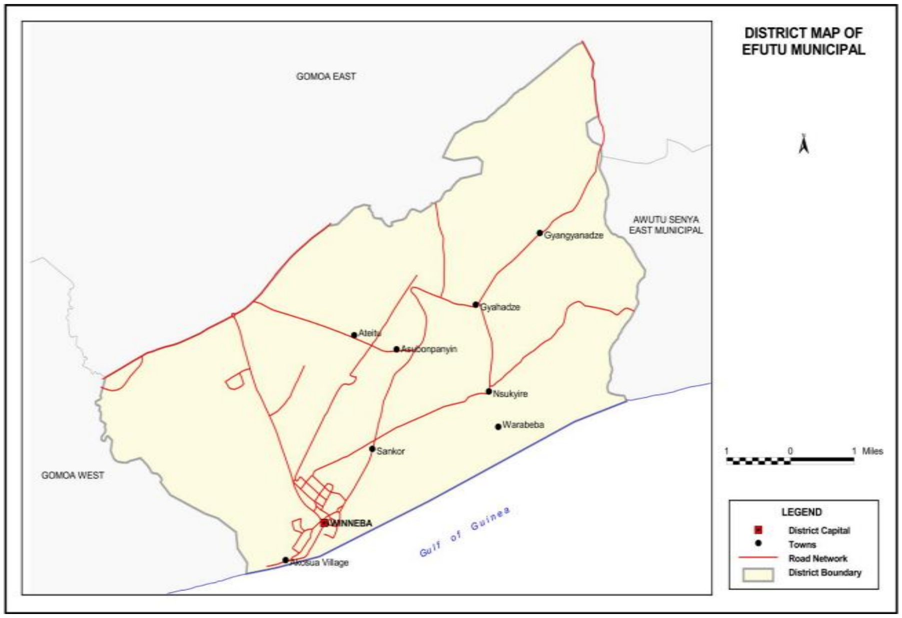

Figure 3.1: Map of Effutu Municipality.

Source: Ghana Statistical Service, 2021

3.5 Population

Population refers to a defined group of elements, such as objects or people, that the researcher aims to investigate within a specific geographic area (Murphy, 2016). In this study, the population consisted of public junior high school pupils in the Effutu Municipality, with a total population of 5047 pupils according to the Effutu Municipal Education Directorate. Public schools were the focus of the study as a result of findings by Mill and Mereku (2016) suggested that pupils in public junior high schools had difficulty in solving area and perimeter problems. The target population specifically focused on basic 7 pupils in the Effutu Municipality of the Central Region in Ghana, which comprised of 1276 pupils in total, consisting of 664 boys and 612 girls. The Accessible population consisted of two in-tact classes selected from two different junior high schools from the Effutu Municipality with a total population of 109 pupils comprised of 51 pupils in school A and 58 in school B.

3.6 Sample and Sampling Procedure

The sample is derived from the population (Neuman, 2007). There are 3 circuits in the Effutu Municipality which are West, East and central circuits. One circuit, specifically the central circuit was selected through the cluster sampling technique. After selecting the Effutu central circuit, two intact schools were selected through simple random sampling technique. In the two schools, basic 7 classes were purposively selected, because the topic of interest, area and perimeter which falls under the sub-strand measurement is expected to be taught in basic seven (MoE,2020). After the administering of the pre-test to basic 7 learners from both schools, the school with a lower average pre-test score was designated as the experimental group, whilst the one with the higher average was designated as the control (source).

3.7 Instructions in Area and Perimeter of Plane Figures

Experimental group

The experimental group in this study was taught area and perimeter of plane figures using Geoboard Application as the instructional tool. To ensure effective implementation, a tutorial on Geoboard application was done for the teacher of the experimental group. During the instructional sessions, the teacher utilised a laptop connected to a projector to demonstrate the features of Geobaord application to the pupils in the ICT laboratory. The pupils practiced on the computers in the ICT laboratory. The teacher was provided with lesson plan and worksheets to be employed during lesson delivery. The teaching process involved one day of Geoboard application and computer introduction session, with the session lasting 70 minutes. Throughout, 8 (8) lessons were conducted for the experimental group within 3 weeks.

Week 1

Objective: Introduction of Geoboard Application and introduction of the concept of area and perimeter using the Geoboard application.

During the first week of our lessons, the primary goal was to introduce the pupils to the Geoboard application and lay the groundwork for understanding the fundamental concepts of area and perimeter. In the initial lesson, the teacher took the time to familiarize the pupils with the Geoboard interface, training them on its functions and illustrating its significance in the context of learning geometry. The objective was not only to introduce them to the application but also to highlight its purpose and the benefits it offers for grasping geometric principles.

The teacher guided the pupils through the creation and manipulation of basic shapes such as squares, rectangles, and triangles. An illustrative example involved the creation of a square on the Geoboard with a side length of 4 units and discussed its inherent properties, emphasizing equal sides and right angles. Following this, the teacher encouraged the pupils to independently apply their newfound knowledge by creating shapes and identifying their unique properties.

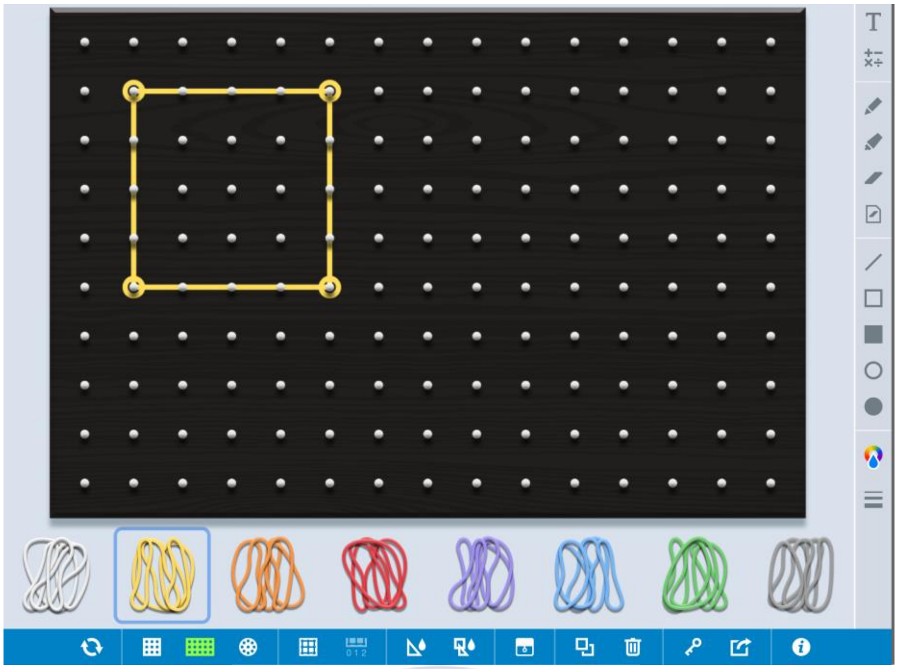

Figure 3.2: Construction of a square of 4 units

In the subsequent lesson, the teacher revisited the concept of perimeter, reinforcing its definition as the distance around the boundary of a shape. Leveraging the Geoboard application, the teacher demonstrated the process of measuring perimeter by counting the units along the boundary. For instance, a rectangle on the Geoboard with side lengths of 5 units and 3 units, subsequently counting the units around its perimeter, totalling 16 units. To reinforce their understanding, the teacher provided additional examples of shapes with varying dimensions, challenging the pupils to measure their perimeters using the Geoboard application.

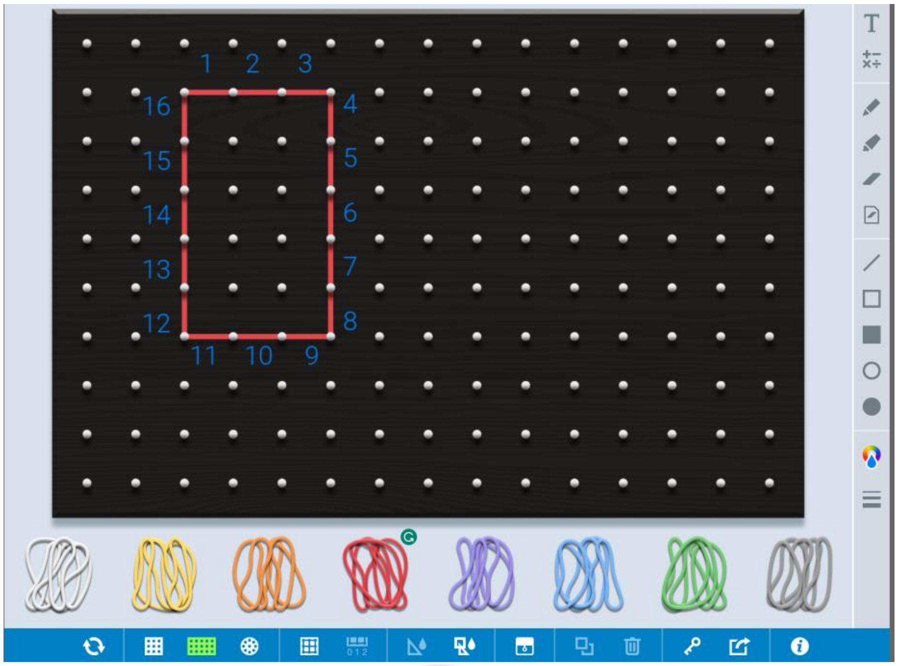

Figure 3.3: Determining the perimeter of a rectangle

The third lesson focused on exploring the concept of area, with a thorough review of its definition as the measure of the space inside a shape. The teacher introduced the idea of calculating area using the Geoboard application, demonstrating the process by creating a square with a side length of 5 units and counting the unit squares inside to determine the area, which amounted to 25 square units. Extending the practice, the teacher presented the pupils with diverse shapes, prompting them to calculate their respective areas using the Geoboard application. For example, a rectangle with side lengths of 4 units and 7 units yielded an area of 28 square units.

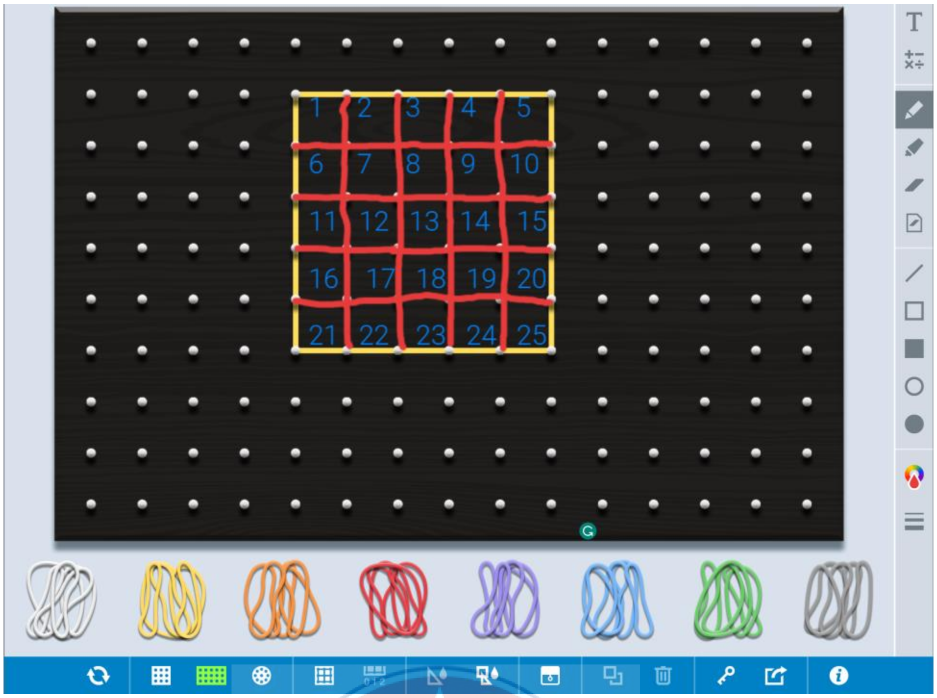

Figure 3.4: Determining area of a rectangle illustration.

Week 2

Objective: Apply the concept of area and perimeter to solve real-world problems using the Geoboard application.

In the fifth lesson, the teacher focused on problem-solving with area, applying geometric concepts to real-world scenarios. The teacher presented pupils with situations like calculating the area of irregular shapes, such as determining the area of a triangular field with a base of 5 units and a height of 9 units. The teacher discussed the step-by-step approach to solving such problems, emphasizing the breakdown of shapes into smaller parts and the subsequent calculation and addition of their individual areas. To reinforce these concepts, the teacher demonstrated how to use the Geoboard application to create irregular shapes similar to the given scenarios and calculate their areas. Pupils were then provided with practice problems, encouraging them to apply their knowledge using the Geoboard application and explain their solutions.

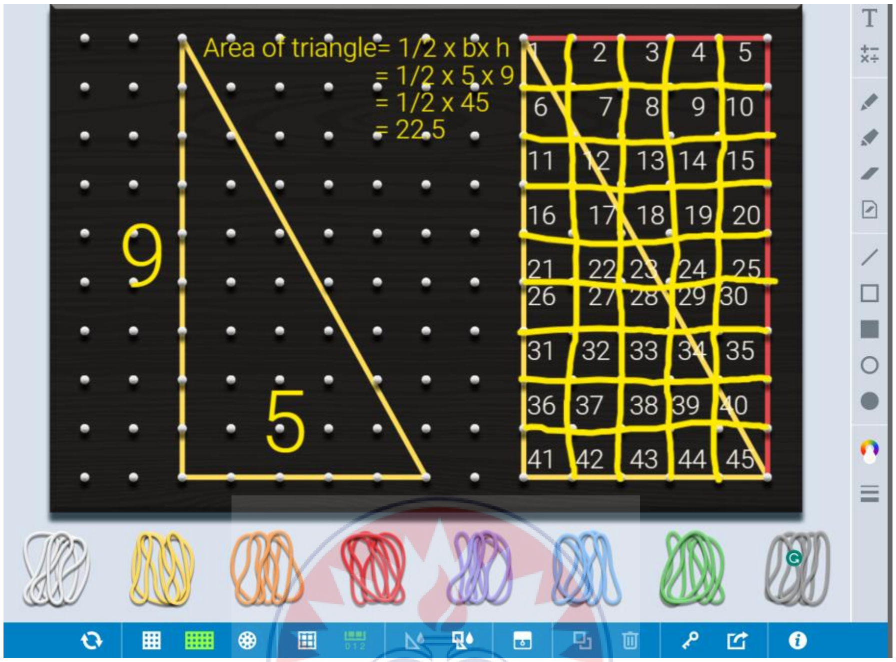

Figure 3.5: Determining area of a triangle illustration.

In the sixth lesson, the teacher delved into comparing area and perimeter. To engage pupils in understanding the relationship between area and perimeter, the teacher initiated a discussion about shape optimization. This involved exploring scenarios where different shapes had the same perimeter but different areas, and vice versa. Using the Geoboard application, pupils were presented with examples of shapes, such as a square and a rectangle, with equal perimeters but differing areas. Pupils were encouraged to compare their areas and engage in discussions about the observed relationships. Throughout the lesson, pupils were motivated to explore and discover patterns and relationships between area and perimeter using the Geoboard application, fostering a deeper understanding of these geometric concepts.

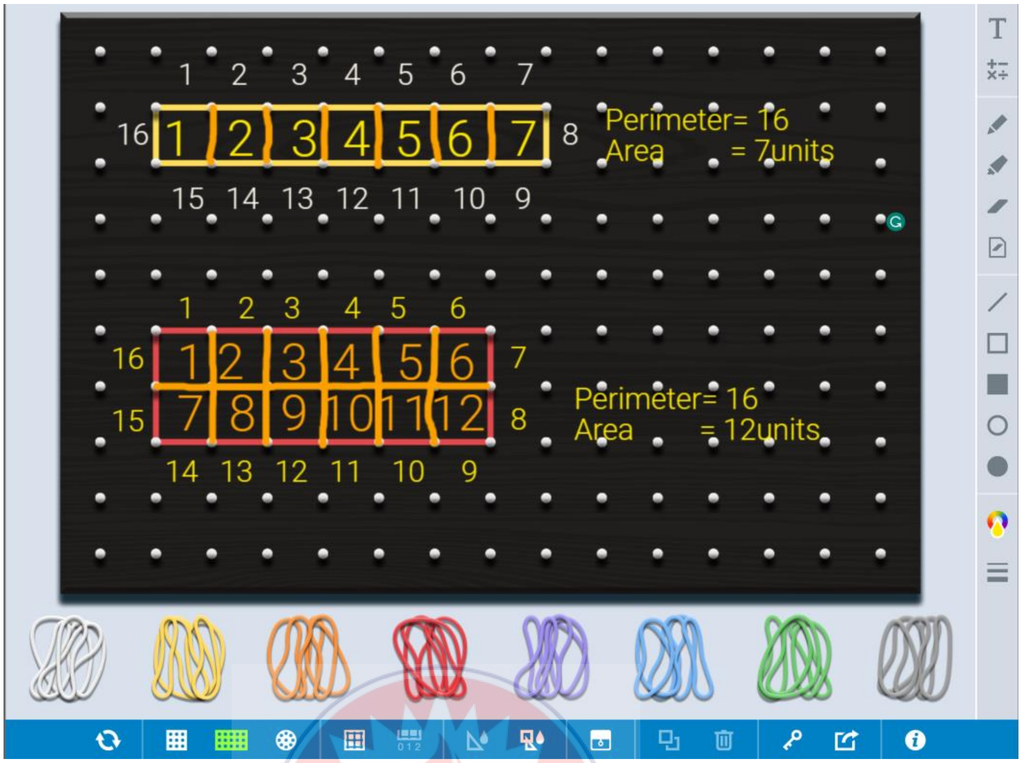

Figure 3.6: Comparison area and perimeter of different figures.

Week 3

Objective: Reinforce the understanding of area and perimeter through interactive activities and assessments using the Geoboard application.

In the seventh lesson, pupils explored interactive and engaging activities centered around area and perimeter, utilising the Geoboard application. The class participated in games that required pupils to create shapes on the Geoboard within specified perimeters or areas, all while working against a time limit. To promote collaborative learning, the class was divided into groups, with each group assigned different games or activities. Throughout the session, pupils were monitored, offering guidance as needed to ensure a productive and enjoyable learning experience.

on the eighth lesson, the focus shifted to solving problems through an area and perimeter exercise. Pupils were giving exercise that consisted of subjective questions challenging them to apply their knowledge in calculating area and perimeter using the Geoboard application. During the review, there was a discussion of the correct answers, providing explanations where necessary to reinforce understanding. Pupils were encouraged to share insights, highlight challenges faced, and articulate any connections they made between the application and real-world applications. Summarizing the key concepts of area and perimeter, the teacher emphasized their relevance to everyday life. Additionally, the session provided an opportunity for pupils to ask questions and seek clarification on any remaining doubts, ensuring a comprehensive understanding of the covered material.

Control group

The teacher for the control group employed a conventional teaching technique, specifically the talk-and-chalk technique, to instruct pupils on the concepts of area and perimeter of plane figures. In this approach, the teacher primarily conveyed information verbally while writing on the chalkboard. The instructional materials and exercises provided to both the experimental and control groups were identical, ensuring a consistent baseline for comparison.

While the content of the lessons was the same for both groups, the distinguishing factor lay in the manner in which the pupils engaged with the material. In the control group, the conventional talk-and-chalk teaching technique was implemented. This involved pupils predominantly learning through auditory means, listening to the teacher's explanations, and visually processing information presented on the chalkboard.

The control group underwent a series of eight lessons, each lasting 70 minutes. Throughout these sessions, pupils in the control group were exposed to the conventional teaching techniques, where emphasis was placed on passive learning through listening and visual observation. The teacher's role was central, guiding the pupils through the concepts of area and perimeter in a traditional classroom setting.

It's worth noting that this traditional approach was selected for the control group to establish a clear contrast with the experimental group, allowing for a comprehensive evaluation of the effectiveness of different teaching methods in facilitating understanding and retention of the subject matter.

3.8 Research Instrument

The data collection instrument used in this study was a teacher-made test, which included both a pre-test and a post-test. A test is a method of data collection that involves a series of exercises or tasks used to measure individuals' or groups' characteristics (Igwenagu, 2016).

The test consisted of objective and subjective-type questions designed to assess various aspects of the participants' knowledge on the concept of area and perimeter of plane figures. According to Creswell (2014), a test functions as a systematic procedure for systematically observing and describing one or more characteristics of pupils. It may employ numerical scales or classification systems. The tool utilized in this research was divided into two parts. The initial segment gathered biographical information about the pupils, while the second segment included test items organized into three sections. Section A, which was objective-based and was adapted from Usiskin (1982), collected data to measure the first level of Van Hieles' Geometric thinking (Visualization). Section B consisted of subjective questions addressing the analysis level of Van Hieles' Geometric thinking which was adapted from area and perimeter problems in Mathematic Common Core Programme (CCP) Curriculum, while Section C included subjective questions focused on the abstraction level of Van Hieles' Geometric thinking which was also adapted from area and perimeter problems in Mathematic Common Core Programme (CCP) Curriculum.

The researcher deemed the test as the most suitable instrument for collecting data to address the research questions in this study, hence its utilisation. The test was scored out of a total of 45 marks, with specific marks allocated to each component (Visualization=5 marks, Analysis= 20 marks, and Abstraction= 20 marks).

3.9 Pilot-Testing

Pilot testing, a widely adopted practice in "soft" research, serves as a fundamental scientific tool employed prior to embarking on a full-scale study, as outlined by Brooks et al. (2016). The primary goal of pilot testing is to conduct a preliminary analysis, pinpointing potential issues with the research instrument. This process allows for essential revisions to both the methodology and instrument, ensuring a more robust and effective approach before advancing to the actual study.

To bolster the validity of the current study, the research tools underwent a comprehensive pilot test. This evaluation aimed to gauge whether the items elicited the intended responses and to verify their freedom from any unacceptable errors. Simultaneously, the pilot test sought to confirm that the test items remained pertinent to the study's objectives, aligning with the framework established by Heale and Twycross (2015). By subjecting the components to this rigorous examination, the researchers aimed to refine and optimize their methodology, ultimately enhancing the overall quality and reliability of the impending full-scale investigation.

The pilot test encompassed a sample population consisting of 15 basic 7 pupils from a Junior High School in Winneba (University Practice School, South Campus), located in a different circuit within the Effutu Municipality. It is crucial to emphasize that no statistically significant difference was observed in terms of class and age between the pupils engaged in the pilot test and those who later took part in the main study. This aspect is vital as it guarantees that the pilot test faithfully mirrors the characteristics of the target population, thereby contributing to the validation of the appropriateness of the test items for the broader study.

3.10 Validity and Reliability of Instruments

According to Cohen et al. (2017), validity in research refers to how well a measurement tool accurately assesses the intended concept, with types such as content, criterion-related, and construct validity. Reliability, meanwhile, focuses on the consistency and stability of a measurement tool, encompassing test-retest, internal consistency, and inter-rater reliability. Both validity and reliability are crucial for trustworthy and meaningful research findings and assessments.

3.10.1 Validity

Validity, as articulated by Heale and Twycross (2015), encompasses the appropriateness, meaningfulness, and usefulness of inferences drawn from numerical scores. It serves as a critical metric to ascertain that the measurement instrument effectively captures the intended conceptual framework. Within the context of this study, content validity underwent rigorous evaluation to guarantee the precise measurement of targeted concepts by the test. The researcher's supervisors meticulously scrutinized both the pre-test and post-test test items, offering valuable insights that prompted the refinement of questions through restructuring, addition, and deletion. They worked to ensure that the items adequately covered all the key aspects of the concepts area and perimeter of plane figures as prescribed in the mathematics Curriculum for JHS. Their constructive feedback played a pivotal role in enhancing the overall quality and accuracy of the assessment instrument. The face validity of the instrument was established with the assistance of the research supervisors as well as experienced mathematics educators in the department of Basic Education, of the University of Education, Winneba.

3.10. 2 Reliability

Reliability, in contrast, pertains to the extent of consistency with which a test measures its intended constructs (Creswell, 2014). In the present study, the focus was on securing the equivalent or alternative-form reliability of the research instrument, encompassing both the pre-test and post-test. To establish this reliability, an experienced mathematics teacher was consorted to check the scores of both the pre-test and post-test responses, evaluating the academic achievements of the pupils.

The pilot test involved the administration of pre-test items and post-test items, the pre-test and post-test were administered to the same groups of pupils. This process allowed for a meticulous examination of the relationship between scores on the two forms. The test-retest and interrater reliability approach was employed for both the pre-test and post-test to ensure that corresponding items on both tests effectively measured the same academic achievements. This strategy facilitated an assessment of the degree to which the two tests paralleled each other, a crucial consideration, especially when one form serves as a pre-test and the other as a post-test. This methodological approach adds a layer of robustness to the study by bolstering the trustworthiness of the obtained results through consistency in measurement across both testing phases.

Table 3.1 presents the intraclass correlation coefficient for the pre-test and post-test instruments.

Table 3.1: Intraclass Correlation Coefficient for Pre-test and Post-test

	Intraclass Correlation[b]
Single Measures	0.777[a]
Average Measures	0.875[c]

Source: Field Data, 2023

After the pilot test, the reliability of the instrument was determined by calculating the relationship between the test forms using the intraclass correlation coefficient. The intraclass correlation coefficients for the instrument items were 0.875. According to Koo and Li (2016) values less than 0.5, between 0.5 and 0.75, between 0.75 and 0.9, and greater than 0.90 are indicative of poor, moderate, good, and excellent reliability, respectively.

3.11 Threats to Validity

Threats to validity as defined by Rogers and Revesz (2019) are factors or issues in a research study that can compromise the accuracy, reliability, and generalizability of the results. These threats can affect the internal or external validity of a study. The changes observed in the dependent variable result from the influence of the independent variable, and not from unintended variables, also referred to as extraneous or lurking variables, alternative explanations, or rival hypotheses. When these extraneous variables are effectively controlled, the outcomes can be attributed to the treatment, establishing internal validity in the study (Flannelly et al., 2018). To ensure internal validity and confidence in a study, researchers must implement experimental controls to substantiate those differences arise as a consequence of the experimental treatment. In studies lacking internal validity, researchers cannot ascertain whether the observed differences between groups are a result of the experimental treatment or uncontrolled factors. Gravetter and Forzano (2018) identified categories of extraneous variables that could introduce internal bias if left uncontrolled. This section examines such factors.

Testing

Testing invalidity arises when the experience of a pre-test influences subsequent post-test academic performance. Many experiments incorporate pre-tests to gauge subjects' initial states concerning variables of interest. The act of undergoing a pre-test may heighten the probability of subjects improving their academic achievement in the subsequent post-test, especially if it mirrors the pre-test(Yu & Ohlund, 2010). Consequently, the post-test may not solely measure the impact of the experimental treatment, potentially leading to an overestimation or underestimation of the intervention effect (Yu & Ohlund, 2010). To mitigate the threat of testing, the researcher employs distinct yet equivalent versions of a test for the pre-test and post-test. Additionally, the researcher acknowledges the possibility that observed changes between the pre-test and post-test could result from alterations in the testing procedure, such as changes in content, mode of administration, and data collection. To address this concern, diligent efforts was made to maintain consistency in the pre-test and post-test, as well as in the administrators and the administration procedure.

History

In research, the term history refers to events occurring in the environment at the same time that a study tests the experimental variable (Yu & Ohlund, 2010). One common source of history bias, termed teacher effect. results from a comparison of results for Teacher A teaching by Method A to those for Teacher B teaching by Method B. In such cases, analysis cannot possibly separate the effect of the teacher from the effect of the instructional method. According to Supino (2012, the researcher prevents limitations on internal validity due to history by comparing results for an experimental group to those for a control group with the same external or historical experiences during the experiment. In addition, experimental group participants and members of the control group must experience a comparable history within the experiment in all aspects other than the experiences being tested (Supino, 2012). Specifically, materials, conditions, and procedures within the experiment other than those specific to one of the variables being manipulated (that is, independent or moderator variables) were identical for experimental and control subjects.

Selection Bias

Numerous studies aim to compare the impacts of diverse experiences or treatments on distinct groups of individuals. Bias may arise if the group undergoing one treatment comprises members who are brighter, more receptive, or older than the group receiving no treatment or an alternative treatment (Evans et al., 2011). The results for the first group might alter not due to the treatment itself but because of the inherent differences in the group selected for the treatment compared to the others. Without addressing selection bias, the researcher cannot confidently assert that the study's outcomes are solely reflective of the treatment under evaluation, rather than initial disparities between groups. To address this issue, the groups were carefully matched in terms of age, grade level, and engagement with the same curriculum.

Statistical Regression

The selection of group members based on extreme scores on a specific variable can lead to issues of statistical regression. This phenomenon arises because chance factors are more likely to influence extreme scores than average scores, and these factors are unlikely to replicate during a subsequent test or when using a different measure (Preacher et al., 2005). To prevent the tendency of extreme pre-test scores to regress toward the population mean, participants for the study were not chosen based solely on extreme pre-test results. This decision was made as post-test scores for such individuals are inclined to shift towards the mean score. The problem was effectively managed by avoiding the exclusive selection of extreme scorers and instead including participants with average scores.

Experimental Mortality (Attrition)

In any study, researchers should make an effort to collect post-test data from all subjects initially enrolled in the study. Failure to do so may introduce bias if the characteristics of subjects who withdraw differ from those who remain, leading to differences relevant to the dependent variable and introducing post-test bias (or internal invalidity based on mortality). This bias is also observed when a study assesses more than one condition, and subjects are lost disproportionately from groups experiencing different conditions (Cesario, 2022). To address issues stemming from experimental mortality, the researcher opted for reasonably large groups and implemented measures to ensure their representativeness.

Maturation

Regarding maturation, this refers to the natural processes of change within subjects during an experiment (Campbell, 2017). Extended experiments risk losing validity because uncontrolled processes, such as developmental changes, can occur simultaneously, confounding the results (Campbell, 2017). Since people, especially pupils, undergo normal developmental changes, a study's outcome might be attributed to these changes rather than the experimental treatment. To circumvent such complications, the researcher established a control group consisting of comparable pupils who shared similar maturational experiences. Additionally, the researcher minimized the time gap between the pre-test and post-test evaluation questions. This precaution allowed the researcher to conclude the experimental treatment independently of the potentially confounding maturation effect.

Instrumentation Bias

The techniques used for measurement or observation in an experiment are collectively known as instrumentation. These processes often involve testing, mechanical measuring devices, and scorer judgment. While mechanical measuring instruments typically remain unchanged throughout a study, scorers may alter their approach to collecting and recording data as the study progresses (Abowitz & Michael, 2010). A potential threat to validity arises if scorers become aware of the study's purpose and, consciously or unconsciously, try to influence results in favour of the desired hypotheses. To address this issue, the researcher ensured consistency by keeping both the measuring instrument and the data collectors constant over time and across groups (conditions). Additionally, participants were allocated the same duration for both the pre-test and post-test.

3.12 Data Collection Procedure

To assess the effect of the independent variables (instruction with the Geoboard application and conventional teaching techniques) on the dependent variable (academic achievement), a pre-test and post-test were employed. The pre-test was administered to both groups to ascertain whether pupils had comparable knowledge of area and perimeter of plane figures before the interventions were introduced. This step aimed to compensate for the non-random assignment of pupils to the control and experimental classes. By utilizing the pre-test, the study aimed to establish the comparability of the classes at the outset, determining the baseline knowledge or preparedness for learning area and perimeter of plane figures.

The post-test was administered to pupils in both the experimental and control groups to assess the impact of the Geoboard application on their academic achievement in area and perimeter of plane figures. All test items in the post-test were centred around the treatment topic. The post-test included questions categorized under the various levels of Van Hiele's geometry thinking. This categorization facilitated the researcher in analysing and identifying potential differences in academic achievement between the experimental and control groups at different levels of geometric thinking according to Van Hiele's framework. The purpose of administering the post-test was to determine the effectiveness of the intervention (Geoboard application) in teaching and learning of area and perimeter of plane figures

3. 13 Data Processing and Data Analysis Procedure

The data underwent a thorough accuracy check before being entered into the computer and subjected to transformation. Statistical Package for the Social Sciences

(SPSS) version 27 was employed to characterize the fundamental aspects of the data. The analysis encompassed both descriptive and inferential statistical methods. Descriptive statistics, including frequency, percentages, mean and standard deviation, were utilized to assess the level of pupils' academic achievement as well as the dispersion or clustering of scores obtained from both the pre-test and post-test.

In addition to descriptive statistics, inferential statistics were employed to analyse the data collected from the post-test. As per Cohen, Manion, and Morrison (2018), inferential statistics encompass techniques used to ascertain whether the results derived from the analysis of data obtained from a sample would yield comparable outcomes for the entire population. The independent t-test statistical method was utilized to determine the comparability of mean scores between both groups. This test was also applied to assess whether a significant difference existed between the mean scores of the post-test for the experimental group and the control group. Additionally, it was employed to investigate the statistical differences between female and male pupils within the experimental group.

To evaluate the impact or influence of extraneous variables (covariates) that could potentially confound the study's outcomes, an analysis of covariance (ANCOVA) was conducted. Effect size statistics, specifically Eta squared, were employed to quantify the effect size of the independent variable on the dependent variable. According to Cohen, Manion, and Morrison (2018), an effect size of 0.1 is considered small, 0.6 is deemed a moderate effect, and 0.8 is considered a large effect, providing a guideline for interpreting the magnitude of the observed effects.

3.14 Ethical Considerations

Creswell (2014) underscores the paramount importance of addressing ethical considerations meticulously in any research study. Accordingly, stringent adherence to ethical principles concerning human subjects involved in the study was adhered to. An introductory letter, sanctioned by the Department of Basic Education, was submitted to the Effutu District Director of Education, seeking approval for the inclusion of their subjects in the research study. Before any test administration or intervention, explicit consent was obtained from both teachers and pupils in both the control and experimental groups. This proactive approach ensured the voluntary and informed participation of all involved parties. Moreover, to safeguard the privacy and confidentiality of the names of schools, teachers, and pupils were deliberately omitted, underscoring a commitment to anonymity. Notably, all external sources cited in the research were duly acknowledged, adhering to scholarly and ethical standards. This approach not only aligns with ethical guidelines but also reflects a conscientious effort to uphold the integrity and credibility of the research study.

3.15 Summary of Chapter

This chapter provided a detailed account of the study's methodology, encompassing various essential components. Specifically, it delved into the research philosophy, research approach, research design, study area, population characteristics, sampling methods, research instrument, considerations of validity and reliability, potential threats to internal validity, procedures for data collection and analysis, and ethical dimensions within the study, addressing crucial aspects such as informed consent, confidentiality, and anonymity.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter discusses the data that were collected and used to interpret the results. The presentation consisted of two sections, namely the background information of the participants and the main results. Based on the research questions and hypotheses, the main results were presented in response to one research question and three research hypotheses.

This study investigated the effect of Geoboard software on the academic achievement of junior high school pupils in the Effutu Municipality of Ghana. Specifically, the study focused on the calculation of the perimeter and area of plane figures. The findings of this study are immensely significant as they shed light on how technology can be effectively utilized to enhance learning outcomes in mathematics.

4.1 Data Analysis and Discussion

The data analysis and discussion were done in two Section A and Section B: Section A focused on data analysis based on participant background information, including gender, the average age of the participants, their varying levels of computer literacy, mathematical ability, and expressed interest in mathematics. Section B focused on data analysis based on the results collected on pupils' academic achievement before and after being introduced to the use of Geoboard in learning of perimeter and area of plane figures.

Section A: Background Information of Participants

This section presents the results on the background information of the participants. The section provides demographic factors such as age, gender, and computer literacy level of the participants, providing a nuanced understanding of the composition of the studied cohort. Additionally, this section unveils insights into mathematics that may have a bearing on the participants' academic performance.

Distribution of Participants by Gender and Group Assigned

Table 4.1 shows the distribution of participants based on their gender and the group they were assigned to. The study included two groups of participants, namely the control group and the experimental group. The control group was taught perimeter and area of plane figures using the conventional instructional approach while the experimental group was taught using geoboard software. The data shows the number and percentages of males and females that were in each of these groups.

Table 4.1: Distribution of Participants by Group and Gender

	Control		Experiental		Total	
Gender	*F*	*%*	*F*	*%*	*N*	*%*
Male	27	52.9	28	48.3	55	50.5
Female	24	47.1	30	51.7	54	49.5
Total	**51**	**100.0**	**58**	**100.0**	**109**	**100.0**

Source: Field Work, 2023

The data presented in Table 4.1 indicates that the study's sample size was 109 pupils. Out of this number 55 (50.5%) were males and the remaining 54 (49.5%) being females. Based on the two groups, the control group had 51 pupils out of which 27 (52.9%) were males and 24 (47.1%) were females, while the experimental group included 58 pupils comprising 28 (48.3%) as males and 30 (51%) being females. This implies that the slightly more pupils were in the Experimental group than the control. Yet the control group had more males than females. Conversely, the experimental group had more females. Generally, there was an equal distribution of males and females in the study.

Distribution of Participants by Age

Table 4.2 aims at helping to understand the average age distribution among pupils, categorized by their respective groups (Control and Experimental). The results is presented as follows:

Table 4.2: Average Age Distribution of Pupils

Group	Frequency	Min.	Max.	Mean
Control	51	12	18	14.55
Experimental	58	12	17	14.05
Total	**109**			

Source: Field Work, 2023

Based on Table 4.2, the average age of the control group was 14.55 years while the average age of the experimental group was 14.05 years. However, the oldest person in the control group was age 18 years, while the youngest was 12 years. Similarly, the minimum age for the experimental group was 12 years while the maximum was 17 years. It can be convincingly said that the study involved two groups of pupils within similar age groups.

Distribution of Participants by Computer Ability Level

In Table 4.3, data on the computer literacy levels among pupils within the Experimental Group is presented. The study categorizes pupils ability to use computers into three: Foundational, Intermediate, and Advanced, offering both frequency and percentage representations. This is shown as follows:

Table 4.3: Pupils' Computer Ability

Computer Literacy Level	Frequency	Percentage
Foundational	12	11.0
Intermediate	97	89.0
Advanced	0	0
Total	**109**	**100.0**

Source: Field Work, 2023

The data in Table 4.3 revealed that 12 (11%) of the pupils had foundational computer ability, and 97 (89%) of the pupils had intermediate computer ability. It can be seen that no pupil had advanced computer ability. This indicates that the majority of the pupils' computer literacy ability was intermediate. Hence, before the study, the pupils taught using the geoboard software had no superior knowledge of computer literacy though this level of could have significantly influenced their performance, of which the researcher controlled for this effect.

Distribution of Participants by Mathematics Abilities

Table 4.4 outlines the mathematics abilities of pupils based on three levels as Below Average, Average, and Above Average, with scores ranges indicated.

Table 4.4: Pupils' Mathematics Ability

Mathematics Ability	Range	Frequency	Percentage
Below Average	1-15	70	64.2
Average	16-30	39	35.8
Above Average	31-45	0	0
Total		**109**	**100.0**

Source: Field Work, 2023

It can be seen on Table 4.4 that 70 (64.2%) of the pupils' mathematics ability was below average, 39 (35.8%) of the pupils' mathematics ability was average and none of the pupils had above average mathematics ability. This indicates that the majority of the pupils' mathematics ability did not meet the average mark.

Distribution of Participants by Mathematics Interest

Table 4.5 outlines the mathematics interests of pupils based on three levels low, average, and high with frequency and percentage indicated.

Table 4.5: Mathematics Interest

Mathematics Interest	Frequency	Percentage
Low	2	1.8
Average	48	44.0
High	59	54.2
Total	**109**	**100.0**

Source: Field Work, 2023

The data in Table 4.5 reveals that 2 (1.8%) of the pupils' mathematics interest was low, 48 (44.0%) of the pupils' mathematics interest was average and 59 (54.2%) of the pupils' mathematics interest was high. This suggests that the majority of the pupils had a high interest in mathematics.

Section B: Main Data Analysis

This section focused on the main analysis of data using the scores collected on pupils' academic achievement before and after being introduced to the use of geoboard in learning of perimeter and area of plane figures.

Results of Pre-test

The pre-test was conducted for both the control and experimental groups. The purpose of the pre-test was to determine if pupils in both groups had equivalent entry levels in area and perimeter of plane figures before the introduction of geoboard as an intervention. The test was scored out of forty-five (45) marks. The test items were in 3 sections. Each section focused on a level of Van Hiele's Levels of Geometric Thinking. Section A comprised of 5 test items on Level 0 (Visualisation), section B comprised of 5 test items on Level 1(Analysis), and Section C comprised of 5 test items on Level 2 (Abstraction) The results of the pre-test are shown in Table 4.6 and Table 4.7

Assumption Test Results for Pre-test Scores

Before employing the T-test as inferential statistics to test the hypotheses formulated for the study, the researcher conducted a preliminary test on the assumptions of T-test. The specific assumptions subjected to scrutiny included, but were not limited to, normality, homogeneity of variances, not significant outliners, scale of measurement of the data, and independence of observations. These assumptions were considered and steps were taken to satisfy them as follows;

Scale of Measurement of Data

They are test scores, which are continuous data, measured within the interval or ratio level.

Normality

Kolmogorov-Smirnov was used to test normality. A significant value of 0.200 was obtained which indicated the scores were normally distributed and the assumption of normality was not violated.

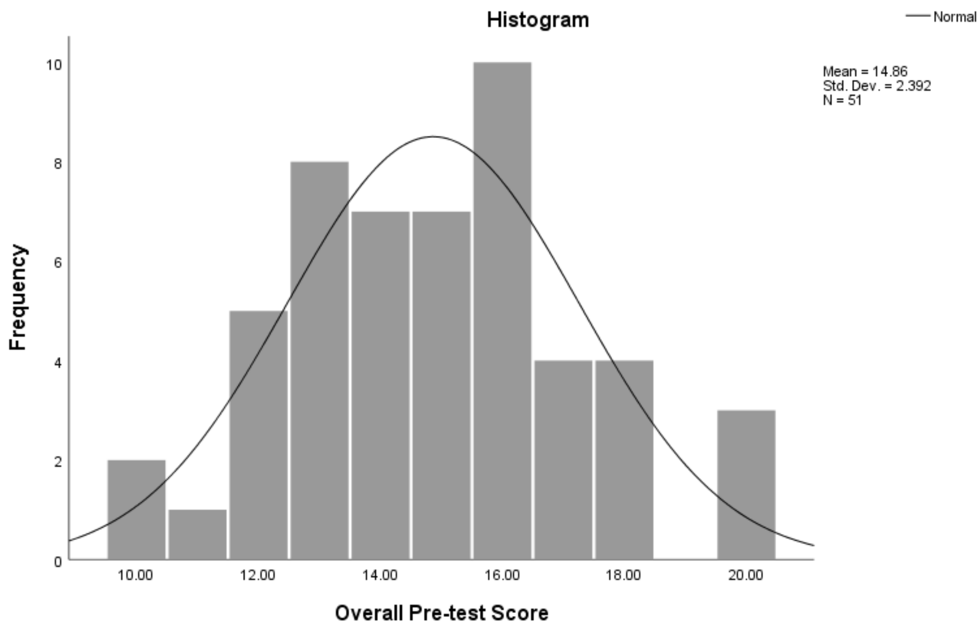

***Figure 4.1*: Histogram on Pre-test Scores**

Independence of Observation

In to ensure independence of observation, the test was conducted with rigorous adherence to supervision in class, ensuring that no substantial interaction occurred either among or within the groups. Consequently, this prevented any influence or dependency among the pupils used in the study. Similarly, the two different schools used for the study were situated very far from each other discouraging any form of interaction between pupils within the two different groups.

No Outliners

To ensure that there were no missing data as well as no extremely low or high values in the data, the researcher first screened the data to identify and address potential outliers and missing values. This thorough examination utilized both stem-and-leaf plots and box plots, offering a comprehensive visualization of the dataset's distribution and highlighting any data points that deviated significantly from the norm.

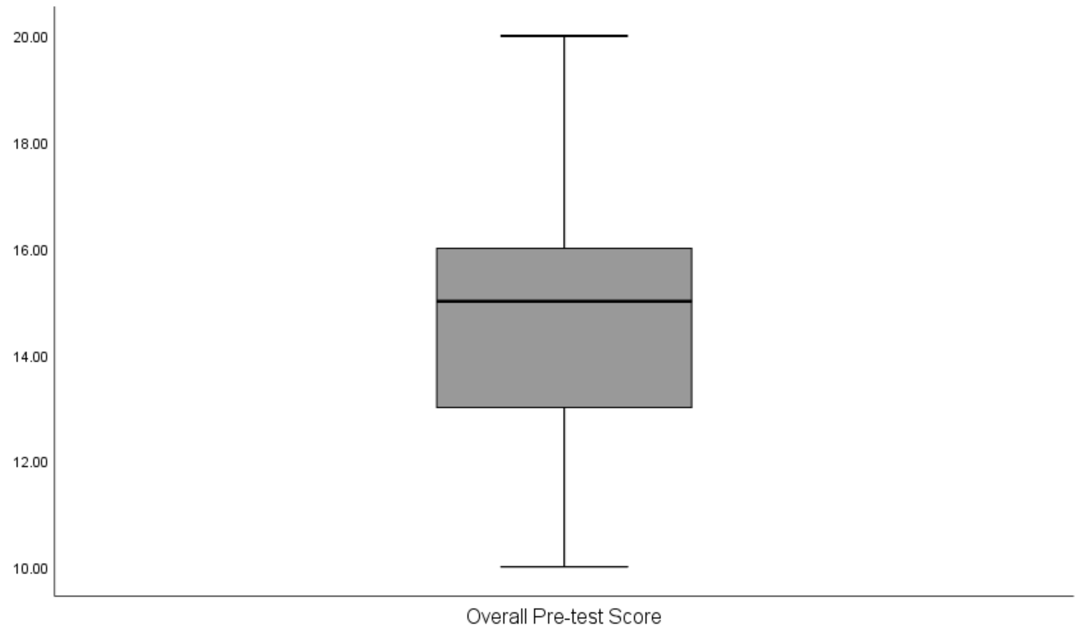

***Figure 4.2*: Box and Whisker for Pre-test Scores**

Homogeneity of variance

Table 4.6 outlines Levene's test of equality of variance for pre-test scores to determine whether the variances of the control and experimental groups are, in fact, approximately equal.

Table 4.6: Levene's Test of Equality of Variance for Pre-test Scores

F	df1	df2	Sig.
0.203	1	107	0.653

Test the null hypotheses that the error is variance of the dependent

Levene's test was employed as a pivotal step in validating the assumption of homogeneity of variance. The calculated p-value, specifically 0.653, provided substantial evidence against the violation of the homogeneity of variance assumption. This statistical assessment served to confirm that the variances across different groups were reasonably consistent, ensuring the reliability of subsequent analyses.

All assumptions were met, thereby justifying the use of the T-test as a parametric test.

What is the level of academic achievement of pupils on areas and perimeters of plane figures on the pre-test?

Research Question 1 sought to determine the level of academic achievement of pupils in terms of the perimeter and area of a plane figure on the pre-test.

Before the start of the study, a pre-test was administered to know the general entry academic achievement levels of pupils. The scores of pupils were then classified into ranges of below average (0-15), average (16-30), and above average (31-45). The frequencies and percentages for each academic achievement category are presented separately for the control and experimental groups is presented on Table 4.7.

Table 4.7: Descriptive Statistics of both Groups on the Pre-test

Remarks	**Range**	**Control**		**Experimental**	
		F	**(%)**	**F**	**(%)**
Below Average	0-15	30	59	40	69
Average	16-30	21	41	18	31
Above Average	31-45	0	0	0	0
Total		**51**	**100**	**58**	**100**
Mean (Control and Experimental group					14.486

Source: Field Work, 2023

The pre-test results in Table 4.7 reveal that, before the implementation of the intervention, pupils' academic achievement fell below the average threshold. In both the control and experimental groups, a significant majority of pupils achieved scores within the below-average range. A detailed comparison between the two groups indicates that, in the control group, 30 pupils (59%) scored below average, while 21 pupils (41%) achieved average scores, with no pupils attaining marks in the above-average range. Similarly, in the experimental group, 40 pupils (69%) scored below average, 18 pupils (31%) achieved average scores, and none scored in the above-average range. Furthermore, examining the overall academic achievement levels in both the control and experimental groups, it is evident that a majority of pupils 70, (69%) scored within the 0-16 marks range, with an average score of 14.486, indicating an overall below-average academic achievement level. These findings suggest a comparable entry-level knowledge of both groups in topic, area and perimeter of plane figures.

This result confirms the findings of Abadi and Amir (2022) basic school pupils have difficulty solving problems of area and perimeter of plane figures because of basic problems, namely experiencing obstacles in verbal problems and inadequate conceptual knowledge. Their findings also show that pupils with low levels of ability experienced verbal difficulties in not working on the questions according to the instructions. pupils with a moderate level of ability face conceptual difficulties in the form of being unable to make relevant decisions according to the requirements of the questions. In addition, pupils experience principal difficulties in the form of an inability to determine the relevant factors and incorrectly using the perimeter unit for the area unit. pupils with a high level of ability experience principal difficulties in using formulas, so they tend to experience inaccuracies in solving problems. Similarly, the result confirms the findings of Sisman and Aksu (2009) who observed that 7th grade pupils struggled with understanding and applying area and perimeter formulas, often confusing the two concepts. The results of the pre-test is as a result of overemphasis on formulas and their premature introduction (Walton & Randolph, 2017).

To further establish if any differences in the academic achievement of the two groups of pupils were statistically significant or not, an independent samples t-test was conducted. The results if shown in Table 4.8 as follows:

Table 4.8: Independent Samples T-Test on the Pre-test Results

	N	Mean	SD	F	Levene's Sig.	t	df	Sig (2 tailed)
Control	51	14.86	2.39	0.203	0.653	1.501	107	0.136
Experimental	58	14.16	2.51					

Source: Field Work, 2023

The results on Table 4.8 of the independent samples t-test conducted showed that the pre-test academic achievement of the control group (M=14.86, SD=2.39) was not statistically and significantly different from the academic achievement of the experimental group (M=14.16, SD=2.51) at 0.05 level of significance, (t (107) = 1.501, n = 109, p > 0.05) and 95% confidence interval. Thus, the critical P-value obtained (0.653, 2-tailed) is greater than the alpha level of 0.05 indicating that the difference in mean pre-test scores between the control and experimental group of pupils was not statistically significant. Therefore, the researcher failed to reject the null hypothesis and concluded that there is no statistically significant difference between the control and the experimental group in terms of their entry knowledge of area and perimeter of plane figures. This result also confirms that both groups' academic achievement in area and perimeter of plane figures were similar in terms of their entry knowledge.

Results of Post-test

To examine any observed difference between the two groups, three hypotheses were formulated. These hypotheses were tested at 95% level of confidence and a significant level of 0.05. Independent sample t-test was used for all the hypotheses. All key assumptions of t-test were checked and found tenable. The results are indicated as follows:

Assumption Test Results for Post-test Scores

Scale of Measurement of Data

The post-test scores were continuous data, measured within the interval or ratio level.

Normality

Kolmogorov-Smirnov was used to test normality of the post-test scores. A significant value of 0.180 was obtained which indicated the scores were normally distributed and the assumption of normality was not violated.

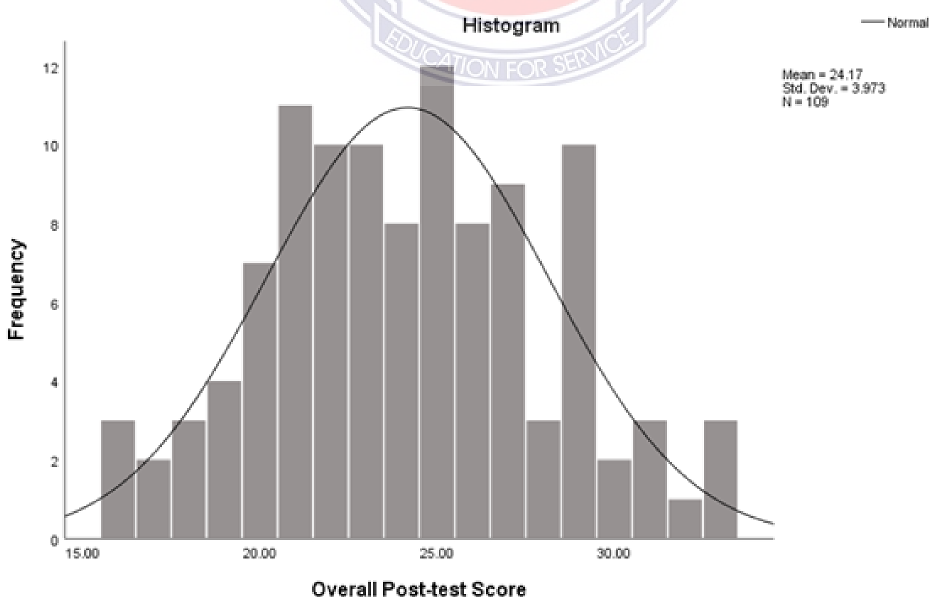

***Figure 4.3*: Histogram of Post-test Scores**

No Outliners

To ensure that there were no missing data as well as no extremely low or high values in the data, the researcher first screened the data to identify and address potential outliers and missing values. This thorough examination utilized both stem-and-leaf plots and box plots.

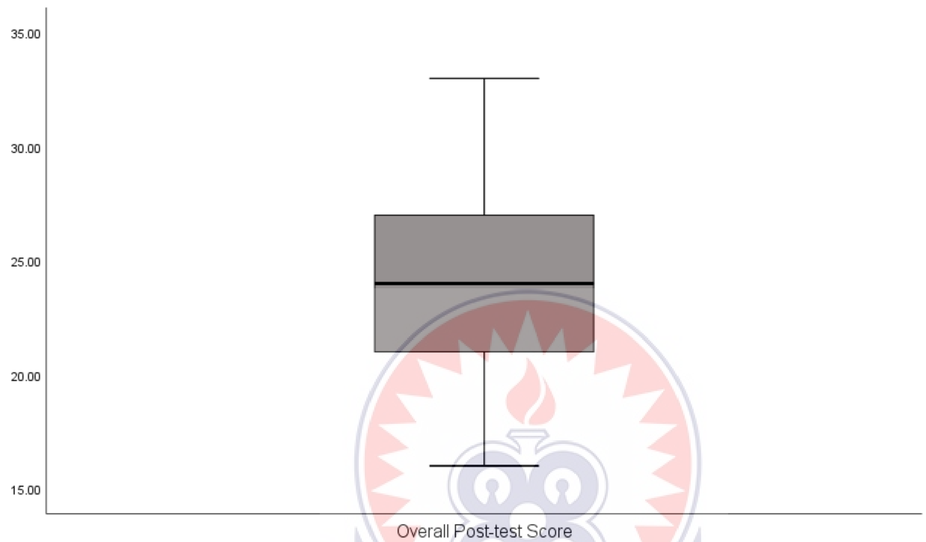

***Figure 4.4*: Box and Whisker for Post-test Scores**

Independence of Observation

In to ensure independence of observation for the post-test, the same condition of the pre-test was applied in the post-test. The test was conducted with strict supervision in class to prevent any substantial interaction within or among the groups. This ensured that there was no influence or dependency among the pupils in the post-test.

Homogeneity of variance

Table 4.9 outlines Levene's test of equality of variance for post-test scores to determine whether the variances of the control and experimental groups are, in fact, approximately equal.

Table 4.9: Levene's Test of Equality of Variance

F	df1	df2	Sig.
0.014	1	107	0.907

Test the null hypothesis that the error is variance of the dependent

The null hypothesis for Levene's test is that the variances of the groups being compared are equal (i.e., there is homogeneity of variances). Given that the significance value (Sig.) is 0.907, which is much greater than the usual alpha level of 0.05, we fail to reject the null hypothesis. This suggests that the assumption of homogeneity of variances has been met, meaning that the variances across the groups are statistically equal.

Hypothesis 1

$H_{o1:}$ There is no statistically significant difference in the academic achievement between pupils taught area and perimeter of plane figures using Geoboard software and pupils taught area and perimeter of plane figures without Geoboard software.

Table 4.10 shows the post-test academic achievement of pupils based on their levels, as categorized by the defined ranges of Below Average (0-15), Average (16-30), and Above Average (31-45) as follows:

Table 4.10: Descriptive Statistics of both Groups on the Post-test

Remarks	**Range**	**Control**		**Experimental**	
		F	**(%)**	**F**	**(%)**
Below Average	0-15	0	0	0	0
Average	16-30	51	100	51	88
Above Average	31-45	0	0	7	12
Total		**51**	**100**	**58**	**100**
Mean (Control and Experimental group)				24.1651	

Source: Field Work, 2023

The results from the post-test in Table 4.10 show that after implementation of the intervention, the academic achievement of pupils involved in the study was average. In both groups, the majority of pupils, 102 (96%) scored within the average range, with a mean score of 24.165 for both groups. Comparing the academic achievement between the control and experimental groups, the results indicate that in the control group, all the pupils 51 (100%) of pupils scored average marks. In the experimental group, 51 (88%) of pupils scored average marks, while 7 12%) of pupils scored above average marks. This result indicates that both groups' academic achievement in area and perimeter of plane figures had improved on the post-test as compared to the pre-test results. This result is in line with the findings of Saidu and Bunyamin (2016) found that the use of geoboard led to a significant difference in pupils' performance, while Abari and Andrews (2021) reported that the use of geoboard in teaching geometry was more effective than the lecture method. Bakar (2015) further supported these findings, showing that the use of dynamic mathematics software, including geoboard, led to better test scores. Trimurtini et al., (2020) also found that the contextual teaching and learning approach with geoboard media was effective in improving mathematics learning outcomes for elementary pupils. These studies collectively suggest that geoboard instruction can enhance pupils' academic achievement in mathematics.

To test for any statistical difference in the academic achievement of the two groups, an independent sample t-test was conducted and the results is shown on Table 4.11 as follows:

Table 4.11: Independent Samples T-Test on the Post-test Results

	N	Mean	SD	F	Levene's Sig.	t	df	Sig (2 tailed)
Control	51	22.12	3.55	0.014	0.907	-5.74	107	0.000
Experimental	58	25.97	3.43					

Source: Field Work, 2023

The results in Table 4.11 of the independent samples t-test conducted showed that the post-test academic achievement of the experimental group (M=25.97, SD=3.43) was statistically and significantly different from the academic achievement of the control group (M=22.12, SD=3.55). at 0.05 level of significance, (t (107) = -5.74, n = 109, p > 0.05) and 95% confidence interval. Thus, the critical P-value obtained (0.000, 2-tailed) is less than the alpha level of .05 indicating that the difference in mean post-test scores between the control and experimental group of pupils was statistically significant and did not occur by chance. Therefore, the researcher rejects the null hypothesis and accept the alternate hypothesis that there is a statistically significant difference in the academic achievement between pupils taught area and perimeter using geoboard software and pupils taught area and perimeter of plane figures without geoboard software. This result also implies that the use of Geoboard in teaching and learning of area and perimeter of plane figures helps to improve pupils' performance. This result is in line with the results of Trimurtini et al. (2020) which showed that the mastery learning of the experimental group reached 75%; the experimental group's average learning outcome was higher than the control group; the experimental group's activities in solving problems enhanced from 88.34% to 96.66%.

Since the hypothesis was rejected, it was crucial to establish the effect size. To determine the effect size of the use of Geoboard software in the teaching of area and perimeter of plane figures. The computed effect size statistics was 1.023. The value of 1.023 represents a large effect size. The intervention was shown to be highly effective, explaining more than 80% of the control group scored below the experimental group mean. Again, Sawilowsky (2009) stated that an effect size of 0.10 very small effect, 0.2 represents a small effect, an effect size of 0.5 represents a medium effect, and an effect size of 0.8 represents a large effect, 1.20 represents a very large effect size, and an effect size of 2.00 represents a huge effect size. As a result, the calculated effect size of 1.023 suggested a large effect.

In this study, there are several variables such as extraneous variables. Extraneous variable is any variable not under investigation but can potentially affect the outcomes of the research study. If these extraneous variables remain uncontrolled, they can lead to inaccurate conclusions about the relationship between the independent variable (use of Geoboard software in teaching area and perimeter of plane figures) and the dependent variables (academic achievement of pupil in area and perimeter of plane figures) (Sturman et al., 2022). It is therefore important to determine the effect of these variables on the dependent variable through statistical analysis. To determine the effect of the covariates on the academic achievement of pupils in the experimental groups, an Analysis of Covariance (ANCOVA) was performed.

Assumptions Test for Analysis of Covariance (ANCOVA)

Homogeneity of Variance

Table 4.12 presents the result of Levene's test for equality of variance examining the homogeneity of variance.

Table 4.12: Levene's Test of Equality of Variance

F	df1	df2	Sig.
0.106	1	107	0.746

Test the null hypotheses that the error is variance of the dependent is across group

a. Design: Intercept + Group + Gender + Age + Computer Proficiency + Mathematics Interest+ Pre-test

The results of Levene's test when the covariates are included in the model as a covariate. Levene's test was insignificant with a p value of 0.746, indicating that the group variances are equal hence the assumption of homogeneity of variance is not violated.

Correlation of Dependent Variable and Covariate

Table 4.13 presents the results of the correlation between the covariates and dependent variables.

Table 4.13: Levene's Test of Equality of Variance

Correlations

		Overall Post-test
Gender	Pearson Correlation	-0.181
	Sig. (2-tailed)	0.059
	N	109
Age	Pearson Correlation	-0.098
	Sig. (2-tailed)	0.309
	N	109
Computer Proficiency	Pearson Correlation	0.034
	Sig.(2-tailed)	0.728
	N	109
Mathematics Interest	Pearson Correlation	0.115
	Sig. (2-tailed)	0.233
	N	109
Pre-test	Pearson Correlation	0.453**
	Sig. (2-tailed)	0.000
	N	109
Experience using mathematics software or application	Pearson Correlation	-0.038
	Sig. (2-tailed)	0.692
	N	109

Correlation is significant at the 0.01 level (2-tailed)**
Correlation is significant at the 0.05 level (2-tailed) *

The result of the correlation test shows the correlation between the dependent variable (Post-test) and the covariates (Gender, Age, Computer Ability, Mathematics Interest, Pre-test, Experience using mathematics software or application). The result shows all the covariates correlated less than 0.80. This indicates that the assumption of correlation of the dependent variable and covariate was not violated.

Table 4.14 presents key statistical measures for the test of between-subject effect to determine the effect of the covariates on the dependent variable (post-test scores).

Table 4.14: Analysis of Covariance Test

Dependent Variable: Post-test Scores

Source	**Type III Of Squares**	**df**	**MS**	**F**	**Sig.**	**Partial Eta Squared**
Intercept	36.618	1	36.618	4.542	0.035	0.043
Gender	3.051	1	3.051	0.378	0.540	0.004
Age	5.813	1	5.813	0.721	0.398	0.007
Computer Ability	0.002	1	0.002	0.000	0.988	0.000
Exp. With Maths Apps	4.347	1	4.347	0.539	0.464	0.005
Mathematics Interest	1.879	1	1.879	0.233	0.630	0.002
Pre-test	437.441	1	437.441	54.265	0.000	0.349
Group	487.926	1	487.926	60.527	0.000	0.375
Error	814.186	109	8.061			
Total	1705.028	108				
Corrected Total						

a. R Squared = 0.522 (Adjusted R Squared = 0.489)

The results from Table 4.14 show the Analysis of Covariance (ANCOVA) test. From Table 4.14 there was a statistically significant difference in the post-test scores of the control (pupils taught area and perimeter of plane figures with the conventional techniques) and experimental group (pupils taught area and perimeter of plane figures using Geoboard

Software), *F* (1, 109) = 60.527, p = 0.000 (i.e., $p < 0.05$), partial eta squared= 0.375. From the results, it can be said that, practically, the group accounted for 37.5% of the variations in pupils' test scores. The results provide robust evidence that the teaching technique has a significant impact on post-test scores, even when controlling for covariates. Pupils taught area and perimeter with Geobaord software demonstrated significantly different academic achievement compared to those taught with the conventional technique.

Hypothesis 2

H_{o2} : There is no statistically significant difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught area and perimeter without Geoboard software at the Van Hieles' Levels of Geometric Thinking.

Table 4.15 presents key statistical measures for the two groups, the control and experimental groups, providing insights into the distribution of a specific variable under investigation.

Table 4.15: Descriptive Statistics for Post-test Results on Van Hieles' Level 0 (Visualisation) of Geometric Thinking

Group	N	Max	Min
Control	51	5	4
Experimental	58	5	4

Source: Field Work, 2023

The data presented in Table 4.15 showed that the highest and lowest scores for the control group were 5 and 4 respectively. For the experimental group, the highest and lowest scores for the control group were also 5 and 4 respectively. This result indicates that the highest score was identified with both the control and experimental groups with. Indicating a similar academic achievement in both groups.

To detect any statistically significant difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught with the conventional technique at the Van Hieles' level 0 (Visualisation) of Geometric Thinking, a t-test was used. The result of the test is shown in Table 4.16 as follows;

Table 4.16: Independent Samples T-Test for Post-test Results on Van Hieles' Level 0 (Visualisation) of Geometric Thinking

	N	Mean	SD	F	Levene's Sig.	t	df	Sig (2 tailed)
Control	51	4.75	0.44	13.89	0.62	-1.817	107	0.072
Experimental	58	4.88	0.33					

Source: Field Work, 2023

The results in Table 4.16 of the independent samples t-test conducted showed that the post-test academic achievement of the control group (M=4.75, SD=0.44) at Van Hieles' level 0 (Visualisation) of Geometric Thinking, was not statistically significantly different from the academic achievement of experimental group (M=4.88, SD=0.33). at 0.05 level of significance, (t (107) = -1.817, n = 109, p > 0.05) and 95% confidence interval. Thus, the critical P-value obtained (0.072, 2-tailed) is greater than the alpha level of 0.05 indicating that the difference in mean post-test scores between the control group and the experimental group was not statistically significant. Therefore, the researcher failed to reject the null hypothesis and concludes that there is no statistically significant difference in the academic achievement between the control group and experimental group at Van

Hieles' level 0 (Visualisation) of Geometric Thinking. This result implies that at the first level of Van Hieles' Geometric thinking, the use of Geoboard software does not bring about any significant gain compared to the conventional teaching technique. This result is in line with Tieng and Kwan Eu (2014) who found no significant difference in the academic achievement of pupils using Geometer's Sketchpad compared to a control group. Again, the study found that there was no correlation between pupils' literacy in using Information and Communications Technology and their van Hieles' level of geometric thinking after using Geometer's Sketchpad

To determine the effect size of the use of Geoboard in the teaching area and perimeter of plane figures in terms of Van Hieles' Level 0 (Visualisation) of Geometric Thinking, the researcher computed the effect size. The computed effect size statistics was 0.334. The value of 0.334 represents a small effect. It is therefore evident from Sawilowsky (2009) that the intervention accounted for a 33% difference in pupils' academic achievement in area and perimeter of plane figures in terms of Van Hieles' Level 0 (Visualisation) of Geometric Thinking.

Difference in the academic achievement of pupils at Van Hieles' Level 1 (Analysis) of Geometric Thinking

Table 4.17 presents key statistical measures for the two groups, the control and experimental groups, providing insights into the distribution of a specific variable under investigation in determining the academic achievement of pupils at Van Hieles' Level 1 (Analysis) Geometric thinking.

Table 4.17: Descriptive Statistics for Post-test Results on Van Hieles' Level 1 (Analysis) of Geometric Thinking

Group	N	Max	Min
Control	51	16	8
Experimental	58	18	12

Source: Field Work, 2023

The data presented in Table 4.17 showed that the highest and lowest scores for the control group were 16 and 8 respectively. For the experimental group, the highest and lowest scores for the control group were 18 and 12 respectively. This result indicates that the highest score was identified with the experimental group with the control recording the least score. This result offers initial support for the efficacy of the experimental intervention.

To determine any statistically significant difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught with the conventional technique at Van Hieles' Level 1 (analysis) of Geometric Thinking, a t-test was used.

Table 4.18 presents the results of an independent samples t-test examining the post-test outcomes for males and females in both control and experimental groups at Van Hieles' level 1 (Analysis) of Geometric Thinking. This table serves as a crucial tool for shedding light on specific differences in post-test results between the control and experimental groups on academic achievement at Van Hieles' Level 1 (Analysis) of Geometric Thinking.

Table 4.18: Independent Samples T-Test for Post-test Results on Van Hieles' Level 1 (Analysis) of Geometric Thinking

	N	Mean	SD	F	Levene's Sig.	t	df	Sig (2-tailed)
Control	51	12.75	2.15	3.921	0.051	-8.20	107	0.000
Experimental	58	15.76	1.68					

Source: Field Work, 2023

The results in Table 4.18 of the independent samples t-test conducted showed that the post-test academic achievement of the control group (M=12.75, SD=2.15) at Van Hieles' Level 1 (Analysis) of Geometric Thinking, was statistically significantly different from the academic achievement of the experimental group (M=15.76, SD=1.68). at 0.05 level of significance, (t (107) = -8.20, n = 109, p > 0.05) and 95% confidence interval. Thus, the critical P-value obtained (0.000, 2-tailed) is less than the alpha level of .05 indicating that the difference in mean post-test scores between the control group and the experimental group was statistically significant. Therefore, the researcher rejects the null hypothesis and concludes that there is a statistically significant difference in the academic achievement between the control group and experimental group at Van Hieles' Level 1 (Analysis) of Geometric Thinking. This result implies at the second level of Van Hieles' Geometric thinking (Analysis), the use of Geoboard software brings about significant improvement compared to the conventional teaching technique. These results are in line with Meng et al. (2013) that the use of technology, such as Geometer's Sketchpad, can enhance geometric thinking.

To determine the effect size of the use of Geoboard software in the teaching area and perimeter of plane figures in terms of Van Hieles' Level 1 (Analysis) of Geometric Thinking, the researcher computed the effect size. The computed effect size statistics was 1.561. The value of 1.561 represents a very large effect. The intervention was shown to be highly effective on pupils' academic achievement in terms of Van Hieles' Level 1 (Analysis) of Geometric Thinking, explaining that more than 92% of the control group scored below the experimental group mean. It is therefore evident from the Cohen's d that the Geoboard software accounted for a large effect in pupils' academic achievement in area and perimeter of plane figures in terms of Van Hieles' Level 0 (Visualisation) of Geometric Thinking.

Difference in the academic achievement of pupils at Van Hieles' Level 2 (Abstraction)

Table 4.19 presents key statistical measures for the two groups, the control and experimental groups, providing insights into the distribution of a specific variable under investigation in determining the academic achievement of pupils at Van Hieles' Level 2 (Abstraction) Geometric thinking.

Table 4.19: Descriptive Statistics for Post-test Results on Van Hieles' Level 2 (Abstraction) of Geometric Thinking

Group	N	Max	Min
Control	51	10	0
Experimental	58	15	0

Source: Field Work, 2023

The data presented in Table 4.19 showed that the highest and lowest scores for the control group were 10 and 0 respectively. For the experimental group, the highest and lowest scores for the control group were also 15 and 0 respectively. This result indicates that the highest score was identified with the experimental group with the control and experimental recording the similar least scores.

To determine any statistically significant difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught with the conventional technique at Van Hieles' Level 2 (Abstraction) of Geometric Thinking, a t-test was used.

Table 4.20 presents the results of an independent samples t-test examining the post-test outcomes for males and females in both control and experimental groups at Van Hieles' Level 2 (Abstraction) of Geometric thinking.

Table 4.20: Independent Samples T-Test for Post-test Results on Van Hieles' Level 2 (Abstraction) of Geometric Thinking

	N	Mean	SD	F	Levene's Sig.	t	df	Sig (2 tailed)
Control	51	4.55	2.03	1.58	0.211	-2.13	107	0.036
Experimental	58	5.50	2.56					

Source: Field Work, 2023

The results in Table 4.20 of the independent samples t-test conducted showed that the post-test academic achievement of the control group (M=4.55, SD=2.03) at Van Hieles' level 2 (Abstraction) of Geometric Thinking was statistically significantly different from the academic achievement of experimental group (M=5.50, SD=2.56). at 0.05 level of significance, (t (107) = -2.13, n = 109, p > 0.05) and 95% confidence interval. Thus, the critical P-value obtained (0.036, 2-tailed) is less than the alpha level of .05 indicating that the difference in mean post-test scores on Van Hieles' Level 2 (Abstraction) of Geometric Thinking between the control group and the experimental group was statistically significant.

Therefore, the researcher rejects the null hypothesis and accept the alternate hypothesis that there is a statistically significant difference in the academic achievement between the control group and experimental group at Van Hieles' Level 2 (Abstraction) of Geometric Thinking. This result implies at the third level of Van Hieles' Geometric thinking (Abstract), the use of Geoboard software brings about significant improvement compared to the conventional teaching technique. These results are in line with the results of Abdullah and Zakaria (2013) that the use of Geometer's Sketchpad (GSP) led to a significant improvement in pupils' geometric thinking, with a high acquisition of level 2. Again, the result also confirms the results of Alex (2016) who observed significant improvement in the academic achievement of pupils at level 2 when using van Hieles' theory-based instruction utilising geometric software. Kutluca (2013) further supported these results, noting that the use of dynamic geometry software, such as GeoGebra and Geometry Sketchpad led to a significant increase in pupils' understanding of geometry at level 2. These studies collectively suggest that the use of software for teaching geometry can positively impact pupils' academic achievement at Van Hieles' level 2.

To determine the practical effect of the use of Geoboard software in the teaching and learning of area and perimeter of plane figures in terms of Van Hieles' Level 2 (Abstraction) of Geometric Thinking, the researcher computed the effect size after calculating the t-test. The computed effect size statistics was 0.411. The value of 0.411 represents a small effect. According to Mcleod (2019), Cohen suggested that an effect size of 0.2 – 0.4 represents a small effect, an effect size of 0.5 represents a medium effect, and an effect size of 0.8 represents a large effect. It is therefore evident from Cohen's d that the intervention accounted for a 41% difference in pupils' academic achievement in area and perimeter of plane figures in terms of Van Hieles' Level 0 (Visualisation) of Geometric Thinking.

From the results presented on pupils' academic achievement on Van Hieles' Levels of Geometric Thinking, it is concluded that the utilisation of technology, such as Geoboard software, significantly improves the understanding of geometric concepts such as area and perimeter among pupils. This dynamic software allows for hands-on exploration, enabling pupils to actively manipulate and visualize geometric constructions in real time. Through features like drag-and-drop functionalities, precise adjustments, and real-time feedback, pupils can independently discover and comprehend geometric principles. The visual representation of abstract concepts enhances comprehension, and the software's collaborative capabilities foster peer learning. Moreover, educators can create tailored lessons to accommodate diverse learning styles, making area and perimeter instructions more engaging and personalised. In essence, the integration of technology, exemplified by Geoboard software, transforms the study of area and perimeter into a dynamic, interactive, and inclusive learning experience.

Hypothesis 3

H_{o3}: There is no statistically significant difference in the academic achievement of male and female pupils taught area and perimeter of plane figures using Geoboard software.

This hypothesis sought to find out if there was any statistically significant difference in the academic achievement of male and female pupils taught area and perimeter of plane figures using geoboard software. The comparative analysis in Table 4.21 therefore shows how both males and females performed on the pre-test and post-test on area and perimeter of plane figures as follows:

Table 4.21: Descriptive Statistics of Gender for Both Groups on the Pre-test and Post-test

Gender	N	Pre-test		Post-test	
		Mean	Std. Dev	Mean	Std. Dev
Males	30	14.07	2.69	26.43	3.94
Females	28	14.25	2.35	25.46	2.78

Source: Field Work, 2023

The descriptive statistics in Table 4.21 revealed that in the pre-test, female participants (M=14.25, SD = 2.35) slightly outperformed their male counterparts (M=14.07, SD = 2.69). However, in the post-test, male participants exhibited a substantial increase in mean scores to 26.43 (SD = 3.94), whereas female participants showed a comparable increase to 25.46 (SD = 2.78). This resulted in males slightly outperforming their female counterparts in the post-test. These findings generally suggest a notable improvement in both male and female participants' scores from the pre-test to the post-test.

To ascertain any statistically significant difference in the academic achievement of male and female pupils taught area and perimeter of plane figures using geoboard software, an independent sample t-test was conducted using the post-test results for both groups. Table 4.22 presents the outcomes of this test as follows:

Table 4.22: Independent Samples T-Test of Males and Females on Post-test Results

	N	Mean	SD	F	Levene's Sig.	t	df	Sig (2 tailed)
Males	30	26.43	3.94	6.88	0.011	1.076	56	0.287
Females	28	25.46	2.78			1.088		0.281

Source: Field Work, 2023

The results in Table 4.22 of the independent samples t-test conducted showed that the post-test academic achievement of males (M=26.43, SD=3.94) was not statistically significantly different from the academic achievement of females (M=25.46, SD=2.78). at 0.05 level of significance, ($t(56) = 1.076$, $n = 58$, $p > 0.05$) and 95% confidence interval. Thus, the critical P-value obtained (0.287, 2-tailed) is greater than the alpha level of .05 indicating that the difference in mean post-test scores between males and females was not statistically significant. Therefore, the researcher failed to reject the null hypothesis and concludes that there is no statistically significant difference in the academic achievement between male and female pupils taught area and perimeter of plane figures using geoboard software. This result is in line with the results of Bakar et al. (2015) that the use of Geoboard in teaching area and perimeter of plane figures does not show a significant difference in academic achievement between male and female pupils while refuting results. Similarly, Shavalier (2004) found no significant gains in spatial ability among middle school pupils using CAD-like software, with no differential effects based on gender or spatial ability. However, the results refute the results of Seloraji and Leong (2017) that the use of Geoboard software has been shown to significantly improve pupils' academic achievement in geometry.

To determine the effect size of the difference in the academic achievement of male and female pupils taught area and perimeter of plane figures using Geoboard software, the researcher computed the effect size. The computed effect size statistics was 0.284. The value of 0.284 represents a small effect. It is therefore evident from Cohen's d that the intervention accounted for a 28% difference in pupils' academic achievement in area and perimeter of plane figures in terms of Van Hieles' Level 0 (Visualisation) of Geometric Thinking.

4.3 Chapter Summary

This chapter presented a comprehensive analysis of the collected data, employing a combination of descriptive and inferential statistical methods. Descriptive statistics, including frequency, percentages, and the range (minimum and maximum scores), were utilized to assess the distribution and extremities of pupils' pre-test and post-test scores. In the inferential analysis, the independent samples t-test was employed to determine the comparability of mean scores between the experimental and control groups. This statistical technique was instrumental in gauging whether a significant difference exists in the mean scores of the post-test academic achievement between the two groups. Furthermore, the Analysis of Covariance (ANCOVA) was employed to investigate the effect of covariates on pupils' post-test performance. ANCOVA allows for the examination of group differences while considering the influence of covariates. The primary focus was on discerning whether any observed differences in post-test scores could be attributed to factors other than the independent variable. To quantify the effect size of the independent variable (Geoboard) on the dependent variable (Academic achievement in post-test), Cohen's d was computed. This effect size statistic provides insight into the proportion of variance in the dependent variable attributable to the independent variable, offering a nuanced understanding of the practical significance of the observed effects.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

This chapter provides a comprehensive exploration of the study's objectives, methodology, and key findings. It culminates in drawing conclusions derived from the study's results, followed by a set of recommendations that underscore the significance of integrating Geoboard into the pedagogy of area and perimeter for plane figures. Additionally, the chapter extends insights into potential avenues for future research, emphasizing the importance of continued investigation in this educational domain.

5.1 Summary of the Study

This study aimed to investigate the effect of Geoboard software on the academic achievement of junior high school pupils in of area and perimeter of plane figures within the Effutu Municipality. To achieve this, the study addressed a four research questions and three hypotheses. The key research questions included: (1) What is the current level of academic achievement among pupils in the areas and perimeters of plane figures? (2) What is the difference in academic achievement between pupils taught these concepts using Geoboard software versus those taught without it? (3) How does the academic achievement differ between pupils taught with Geoboard software and those taught without it across the Van Hiele's levels of geometric thinking? (4) What is the difference in academic achievement between male and female pupils taught using Geoboard software?

The study was guided by several hypotheses: H*o1* asserts that there is no statistically significant difference in academic achievement between pupils taught using Geoboard software and those taught without it, while H*a1* suggests that such a difference does exist.

Ho*2* proposes that there is no statistically significant difference in academic achievement at the Van Hiele's levels of geometric thinking between pupils taught with and without Geoboard software, contrasted by H*a2*, which posits that a significant difference does exist. Lastly, H*o3* states that there is no statistically significant difference in academic achievement between male and female pupils taught using Geoboard software, whereas H*a3* hypothesizes that a significant difference exists between these groups. This research seeks to provide insights into how the use of Geoboard software influences geometric learning outcomes and whether these effects vary based on gender and levels of geometric thinking.

This study employed a quasi-experimental research design, which entailed the non-random assignment of participants into two distinct groups: the treatment (experimental) group and the control group. The selection of the two study sites and the respective classes utilized in the research employed a simple random sampling technique. A total of 109 participants from these study sites constituted the sample size for the investigation. The study unfolded across three stages: the pre-test, intervention (or treatment stage), and post-test. Data analysis commenced with the examination of information gathered during the pre-test, serving to address the initial research question. Subsequently, the hypotheses of the study were tested using data acquired from the post-test. The analytical process encompassed the application of statistical measures, including frequencies, percentages, means, standard deviations, and t-tests to extract meaningful insights from the collected data.

5.2 Key Findings

The key findings are presented in this section. The study revealed four key findings of the study. The key findings are discussed as follows:

1. The level of academic achievement of pupils on area and perimeter of plane figures was below-average for both experimental and control groups.
2. There was a statistically significant difference in the academic achievement between pupils taught area and perimeter of plane figures using geoboard software and pupils taught area and perimeter of plane figures without geoboard software
3. There was a statistically significant difference in the academic achievement of pupils taught area and perimeter of plane figures with Geoboard software and pupils taught with the conventional technique at the second and third but not the third levels of Van Hieles' Levels of Geometric.
4. There was no statistically significant difference in the academic achievement of male and female pupils taught area and perimeter of plane figures using geoboard software.

5.3 Conclusions

Four conclusions were drawn from findings of this study. It can be concluded that junior high school pupils in Effutu Municipality have difficulty in solving area and perimeter of plane figures. Therefore, there is the need to introduce interventions to remedy junior high school pupils' difficulty in solving area and perimeter of plane figures.

Secondly, it can be concluded that Geoboard software as a teaching and learning aid helps improve academic achievement in area and plane figures. This implies that when junior high school pupils are taught area and perimeter with the use of Geoboard software, the pupils perform better as compared to being taught using the conventional techniques of teaching area and perimeter of plane figures.

Thirdly, the application of Geoboard software in the teaching and learning of area and perimeter of plane figures help pupils to improve their understanding of geometric concepts in relation to the Van Hiele's Level of Geometric thinking at the second (analysis) and third (abstraction) level but not the first (visualisation) level.

Finally, the performance of males and females were similar when pupils are taught area and perimeter of plane figures with Geoboard software. This implies that the use of Geoboard software improves performance of both males and female pupils.

The findings of the study show that innovative teaching techniques (such as incorporating Geobaord Software into teaching and learning) have proven to be more effective than conventional teaching techniques and as such, it can be integrated into classroom teaching as blended instruction. Previous studies are also favourably disposed to integrating Virtual Manipulatives into mathematics education. It is therefore concluded that *Geoboard* helps to improves junior high school pupils' academic achievement, particularly in area and perimeter of plane figures.

5.4 Recommendations

From the findings of this study, the following recommendations are made for Ghana Education Service and other stakeholders for application.

1. Introducing pre- and in-service mathematics teachers in Effutu Municipality to Geoboard software as an innovative way to teach area and perimeter of plane figures will be most helpful in raising the academic achievement of junior high school pupils. This introduction could be done through workshops and seminars organised by Ghana

Education Service and/or other stakeholders in education. This will help enhance the teaching skills and strategy of mathematics teachers in Effutu.

2. Integrating the use of Geoboard software in teaching and learning of area and perimeter of plane figures in Effutu Municipality to help pupils grasp the concept of area and perimeter.
3. Mathematics teachers in the Effutu Municipality should utilise interactive educational software and incorporate into teaching and learning of Geometric concept. This will enhance development pupils Geometric thinking abilities. This could be done by providing resource materials such as educational applet devices, computers and mathematical instruments.
4. Incorporate Geoboard software into geometry instruction for both male and female pupils. The evidence suggests that this approach can effectively improve performance outcomes for all pupils, regardless of gender. By leveraging Geoboard software, Mathematics teachers in Effutu Municipality can create an inclusive learning environment that supports equal academic achievement for both boys and girls in area and perimeter of plane figures.

5.5 Suggestions for Further Studies

The following are suggestions for further research:

1. Further studies with the use of *Geobaord software* could be done in other areas in mathematics where pupils have demonstrated poor academic achievement such as trigonometry.
2. Further studies with the use of Van Hiele's Geometric Thinking model as an intervention improve pupils geometric thinking level.

This study was limited to only Basic seven (7) classes from junior senior high schools. Further studies could be replicated for a much larger sample for better generalisation.

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APPENDICES

APPENDIX A

PRE-TEST

This test is supposed to provide data to be used in research. Please kindly answer the questions as honestly as possible. Your confidentiality is assured.

Bio-Data

i. Sex: 1. Male [ ] 2. Female [ ]

ii. Age: ………………

Academic information

i. Previous Exams Score:………………

ii. Math Class Rank:……………………

Technological proficiency

i. Computer proficiency?

1. Foundational [ ]
2. Intermediate [ ]
3. Advanced [ ]

ii. Experience using Mathematics software or applications.

1. I have never used Mathematics software or application. [ ]
2. I used a Mathematics software or application. [ ]

iii. Have you received any lessons using the Geoboard software? 1. Yes [ ] 2. No [ ]

Motivation and engagement

Interest in mathematics: Please rate your interest in mathematics:

1. Not interested at all [ ]
2. Moderately interested [ ]
3. Very interested [ ]

INSTRUCTIONS

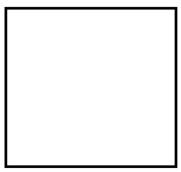
Time allowed: 55 minutes

Answer *all* questions

SECTION A

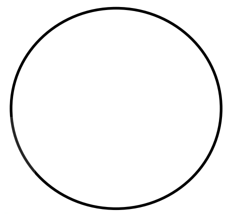
Identify the shapes below based on their appearance.

1\.



A. Rectangle
B. Circle
C. Triangle
D. Square

2\.

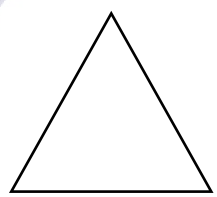


A. Rectangle
B. Circle
C. Triangle
D. Square

3\.

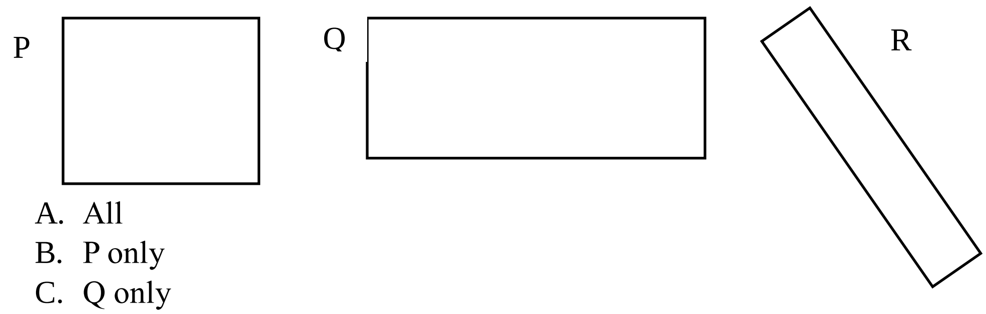
A. Rectangle
B. Circle
C. Triangle
D. Square

4\.



A. Rectangle
B. Circle
C. Triangle
D. Square

5. Which of these can be called rectangle?

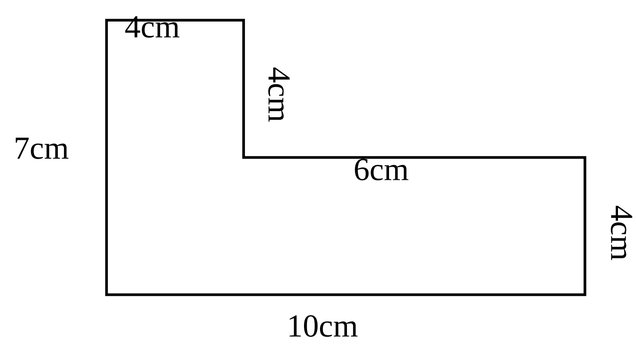


A. All
B. P only
C. Q only
D. R only

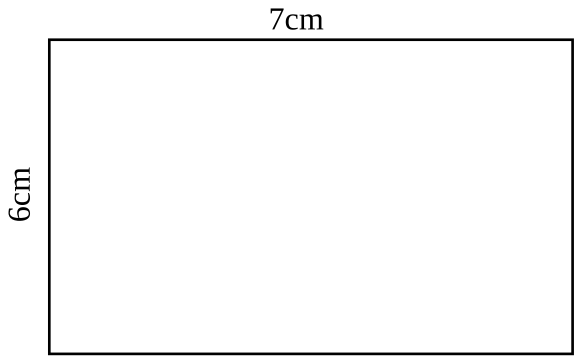
SECTION B

6. Calculate the perimeter of given shapes.

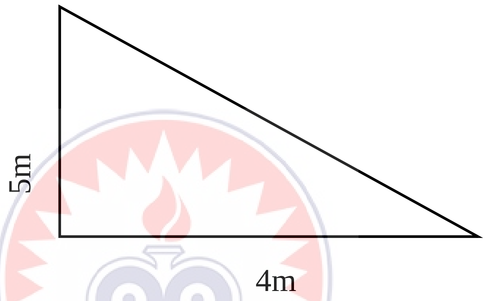
7. Calculate the perimeter of given shapes



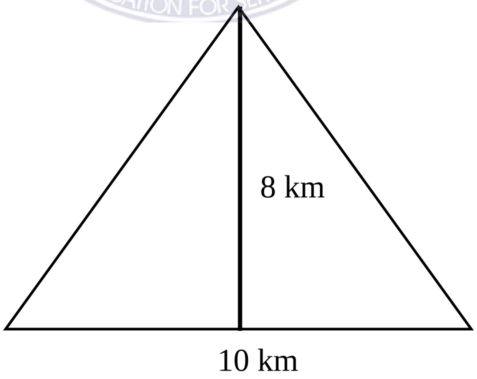
8. Calculate the area of the given shape



9. Calculate the area of the given shape



10. Find the area of the given shape



SECTION C

11. The length of a rectangle is three times its breadth. If the breadth is 6 meters, find the perimeter of the rectangle.

12. A rectangle has length 5cm and breadth 2cm. What happens to the area when the length is doubled?

13. What happens to the area of a rectangle when both the length and the breadth are doubled?

14. Show how two plane figures with the same perimeter can have the different area

15. Explain why a square is a rectangle but not all rectangles are squares.

APPENDIX B

POST-TEST

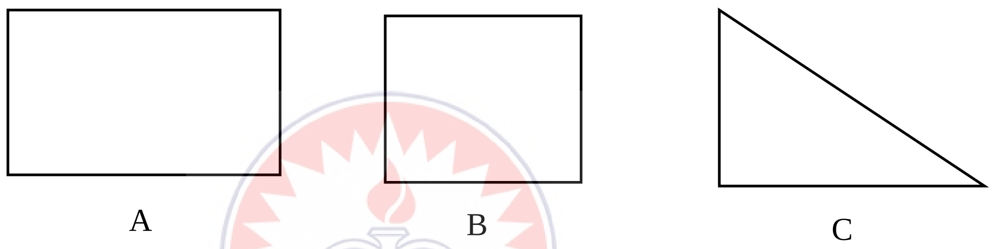
INSTRUCTIONS

This test contains 10 questions. It is expected you answer all questions. Answer all questions in the extra sheets provided.

Time allowed: 55 minutes

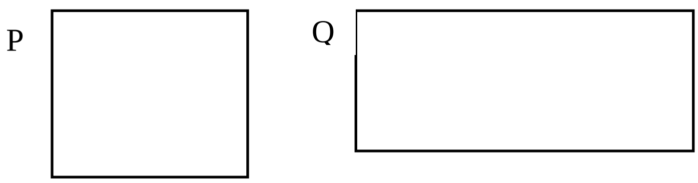
Section A

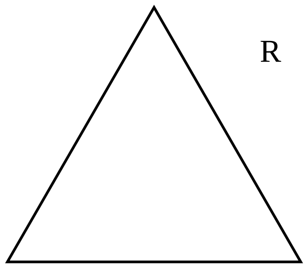
1. Which of these are squares?



A. All
B. A
C. B
D. C
E. None of the above

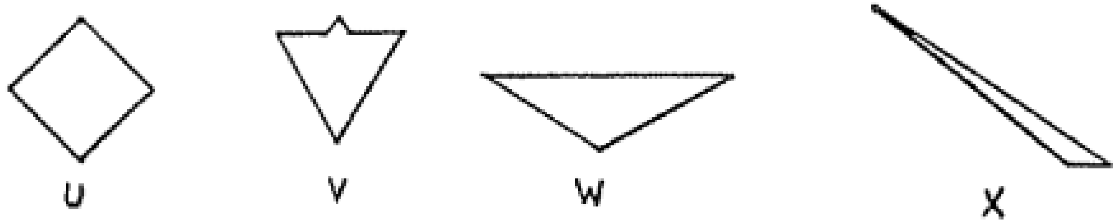
2. Which of these cannot be called a rectangle?





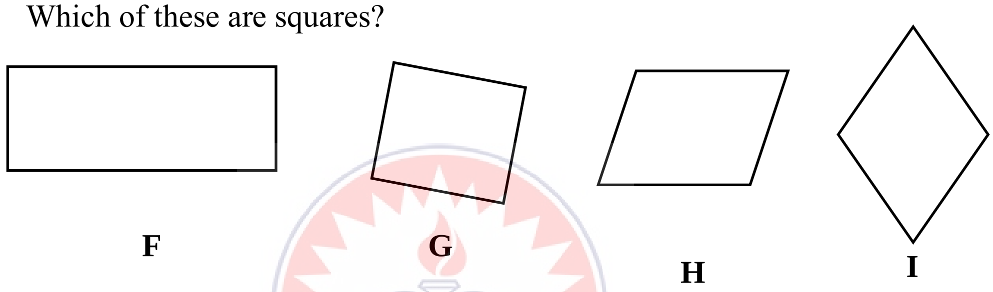
A. All
B. P only
C. Q only
D. R only
E. P and Q only

3. Which of these are triangles



A. None of these are triangles
B. V only
C. W only
D. W and X only
E. V and W only

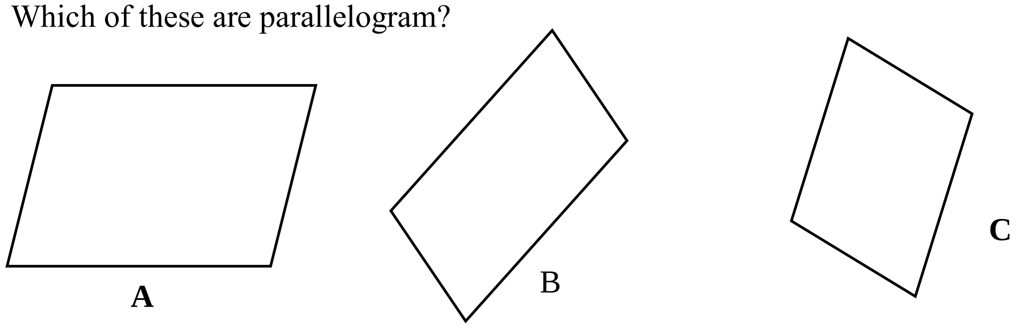
4. Which of these are squares?



A. None of these are squares
B. G only
C. F and G only
D. G and I only
E. All are squares

Section B

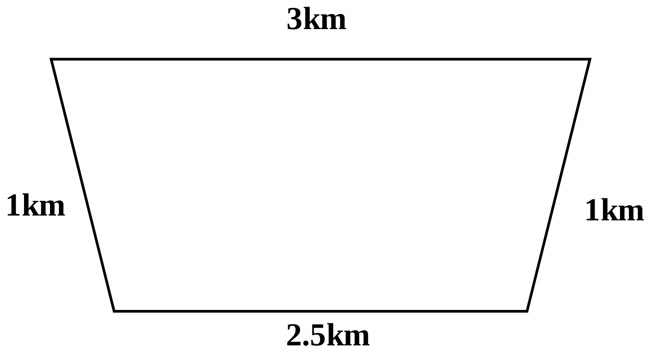
5. Which of these are parallelogram?



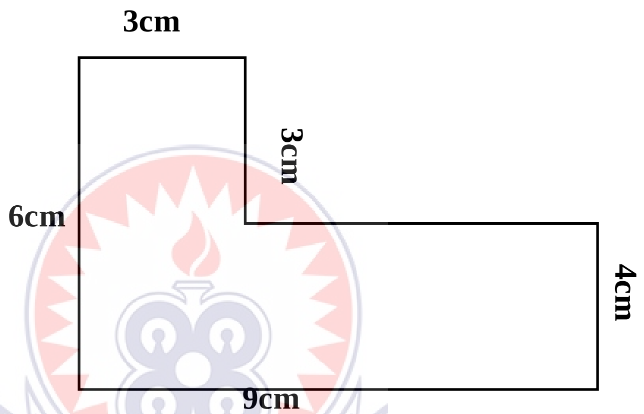
A. All are parallelogram
B. A
C. B
D. C
E. None of the above

Calculate the perimeter of the given shape.

6.

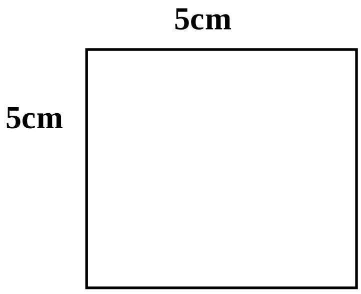


7.

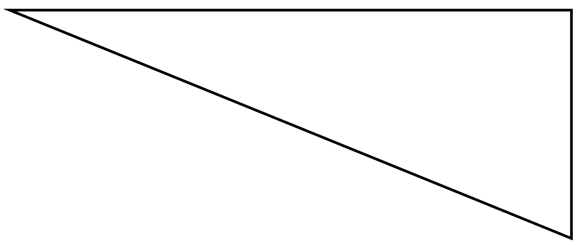


Calculate the area of the given shape

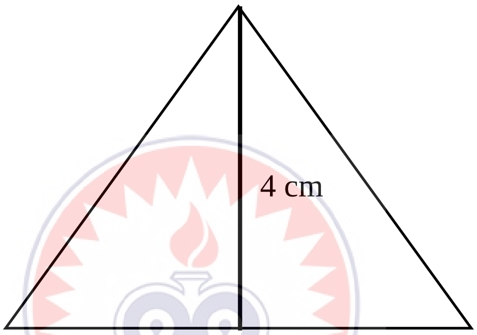
8.



9. Calculate the area of the given shape



10. Find the area of the given shape



Section C

11. The length of a rectangle is twice its breadth. If the breadth is 4cm, find the perimeter of the rectangle.

12. A rectangle has length 8m and breadth 5m. What happens to the area when the length is doubled?

13. What happens to the area of a rectangle when both the length and the breadth are doubled?

14. Show how two plane figures with the same perimeter can have the different area

15. Explain why a square is a rectangle but not all rectangles are squares.

APPENDIX C

PRE-TEST MARKING SCHEME

Pre-test marking scheme

1. D	1 Mark	
2. B	1 Mark	
3. A	1 Mark	
4. C	1 Mark	
5. A	1 Mark	
6. P= S + S + S + S	B1	
P= 6km + 3 km + 3 km + 4 km	M2	
P= 16km	A1	4 Marks
7. P= S + S + S + S + S + S	B1	
P= 4cm + 4 cm + 6 cm + 4 cm + 10 cm + 7 cm	M2	
P= 35cm	A1	4 Marks
8. Area = L × B	B1	
Area = 7 × 6	M2	
Area = 42 cm^2	A1	4 Marks
9. Area $= \frac{1}{2}bh$	B1	
Area $= \frac{1}{2}\ 4\ \times\ 5$	M2	
Area = 10 m^2	A1	4 Marks
10. Area $= \frac{1}{2}bh$	B1	
Area $= \frac{1}{2}\ 10\ \times\ 8$	M2	
Area = 40 km^2	A1	4 Marks
11. P=2 (length + breadth)	B1	
P=2×(3b+b)		
P=2×4b		
P=8b		
Given that the breadth (bb) is 6 meters, we substitute it in:		
P=8×6	M2	
P=48	A1	4 Marks

12. The area of a rectangle is given by the formula:

A=length × breadth
In this case, the original area given by:
A=5×2
A1=10 cm^2
When the length is doubled, the new length
becomes 2×5=10
The new area is given by:
A=length × breadth
A=10× = 20 cm^2
So, when the length is doubled, the area
becomes twice the original area. 4 Marks

13. If both the length and breadth are doubled,
the new area is given by:
A=(length)×(breadth)
Let the original length be L and the original breadth be B.
Original area =L×B
The new length is 2×L, and the new breadth is 2×B.
A=(2×L)×(2×B)
A=4×(L×B)
=4×(L×B)
So, when both the length and breadth are doubled,
the area becomes four times the original area. 4 Marks

14. Let's consider two rectangles.
The perimeter of a rectangle is given by
P=2 × (length + breadth)
For the first rectangle, let the length be 5
and breadth be 3.
So, P1=2×(5+3)=16
For the second rectangle, let the length be 4
and the breadth be 4.
So, P2=2×(4+4)=16
Both rectangles have the same perimeter
but they have different areas
A1=5×3=15 and A2=4×4=16 4 Marks

15. A square is a special case of a rectangle
where all four sides are of equal length.
Therefore, a square satisfies the definition of a rectangle,
as a rectangle is defined as a quadrilateral with
four right angles. However, not all rectangles
are squares because rectangles can have sides of
different lengths, while squares
have all sides equal. 4 Marks

Total Marks = 45

APPENDIX D

POST-TEST MARKING SCHEME

1. B	1 Mark	
2. D	1 Mark	
3. D	1 Mark	
4. B	1 Mark	
5. A	1 Mark	
6. P= S + S + S + S	B1	
P= 3km + 1 km + 2.5 km + 1 km	M2	
P= 7.5 km	A1	4 Marks
7. P= S + S + S + S + S + S	B1	
P= 3cm + 3 cm + 4 cm + 9 cm + 6 cm	M2	
P= 25cm	A1	4 Marks
8. Area = L × B	B1	
Area = 5× 5	M2	
Area = 25 cm^2	A1	4 Marks
9. Area = $\frac{1}{2}bh$	B1	
Area = $\frac{1}{2}$ 6 × 3	M2	
Area = 9 cm^2	A1	4 Marks
10. Area = $\frac{1}{2}bh$	B1	
Area = $\frac{1}{2}$ 7 × 4	M2	
Area = 14 km^2	A1	4 Marks
11. P=2 (length + breadth)	B1	
P=2×(2b+b)		
P=2×3b		
P=6b		
Given that the breadth (bb) is 6 meters, we substitute it in:		
P=6×4	M2	
P=24cm	A1	4 Marks

12. The area of a rectangle is given by the formula:
A=length × breadth
In this case, the original area given by:

A=8×5
A1=40 m^2
When the length is doubled, the new length
becomes 2×8=16
The new area is given by:
A=length × breadth
A=16×5 = 80 cm^2
So, when the length is doubled, the area
becomes twice the original area. 4 Marks

13. If both the length and breadth are doubled,
the new area is given by:
A=(length)×(breadth)
Let the original length be L and the original breadth be B.
Original area =L×B
The new length is 2×L, and the new breadth is 2×B.
A=(2×L)×(2×B)
A=4×(L×B)
=4×(L×B)
So, when both the length and breadth are doubled,
the area becomes four times the original area. 4 Marks

14. Let's consider two rectangles.
The perimeter of a rectangle is given by
P=2 × (length + breadth)
For the first rectangle, let the length be 5
and breadth be 3.
So, P1=2×(5+3)=16
For the second rectangle, let the length be 4
and the breadth be 4.
So, P2=2×(4+4)=16
Both rectangles have the same perimeter
but they have different areas
A1=5×3=15 and A2=4×4=16 4 Marks

15. A square is a special case of a rectangle
where all four sides are of equal length.
Therefore, a square satisfies the definition of a rectangle,
as a rectangle is defined as a quadrilateral with
four right angles. However, not all rectangles
are squares because rectangles can have sides of
different lengths, while squares
have all sides equal. 4 Marks

Total Marks = 45

APPENDIX E

INTRODUCTORY LETTER TO EFFUTU MUNICIPAL EDUCATION DIRECTORATE

UNIVERSITY OF EDUCATION, WINNEBA
FACULTY OF EDUCATIONAL STUDIES
DEPARTMENT OF BASIC EDUCATION

Date: May 29, 2023

The Director
Municipal Education Directorate
Effutu Municipal Assembly
Winneba

Dear Sir/Madam,

LETTER OF INTRODUCTION

We write to introduce to you Mr. Kingsford Bondzie, a second year M. Phil student of the Department of Basic Education, University of Education, Winneba, with registration number 220019292.

Mr. Kingsford Bondzie is carrying out a research on the Topic ***"Effect of Geoboard Software on Junior High School Pupils Academic Achievement in Area and Perimeter."***

We would be grateful if permission is granted him to carry out this study.

Thank you.

Yours faithfully,

PROF.MRS.SAKINA ACQUAH(PHD)
HEAD OF DEPARTMENT

www.uew.edu.gh

APPENDIX F

INTRODUCTORY LETTER TO SCHOOLS

GHANA EDUCATION SERVICE

In case of reply the number and Date of this letter should be Quoted

REPUBLIC OF GHANA

MUNICIPAL EDUCATION OFFICE
POST OFFICE BOX 54
WINNEBA
TEL: 03323 22075
Email.geseffutu@gmail.com

My Ref. No: GES/CR/EMEOW/LC.80/VOL.7/12
Your Ref. No:........................

DATE: 8TH JUNE, 2023

LETTER OF INTRODUCTION

We acknowledge receipt of your letter dated 29th May, 2023 introducing a student who wants to collect data in the Municipality.

Permission has therefore been granted to Mr. Kingsford Bondzie, an M.Phil student of the Department of Basic Education, University of Education, Winneba to collect data in the Municipality from June to August, 2023.

Mr. Kingsford Bondzie is working on his thesis with the theme: **"Effect of Geoboard Software on Junior High School Pupils Academic Achievement in Area and Perimeter"**.

You are to ensure that your data collection would not disrupt teaching and learning in the schools.

Headteachers are to assist the student to gather the relevant data for his thesis while ensuring that he abides by the ethics of the teaching profession.

....
MABEL JUDITH MICAH (MRS)
MUNICIPAL DIRECTOR OF EDUCATION
EFFUTU-WINNEBA

THE MUNICIPAL DIRECTOR
EFFUTU MUNICIPAL EDUCATION OFFICE
WINNEBA

THE HEAD OF DEPARTMENT
DEPARTMENT BASIC EDUCATION
UNIVERSITY OF EDUCATION
WINNEBA

MR. KINGSFORD BONDZIE
DEPARTMENT BASIC EDUCATION
UNIVERSITY OF EDUCATION
WINNEBA

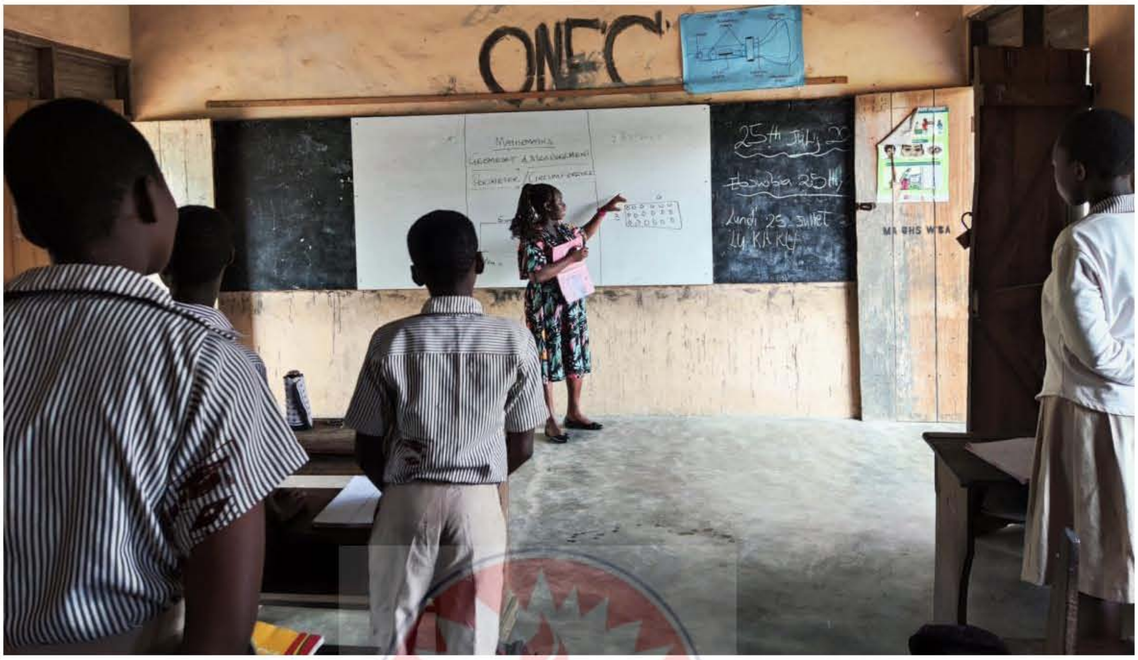
HEADTEACHERS
CONCERNED SCHOOLS
WINNEBA

cc: All SISOs
Effutu Municipality
Winneba

GCMRS

APPENDIX G

SAMPLE PICTURES OF CONTROL GROUP




EMA/DACF/2011
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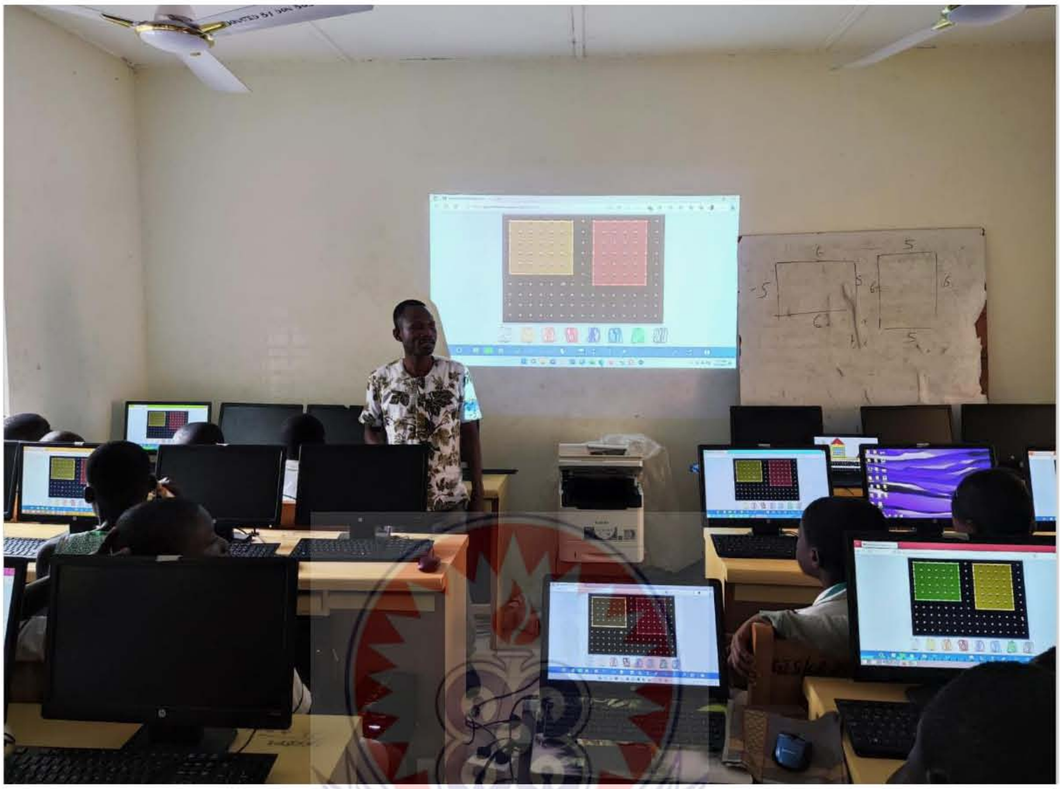
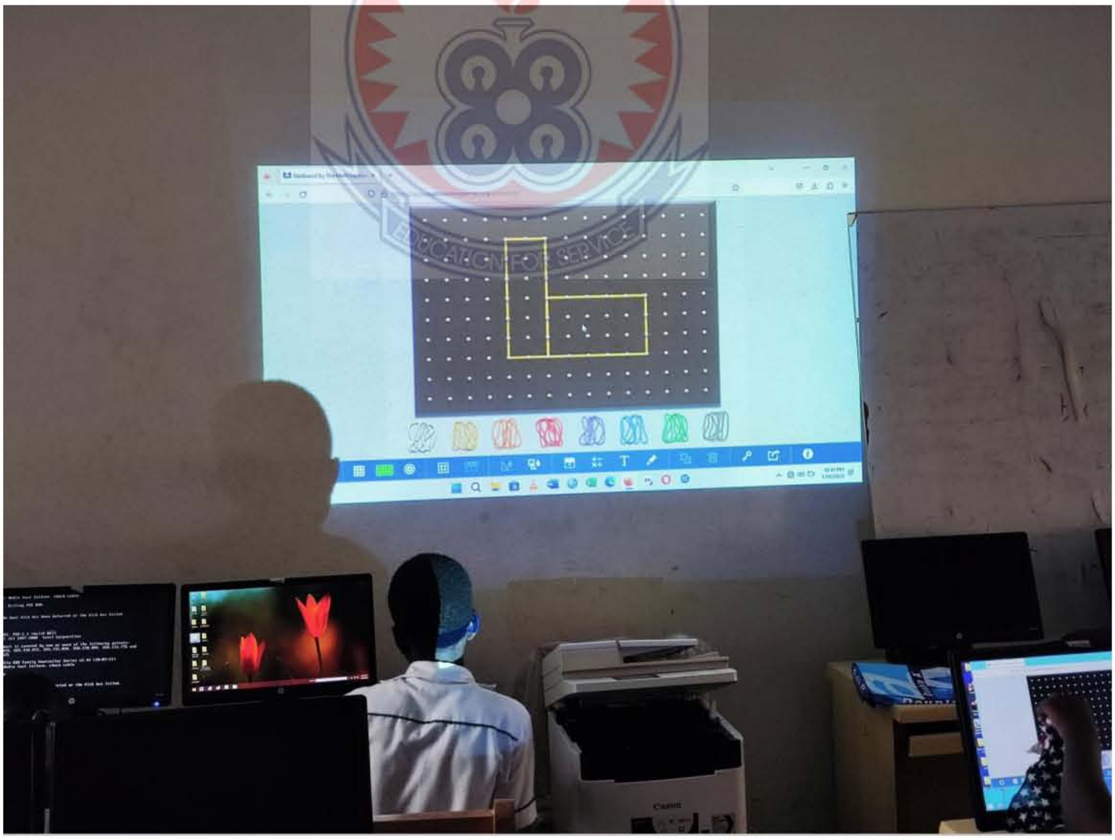
APPENDIX F

SAMPLE PICTURES OF EXPERIMENTAL GROUP





APPENDIX G

CONTROL GROUP PRE-TEST AND POST-TEST SCORES

	PRE-TEST LEV1	PRE-TEST LEV2	PRE-TEST LEV3	OVERALL PRETEST	POST-TEST LEV1	POST-TEST LEV2	POST-TEST LEV3	OVERALL POSTTEST
1.	4	8	0	12	5	12	0	17
2.	4	8	0	12	5	10	2	17
3.	4	6	0	10	4	8	4	16
4.	4	6	0	10	4	8	4	16
5.	4	8	0	12	4	12	0	16
6.	5	8	0	13	5	10	3	18
7.	5	8	0	13	5	11	4	20
8.	4	10	4	18	5	14	4	23
9.	4	8	4	16	5	12	4	21
10.	4	6	4	14	5	12	7	26
11.	4	8	4	16	5	16	8	29
12.	5	8	4	17	5	13	4	22
13.	5	8	0	13	5	16	4	25
14.	5	8	0	13	5	12	4	21
15.	3	8	4	15	4	13	4	21
16.	5	8	0	13	5	12	4	21
17.	4	10	0	14	4	16	4	24
18.	4	10	0	14	4	16	4	24
19.	4	8	4	16	4	16	4	24
20.	4	6	4	13	5	12	4	21
21.	5	10	0	15	5	14	0	19
22.	4	10	0	14	5	12	7	26
23.	4	8	4	16	5	14	4	23
24.	4	8	4	16	4	11	4	19
25.	3	8	4	15	4	12	4	20
26.	5	8	0	13	5	13	4	22
27.	4	12	4	20	5	16	8	29
28.	5	8	4	17	5	12	4	21
29.	4	8	4	16	5	13	8	26
30.	5	10	0	15	5	13	4	22
31.	5	9	0	14	5	16	8	29
32.	4	12	0	16	5	12	5	22
33.	4	10	4	18	5	16	6	27
34.	5	10	0	15	4	12	2	18
35.	4	8	4	16	4	12	4	20
36.	4	7	4	15	5	10	4	19
37.	5	8	4	17	5	12	6	23
38.	4	8	4	16	5	14	3	22
39.	4	8	8	20	5	16	7	28

40.	4	12	0	16	5	14	4	23
41.	4	6	4	14	4	12	4	20
42.	4	7	0	11	5	10	4	19
43.	5	8	7	20	5	14	10	29
44.	4	10	4	18	5	14	8	27
45.	4	8	0	12	5	12	4	21
46.	4	8	0	12	4	8	6	18
47.	4	9	4	17	5	12	6	23
48.	4	9	0	13	5	12	4	21
49.	4	10	0	14	5	16	4	25
50.	4	10	4	18	5	12	6	23
51.	4	8	3	15	5	13	4	22

EXPERIMENTAL GROUP PRE-TEST AND POST-TEST SCORES

	PRE-TEST LEV1	PRE-TEST LEV2	PRE-TEST LEV3	OVERALL PRET-EST	POST-TEST LEV1	POST-TEST LEV2	POST-TEST LEV3	OVER ALL POSTTEST
1.	4	8	0	12	5	16	0	21
2.	4	8	0	12	5	14	2	21
3.	4	6	0	10	4	12	4	20
4.	4	6	0	10	4	12	4	20
5.	5	8	0	13	5	15	0	20
6.	4	8	0	12	5	14	3	22
7.	4	6	0	10	5	15	4	24
8.	4	10	4	18	5	16	6	27
9.	4	10	4	18	5	16	4	25
10.	4	6	4	14	5	16	7	30
11.	4	10	4	18	5	18	10	32
12.	4	6	4	14	5	16	5	26
13.	4	6	0	10	5	16	8	29
14.	5	8	0	13	5	16	4	25
15.	3	8	4	15	5	16	4	25
16.	5	8	0	13	5	14	6	25
17.	4	10	0	14	5	18	5	29
18.	4	10	0	14	5	18	5	29
19.	4	7	4	15	5	18	5	29
20.	4	6	3	13	5	12	4	21
21.	4	10	0	14	5	16	2	23
22.	4	9	0	13	5	16	7	30
23.	4	7	4	15	5	16	7	28
24.	4	7	4	15	5	14	4	23
25.	3	8	3	14	5	15	4	24
26.	5	8	0	13	5	16	5	26
27.	4	12	3	19	5	18	10	33
28.	4	8	4	16	5	14	6	25
29.	4	8	3	15	5	16	10	28
30.	4	10	0	14	5	17	4	26
31.	5	8	0	13	5	18	10	33
32.	4	11	0	15	5	16	5	26
33.	4	10	3	17	5	18	8	31
34.	4	10	0	14	4	16	2	22
35.	4	8	3	15	4	16	4	24
36.	4	6	4	14	5	14	4	23
37.	4	8	4	16	5	16	6	27
38.	4	8	4	16	5	16	15	26
39.	4	8	7	19	5	18	8	31
40.	5	11	0	16	5	16	6	27
41.	4	6	3	13	4	14	6	24

42.	4	6	0	10	5	14	4	23
43.	5	9	6	20	5	18	10	33
44.	4	10	3	17	5	18	8	31
45.	5	6	0	11	5	16	4	25
46.	5	6	0	11	4	12	6	22
47.	4	8	4	16	5	16	6	27
48.	4	8	0	12	5	16	4	24
49.	4	8	0	12	5	18	6	29
50.	5	8	4	17	5	16	6	27
51.	4	8	4	16	5	16	4	25
52.	5	6	0	11	5	16	4	25
53.	5	6	0	11	4	12	6	22
54.	4	8	4	16	5	16	6	27
55.	4	8	0	12	5	16	6	25
56.	4	8	0	12	5	18	6	29
57.	5	8	4	17	5	16	6	27
58.	4	8	4	16	5	16	4	25