UNIVERSITY OF CAPE COAST

USE OF GEOGEBRA COMPUTER-ASSISTED INSTRUCTION FOR TEACHING AND LEARNING OF RIGID MOTION IN SOME SELECTED JUNIOR HIGH SCHOOLS IN THE GREATER ACCRA METROPOLIS

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BY

COLLINS MBRAH

This dissertation is submitted to the Department of Mathematics and Science of the College of Distance Education, University of Cape Coast, in partial fulfilment of the requirements for the award of a Master of Education degree in Information Technology

JANUARY, 2022

DECLARATION

Candidate's Declaration

I hereby declare that this dissertation is the result of my original research and that no part of it has been presented for another degree in the university or elsewhere.

Candidate's Signature………………………………… Date……………………

Name: Collins Mbrah

Supervisor's Declaration

I hereby declare that the preparation and presentation of the thesis were supervised by the guidelines on supervision of thesis laid down by the University of Cape Coast

Supervisor's Signature………………………… Date…………………...

Name: Dr. Emmanuel Arthur-Nyarko

ABSTRACT

The study sought to find out the effects of GeoGebra on the academic achievement of Junior High School (JHS) students in Rigid Motion in some selected schools in the Greater Accra Metropolis. The Solomon four-group design was used as the research design. Students from four comparable schools were purposefully selected as the control and experimental groups for the study. The difference in the performance of students when taught using the traditional method and when taught with GeoGebra was the main objective of the study. The current study used a mixed methods design of qualitative and quantitative approaches to explore the effect of the use of GeoGebra on students' academic performance. The instruments for data collection were test and questionnaire items. The population was the Junior High School 2 (JHS 2) students in Sunflower School, Saint Theresa's School, The Rock School and God's Grace School. The data obtained were analyzed with both descriptive and inferential statistics. The independent variable in this study was the use of GeoGebra in the teaching of rigid motion, while dependent variable is the achievement of students in rigid motion. The data obtained was analyzed with the help of descriptive and inferential statistics for the uptake of technology. The study found out that GeoGebra would help improve the students' understanding of rigid motion and hence improve performance. The study recommends that GeoGebra be used in teaching and learning of rigid motion in Junior High Schools. The findings of this study will be useful to Mathematics Education, Mathematics teachers, students and the school's administration.

KEYWORDS

Geometry

GeoGebra

Translation

Rotation

Rigid

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Most of all, I am grateful to God for giving me the strength to overcome the challenges faced in the course of my studies and for giving me the wisdom and knowledge to complete this work successfully.

DEDICATION

To my wife and children who endured my absence for several weekends and have eagerly waited for this achievement

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CHAPTER ONE

INTRODUCTION

Background to the Study

Mathematics educators have put in efforts geared toward identifying problems related to the teaching and learning of Mathematics in Junior High schools. Despite the efforts, poor achievement in Mathematics continues to be a worry (Ansah, 2020). As a key requirement for entering University in Ghana, it is fundamentally important that students prepare adequately to pass their Mathematics examinations.

The teaching of Mathematics is facilitated by the traditional mode of instruction where teachers measure the understanding of Mathematics through memorization and recitation techniques, thus failing to develop the learner's critical thinking skills (Nugba, 2020). This has culminated in the largely poor performance in Mathematics in Junior High Schools (Frank, 2020). The Ghana Education Service (GES) in collaboration with the Ghana Association of Science and Mathematics Teachers have designed several strategies to help improve upon the overall performance of learners in Mathematics. Such as the constant use of teaching, learning materials, drills and practice. However, this has not contributed effectively to improving the performance of students in Mathematics (Aremu & Sokan, 2002).

The general view of students that Mathematics is difficult to continue to persist affects their Mathematics efficacy (Futrell, 2013). The abysmal performance is attributed to poor attitude towards the teaching pedagogy employed, lack of learning resources, lack of teaching experience and low motivation from teachers (Ministry of Education, 2016). Computers and the internet are fundamental components of delivering computer-assisted instructions a major game changer which offers choices of how, when and where to teach.

The branch of mathematics that has the closest relationship to the world around us, as well as the space in which we live is geometry. (Adolphus, 2011) identifies geometry as an aspect of mathematics which deals with the study of different shapes. These shapes may be plane or solid. A plane shape is a geometrical form such that the straight line that joins any two points on it wholly lies on the surface. Geometry is a natural environment in which students reasoning and judgment abilities improve (Ersoy 2003). In addition, Baykul (2005) stated that geometry is a learning area which has the potential to make students enjoy mathematics while learning. Despite the benefits of geometry most students are unable to construct, visualize and justify geometrical concepts due to traditional approach of teaching and learning process in Ghanaian classrooms (Adolphus, 2011). This method of teaching makes students passive listeners and deficient in geometrical analysis and reasoning.

GeoGebra is a computer-based tool that supplements the teacher-led mode of instruction for the teaching and learning of Mathematics. Geometry is the branch of Mathematics that deals with the measurement, properties and relationships of points, lines, angles, surfaces and solids (Welle, 2016). Geometry as a facet of Mathematics that deals with the study of various shapes (Jones, 2012). These shapes are plane or solid. A plane shape may be a geometrical form such as a line that joins any two points that wholly lie on the surface. Geometry could be a natural environment within which students' reasoning and judgment abilities may be useful as it can enable students to interact (Jones, 2020).

The traditional method of teaching makes students passive listeners and deficient in geometrical analysis and reasoning (Zhao, 2020). In addition, this approach to teaching and learning Geometry lay more emphasis on what proportion a learner can remember and less on how well the learners can reason. It also makes the teacher dominate the classroom and turns learners into passive and mere listeners (Hassan, 2020). Supporting this, (Ibrahim, 2016) reported that, the traditional method affects the response of students and determines whether or not they have an interest in the subject or not. The teacher-centred approach has been identified together with the causes of students' poor performance according to the West African Examination Council (2021). West African Examination Council (2021) reports indicated that over 99,000 students out of 268,812 who sat for the 2021 WASSCE failed in Mathematics with some obtaining F9 in the subjects while 29.75% of the 2021 WASSCE students obtained D7 – E8 and 37.17% had F9. It also stated that candidates showed weakness in reading values on a graph, solving problems in mensuration and geometry. Sample questions were clearly discussed in the report. The report highlighted strengths and weaknesses of students. Geomerty was recorded as one of the areas of weakness and this warrants an investigation.

Statement of the Problem

The use of computer-assisted instruction in teaching has improved the mode of instruction in education (Gambari, 2019). As indicated in the background, computer-assisted instruction can have a positive impact on the learning outcome of students in Mathematics (Bervell et al, 2013).). These researches are limited and inconclusive for students' learning of Rigid Motion (Agyei, 2015). Some researchers think that computer-assisted instruction has great potential for improving learners' understanding of Rigid Motion in Mathematics (Julius, 2018). Others contend, however, that the study of Rigid Motion must be strictly taught via face-to-face interaction (Abdous, 2012). Computer-assisted instruction has supplemented the traditional mode of instruction thereby making it easy to meet learners of varying academic differences.

Unfortunately, education in Ghana has largely and primarily depended on printed instructional materials which also serve as a resource material used to facilitate teaching and learning (Chanda, 2019). These printed learning materials have been used to support teaching and learning rather than computer-assisted instruction and have affected the effectiveness of teaching and learning due to the cost of printing these materials (Onche, 2018). They do not have audio/visual elements and they are time consuming to read.

In the traditional mode of instruction, it is evident that Mathematics concepts are largely taught using abstract examples and words, which makes it difficult for learners to comprehend (Wiggins, 2018). This method of teaching needs highly cognitive skills to assimilate the concepts. It also creates undue pressure on the students leading to a loss of self-confidence and interest in the subject (Hammond, 2014). Most learners of today have declined academically in Mathematics due to the abstract method of teaching the subject (WAEC, 2021). Computer-assisted instruction which incorporates the concept of multimedia would increase learners' attention span as well as understanding of concepts (Jaji, 2012).

Indication emanating from the report compiled by the West Africa Examination Council(West Africa Examination council, 2012, 2014 and 2015) revealed that students' performance in geometry in the Basic Education Certificate Examination(BECE) was very poor as compared to other areas of Mathematics.

Past research showed that the use of GeoGebra as an instructional tool for teaching and learning geometry improves students' performance (Geisert, 2013). Researchers like Edward and Jones (2011) are also of the opinion that GeoGebra a computer-assisted instruction tool can be used to teach geometry. Hence, the need for study to explore and investigate the use of GeoGebra in enhancing students' performance in rigid motion.

Purpose of the Study

The purpose of this study is to investigate the effect of GeoGebra, a computer-assisted instruction tool on student's learning outcomes in understanding Rigid Motion.

The Objective of the Study

The research sought to:

1. determine the difference in students' performance between the control group and the experimental group.
2. establish the difference in the use of GeoGebra between the control group and the experimental group.
3. explore the gender difference in the post-test scores between the control and the experimental group.

Research Questions

The study aims to answer the following research questions.

1. What is the difference in students' performance between the control group and the experimental group?
2. How does GeoGebra affect students understanding of rigid motion?
3. How does GeoGebra influence the performance of students in terms of gender?

Research Hypotheses

1. Ho: There is no statistically significant relationship between the control group and the experimental group
2. Ho: There is no statistically significant effect of GeoGebra on students' understanding of rigid motion.
3. Ho: There is no statistically significant relationship between the performance of students in terms of gender

Significance of the Study

Over the years, students in Junior High School have had a challenge in understanding the concept of Rigid Motion (WAEC, 2018). This study has sought to contribute to the teaching and learning of Rigid Motion using GeoGebra as a computer-instructional tool.

It is believed that the results from the study would introduce to students the relevance and impact of technology (GeoGebra software) on the teaching and learning of Rigid Motion. This will also provide useful information for students, teachers, school administrators and curriculum developers on how to make teaching Rigid Motion easy for students. This study will contribute to the list of existing literature on the use of GeoGebra in the teaching and learning of Mathematics. It will serve as a means of assessment of the technology integration in educational practices which is necessary for informing the content and direction of future policies in education. For that matter, this study will be of significant contribution to the renewal of the curriculum of the Ghana Education Service and to educators of Mathematics.

Delimitations

Delimitations describe the scope of the study or limits of the study. There are many software's for teaching Mathematics but the study was delimited to the GeoGebra software only. Lastly, there are many Junior High Schools in the Accra Metropolis but the population of the study was derived from students from Sunflower school, Saint Theresa's School, Crown Prince Academy and God's Grace School.

Limitations

Every research work is bound to face flaws or shortcomings and this study is certainly not an exception. For instance, it is anticipated that some of the test and questionnaire sheets may not be returned by the respondents. Also, some of the items on the test and questionnaire may be left unanswered. Again, the use of the test and questionnaire may limit both students and instructors on the information they will provide. All these may affect the results of the study which the researcher does not have control over.

Definition of Terms

GeoGebra is an interactive application used to supplement the teaching and learning of science and Mathematics and science from primary school to the university level. GeoGebra is available on the web and can also be installed for use offline.

Computer-Assisted Instruction: Computer-assisted instruction (CAI): Refers to tutorials, drill-and-practice, graded assignments, and other activities delivered by the computer as a supplement to the traditional teacher-led mode of instruction; also referred to as computer-based instruction (CBI) or computer-mediated instruction.

Educational Courseware: it is a software program that consists of educational content used to facilitate teaching and learning. It is designed to be run on a computer. This software incorporates the use of the five elements of multimedia which includes text, graphics, sound, animation, video, and pictures to present information.

Multimedia: this refers to the method of learning through text, images or graphics, sound or audio, videos and animations.

The traditional mode of instruction: Face-to-face instruction delivered by a teacher dispensing knowledge and demonstrating skills using the lecture method sometimes integrated with discussion and group work.

SPSS: The Statistical Package for Social Sciences is a software application for performing statistical calculations and analysis.

Organization of the Study

This research would contain five chapters. Chapter one presents the research overview, highlighting the research objective, the research problem and question, the research significance, the intended target audience, and the method used in the study.

Chapter two gives an overview of the research area, including recent literature on the traditional teacher-led mode of instruction and computer-based instruction.

Chapter three explains the selected research methodology used to achieve the main research objective. It includes an explanation of the survey progress and plan, followed by the ethical considerations that were addressed in the research design.

Chapter four presents the analysis process used in the research study by investigating the use of teacher-led instruction and computer-based instruction.

Chapter five would contain an interpretation of the findings, discusses them in the context of previous literature, identifies some implications, presents the limitations of the study, and suggests future work.

Chapter Summary

This chapter presented an overview of the research study, including teacher-led mode of instruction and computer-assisted instruction in the educational systems of Ghana. It also presented an overview of the objective of this research, including the purpose of the study, the research problem and questions and the significance of the research. Furthermore, this chapter introduced the selected methodological approach used to conduct the study as well as the research structure.

CHAPTER TWO

LITERATURE REVIEW

Markus Hohenwater created GeoGebra, an open-source dynamic Mathematics software that combines geometry, algebra, and calculus into a single, user-friendly application (Frye, 2012). The functionality of older software applications such as Maple, Derive, Cabri, and Geometer's Sketchpad was integrated into this software (Goldenberg, 2000). GeoGebra is a free and easy-to-use program that combines geometry and algebra (Wang, 2000). These contents are extremely condensed, easily accessible, and professionally produced, with additional ideas from users.

The impact of integrating GeoGebra software as a tool to supplement the teaching of Rigid Motion was explored in this chapter. This section also examined the theoretical and conceptual frameworks of the research. The importance of Computer Assisted Instruction using GeoGebra in the teaching of Mathematics is also discussed in this section. The literature on the use of GeoGebra as a tool for teaching Rigid Motion in Mathematics was also discussed. This section addressed what Rigid Motion entails. The effects of GeoGebra in teaching Rigid Motion were also discussed in this chapter.

Theoretical Framework

The acceptance of GeoGebra in the teaching and learning of Rigid Motion in Mathematics is determined by how learners generate and share ideas, the period and the enabling environment needed to support this method of computer-assisted instruction. As a result, Rogers' Diffusion Innovation Model (DIM) was used to lead this research. This model seeks to explain how, why, and at what rate new ideas and technology spread. Diffusion is a social phenomenon that occurs when individuals learn about a new evidence-based method to extend or improve upon their understanding of the concept. Diffusion, in its most basic form, refers to an innovation that is conveyed to members of a social system over time through specific channels (Hoerup, 2001). Diffusion is the method through which an innovation is conveyed to participants of social systems over time through a specific route (Surendra, 2001). DIM is a hypothesis that attempts to explain how, why, and how quickly new ideas and technology spread across civilizations.

According to the Diffusion Innovation Model (DIM), five major elements influence a person's decision to adopt or reject the implementation of a new system of teaching and learning.

1. **Relative Advantage**: This relates to how much better a new system is than an existing system. This is relevant to this study because the researcher will be interested in seeing how teaching geometry with GeoGebra compares to teaching geometry with pen and paper in Junior High School.
2. **Compatibility**- this refers to the ability of a new system to sync into the expectations of the learner and the facilitator. An assessment of GeoGebra was conducted and results measured whether it was able to meet the facilitator and learner’s requirements.
3. **User Difficulty**- this refers to how difficult it is for learners and facilitators to use GeoGebra to facilitate teaching and learning. This also determines whether or not learners and facilitators are willing to use GeoGebra as a computer-assisted instruction to facilitate teaching and learning.

4. **Trialability:** this refers to the ease with which an innovation can be tested. This refers to the ease with which GeoGebra can be tested to supplement the teaching and learning of Rigid Motion using GeoGebra as a computer-assisted instruction. Trialability is also associated with a higher rate of adoption. The more an idea is attempted, the more quickly it gets adopted. The more GeoGebra is tested and used the more it is adopted to facilitate the teaching and learning of Rigid Motion in Mathematics.
5. **Observability**: this refers to how accessible and observable a technology is to users. A simpler technology or system has a higher chance of being accepted. This research looked into GeoGebra, a software to be used to supplement the teaching and learning of Rigid Motion in Mathematics. The Diffusion Model's applicability in the Basic School Mathematics curriculum was investigated. The goal of the study was to see if this mode of instruction followed Rogers' technology implementation methodology. The study compared learners' performance using computer-assisted instruction (GeoGebra) in the teaching and learning of Rigid Motion.

Conceptual Framework

The link between a dependent variable and independent variables, as well as the methodology used for the whole research, made up the conceptual framework. I built the conceptual framework using social constructivism philosophy. The instructor and the student must work together to create a successful classroom. Two classes were used for the study; one was taught using the traditional approach, while the other was instructed using GeoGebra.

For the experimental group, knowledge was created via social engagement, self-exploration, and scaffolding that connected new information to the learner's prior knowledge, in accordance with the aforementioned Conceptual Framework. The instructor inspired the class by setting a positive tone. The instructor then inputted the material using the GeoGebra programme to provide a suitable environment for social engagement and self-exploration.

The degree to which students grasp the concept of Rigid Motion to improve their performance is determined by their attitude towards the use of computer software and GeoGebra and the facilitators' ICT skills (Mukiri, 2016). Learners must be actively engaged throughout the lesson whether abstract or concrete for learning to take place (Clements, 2016). Technology is used appropriately when it is an active integral element of the Mathematics education process (Boyle, 2010). The hypothesis of this study, which used ICT (GeoGebra) to improve Mathematics teaching and learning, was that these computer-assisted tools would have an impact on learning, resulting in better understanding. The purpose of this study was to intervene by using GeoGebra to improve learners' understanding of Rigid Motion.

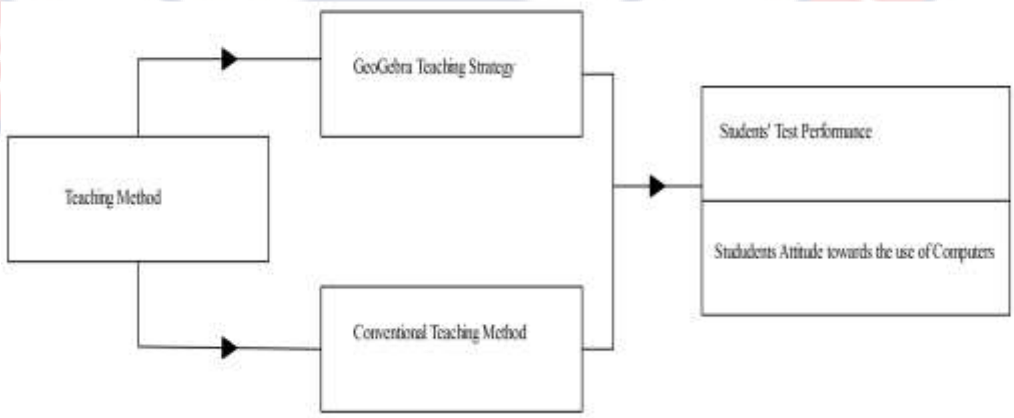

Figure 1: Conceptualized Framework of the Study.

Geometry and Transformation Geometry

Geometry is the branch of Mathematics that has the most direct connection to the world around us as well as the space in which we live. Geometry, according to (Bilgici, 2011), is a branch of Mathematics concerned with the study of various shapes. These shapes might be solid or flat. A plane shape is a geometrical shape in which the straight line connecting any two points on it lies entirely on the surface. A solid shape, on the other hand, is defined by surfaces that may or may not be completely reproduced on a plane surface.

In the subject of Mathematics, there are many different types of geometry. Euclidean, Non-Euclidean, Dynamic, Transformational, Projective, Vectors, Applied, and Menstruation geometry. Transformation can be split into two categories, according to Schopenhauer, (2016). Leong, (2013). initially mentioned transformation geometry in his seminar Erlangen program in 2010. He defined geometry as the shapes of objects that have certain attributes.

A plane transformation is a one-to-one correspondence between the plane and itself (Spector, 2016). Isometric transformations, which retain the qualities in geometry, gained popularity as a result of these formulations (Singler, 2009).

Reflection Transformation

The understanding of subjects in Analytic geometry is likewise based on reflection transformation. It swaps all pairs of points that are perpendicular to the reflection line. Any geometric shape's reflection is created by crossing lines from each angle on the shape and projecting these angles to the opposite side of the axis. As a result, the projected geometric shape and the reflected image according to the axis are of equal length and share the same basic properties, but differ in location and direction.

Translation Transformation

The image of a vector or geometric object has been taken according to the described functionality in a straight line and the same direction is known as translation transformation. It is a function that uses one-to-one correspondence to match one plane to another (Lowther, 2010). Three properties could be used in mathematically conceiving and labelling translation transformations.

The first is that translation transformation preserves the internal dynamic of a geometric shape's edge length, angles, and direction. The second is that following the transformation, the attributes of every point on geometric shapes are the same as among the matched points. As a result, the translation transformation is not performed to certain specified points of a geometric shape, and the image of every point under this transformation is found. Finally, the zero-vector translation transformation matches the geometric item on the plane with itself (Morrison, 2010).

Rotation Transformation

The function that fixes each point on the plane with another point on the plane is known as rotation transformation. Rotation transformation is a function that covers and corresponds one-to-one to all points on the plane using a central point and angle with the plane's points. Angles and distances, which represent the plane's dynamics, are preserved via rotation transformation.

Rotation transformation is used in the interpretation of solids, which is one of the subjects of geometry. A learner who understands that a cone is formed when a right triangle is rotated 360° around one of its legs, a cylinder is formed when a rectangular is rotated 360° around one of its lines, and a sphere is formed when a semicircle is rotated 360° around its diameter can learn solids mentally (Pilli & Aksu, 2013).

Computer-Assisted Instruction in the Learning of Mathematics

ICT (Information and Communication Technology) contributes tremendously to teaching and learning at all levels. ICT has improved the teaching and learning process through the use of computers. It has resulted in considerable transformation, innovation, and creativity among teachers and learners. Mathematics and computers are both essential in today's environment since they open up a universe of possibilities.

In computers, Mathematics is frequently used in both hardware and software. The computer can help students improve their math skills. Classroom instruction can be made more engaging with the help of a computer. Computers can play a significant role in the learning process because they can work with students' imaginations. They also allow instructors to inculcate the five elements of multimedia when setting up instructions. Visuals can be used to teach any mathematical subject and this visual representation can help students understand the concept better.

Students who learn using the paper-pencil approach may become bored soon and find it difficult to remember it. CAI functions as a catalyst for change, piquing students' interests and helping them to learn in a fun way. Furthermore, because computer-assisted classes engage more of the student's senses, anything they learn can be remembered for a longer amount of time. Some chapters, like profit and loss, simple and compound interest, and so on, can be taught using CAI. A range of exercises can be provided, ensuring that the learners participate actively. The material can be customized to meet the needs of learners of varying academic differences.

Advantages of CAI in Learning Mathematics

In today's technology world, teachers must be mindful of their students' needs. CAI can help students find solutions to their problems. CAI lessens instructors' burden while also providing a variety of other advantages, which are outlined below.

Offers a Diverse Range of Experiences

CAI assists the teacher in providing a diverse variety of experiences, allowing him or her to provide several examples and illustrations, as well as making the concept apparent.

Provides Motivation

It can keep students motivated since the material can be delivered enjoyably, with concepts provided logically, interestingly, and with instant feedback, which keeps students motivated. Graphics and graphics can be used to draw in and hold the attention of students. When children properly answer the question, they are rewarded, and the topic is presented in a methodical order of increasing difficulty.

Individualized Instruction

Because it caters to individual differences, CAI is individualized teaching. Some students are slow learners, while others learn quickly. The Indian classroom is made up of a diverse collection of students. Learning pace varies from learner to learner since some students require more time to study while others require less. CAI also offers a variety of learning experiences based on the student's comprehension levels. It also gives them the option of picking their themes of interest. It gives each student personalized attention, improving the quality of the teaching-learning process and allowing us to avoid the problems that arise in overcrowded classrooms.

Interactive Learning

CAI provides immediate feedback to the students and thus constantly interacts with them. In CAI students actively take part in the learning process. As it contains many examples and diagrams it makes the learning process interesting.

Computer-assisted instruction allows students to work at their own pace, time, and at any place of convenience from any computer. This software can provide each student with an individualized study plan. Teachers can create quizzes and tests to be delivered and graded by the software. It also provides the instructor with data to show how students are progressing in the course (Pierce & Stacey, 2011).

Google forms allow instructors to create a quiz that can be self-administered and results are generated immediately after the quiz. Ispring allows instructors to design courseware which is a computer-assisted program used to facilitate teaching and learning. Several types of research in computer-assisted instruction indicate that computer use has a positive impact on student performance, attitude and learning rate.

Characteristics of Computer-Assisted Instruction (CAI)

There are many types of CAI programmes. Each of the CAI programmes is appropriate under different instructional circumstances and therefore takes a different pedagogical approach. The beginning of CAI such as; tutorials, drills and practice and games were oriented to behaviourist theories of learning. But now no type of CAI is solely associated with a specific learning theory, as the sophistication of computer languages has allowed modifying each type of CAI according to any theoretical framework. Bitter and Pierson's 5th edition publication mentioned and explained the following types of CAI software:

Drill and practice, Tutorials, Simulations, Instructional games, Problem-solving Integrated learning, Microcomputer based laboratories (MBL), and Reference software. CAI refers to any usage of computers in the educational process that interacts with students in any form.

Practice: Students can practice as many times as they want with CAI, allowing them to attain the required competencies. Students come from a variety of backgrounds, making them a heterogeneous group with varying levels of comprehension. Because a single teacher cannot cater for such a diverse population, the correct learning tool and a supportive environment are required. A man becomes flawless through practice. Many psychologists, including Thorndike, believe that practice is beneficial to learning.

Immediate Feedback: CAI allows students to see the correct answer as soon as they respond to a question, allowing them to correct their mistakes. If they get the answer right, they will be overjoyed and gain confidence. They can immediately correct themselves if the answer is incorrect.

In a traditional classroom setting, students are given homework to practice with. When the teacher checks the homework and corrects any mistakes, the child is informed. Teachers usually do not provide the correct answer during checking, so the child is aware that his answer is incorrect but is unaware of the correct answer. If the teacher occasionally provides the correct answer, the child may not pay close attention to it and disregard it as part of his work to complete the homework and move on to the next assignment.

Self-Evaluation: CAI enables students to identify their strengths and weaknesses, allowing them to overcome their weaknesses before moving on.

Reinforcement: Many psychologists have found that rewarding pupils right away when they answer the question correctly provides them with a great deal of joy.

Immediate Evaluation: Students should answer questions relevant to each idea as soon as they are finished, allowing for instant evaluation.

Limitations of Computer-Assisted Instruction

Developing a program necessitates a high level of expertise.

1. The instructor must be well-versed in the subject topic as well as programming skills.
2. Steps should be taken in more sequential order and instructive examples should be carefully chosen to reduce a learner's error rate. If the student makes more mistakes, he will become demotivated.
3. It takes up more time to set up.

The use of GeoGebra in Mathematics

GeoGebra is a community-supported open-source Mathematics learning environment that combines numerous dynamic representations, a wide range of mathematical topics and a wide range of modelling and simulation computational utilities. GeoGebra was created in the early 2000s to implement research-based discoveries relating to mathematical knowledge and expertise in a web-friendly manner.

The software can be readily downloaded and then used in the classroom. A mathematically competent person is capable of dynamically coordinating numerous representations of a mathematical idea and gaining insight into the focal mathematical structure Zakaria, (2012). As a result, GeoGebra is very significant to math facilitators because they have the necessary mathematical skills. GeoGebra is more user-friendly than a graphing calculator, according to Zakaria, E. (2012).

GeoGebra has a user-friendly interface, as well as multilingual menus, instructions, and assistance. In addition, it encourages students to do math projects, provide several presentations, and learn through experimentation and guided exploration. GeoGebra is also known for its user-friendly interface and web accessibility which has attracted tens of thousands of visitors from all over the world, including math facilitators and educators. GeoGebra has grown in popularity around the world, thanks to the online GeoGebra Wiki and worldwide and local professional conferences.

Effect of GeoGebra on Mathematics

Kutluca, (2012) discussed how dynamic geometry may be utilized to help students in middle and secondary schools investigate real-world situations. Dynamic models of real-world settings were proven to be beneficial to pupils making mathematical conjectures as well as boosting their comprehension of mathematical topics.

Learners' attitudes toward Mathematics have been found to improve when they use modelling. Funkhouser, (2000) looked at how dynamic GeoGebra models and simulations can help students bridge the gap between their empirical research and mathematical formalizations. Their approach to abstract Mathematics exemplifies the didactic notion of vertical mathematization, which is the process of connecting, refining, and validating mathematical ideas to higher-level formal mathematical structures Sheridan-Ross & Boyle, (2010).

They want to give model-based conceptual interventions that help students construct valid mental models for formal Mathematics, which is an important skill that is often overlooked in upper-division math classes. Novak, Frye & Dornisch, (2012) describe a holistic learning strategy for learning Mathematics by doing Mathematics, and creating simulators with GeoGebra to gain a thorough conceptual knowledge of a real-world scenario and the Mathematics that underpins it (Giamati, 2014). They demonstrate their learning model in a setting that could be described as a mathematical lab, where science and Mathematics mutually define and assist one another in sense-making and mathematical modelling.

GeoGebra provides a variety of digital resources that allow learners to easily solve problems relating to rigid motion, and invent and experiment with personally meaningful models using multiple representations and modelling tools.

GeoGebra has been proven to be effective in teaching integers, as well as integer addition and subtraction to 6th graders. The participants in this study were 6th-grade students in two homogeneous courses. In this study, the students learned about rigid motion using GeoGebra, while the control students were taught using traditional methods.

The treatment group outperformed the control group in the study which was conducted at Istanbul University. According to the researchers, pupils exposed to the traditional teaching style failed to grasp the content at the necessary level since the traditional teaching method primarily appeals to auditory learning. Students who utilized GeoGebra, on the other hand, achieved success at the required level since it appealed to various learning modes. "By using GeoGebra, more intelligence of kids may be reached, resulting in a higher rate of success" (Boyle, 2010).

Researchers discovered that GeoGebra assisted students in conceptualizing addition and subtraction processes and that students who studied numbers using the software retained their knowledge longer than students who did not use GeoGebra. The researchers agree that including GeoGebra in Mathematics instruction is a key component of effective Mathematics instruction and long-term learning.

To explore the efficiency of utilizing GeoGebra software on Mathematics learning among Malaysian students, Sarama and Clements (2016). conducted a study titled "The effects of GeoGebra on learners' accomplishment." This study used a quantitative technique and a quasi-experimental research methodology.

The experimental group consisted of 40 pupils, while the control group consisted of 40 pupils. An accomplishment test was used to collect data, which was then analyzed using SPSS. According to the findings of the study, there was a substantial difference in the means of the learners' post-test scores in favour of the GeoGebra group. The results demonstrated that computer-assisted instruction, when used in conjunction with traditional classroom instruction, is more effective than traditional instruction alone. This study's findings are in line with those of Christou, (2010) all of which revealed a favourable benefit of using Mathematics.

As a result of the use of learning software, pupils' learning and comprehension have improved. When compared to typical construction tools, this proves GeoGebra's teaching effectiveness. This study compares the scores of students who learned transformation geometry using GeoGebra to those who learned using traditional methods.

Benefits of GeoGebra to the Students

Numerous studies have been conducted on the usage of GeoGebra in the teaching of Mathematics. As a result of these investigations, it was discovered that incorporating GeoGebra into the teaching of Mathematics raised student achievement and self-sufficiency, improved teaching process supervision, and simplified learning (Mainali, & Key, 2012).

Utilizing GeoGebra in the classroom to teach the subject of Rigid Motion enhanced student motivation and made understanding basic geometric concepts easier (Mainali, & Key, 2012). Aksu (2013) found that GeoGebra had a positive effect on students' learning and achievement as a result of the tests and group comparisons and the recall test results showed that it is also effective in increasing the permanence of information in a study examining the effectiveness of GeoGebra teaching with activities on the subject of Transformation and the Pythagorean theorem.

GeoGebra instruction also makes teaching procedures fun, allows students to participate successfully in class, and promotes a positive learning competition between groups with in-group and out-group contact, according to research by Mudaly & Fletcher, (2019).

Traditional Method of teaching Rigid Motion in Basic School

Teaching methods are defined as the various formats used by the teacher to convey information to achieve good, long-term changes in the learner. It was characterized as a teacher's primary mode of study for selecting and executing a curriculum (Stacey, 2011).

Teachers employ a variety of methods to ensure that their student acquires the knowledge or abilities that the instructor has predetermined (Gambari, 2013). The style or procedure in which information is conveyed to pupils is referred to as a teaching method. The teaching method was viewed as a method of directing and controlling the experiences of learners, assisting such people or groups in discovering and developing potential for happiness and social welfare. There are a variety of teaching methods available, however, for the sake of this study, the researcher will focus on the methods utilized to teach Rigid Motion in Accra High Schools.

Demonstration Method

Rigid Motion is taught via the demonstrative technique of instruction. This is a teaching style in which the primary mode of communication is sight rather than hearing (Beck, 2010). Demonstration approach is one in which the teacher's primary role is to show the pupils how to create distinct response patterns (Polit, 2010). Meanwhile, the role of the students is to imitate the teacher's response pattern. As a result of such teamwork leading to skill development, the teacher displays while the students imitate. A demonstration technique is a method of instruction presentation in which a teacher does a manufacturing or repair process operation in front of a class on individual pupils or a group of students while describing what he is doing (Ramadhan, 2017). It's a teaching method that blends spoken explanation with "dinging" to communicate processes, concepts and facts. It's especially good for teaching rigid motion.

Demonstration is a method of teaching principles or facts in such a way that pupils can understand (Reister, 2012). It entails demonstrating and telling how to do an activity, process, or observation so that others can easily copy it. This is accompanied by explanatory statements either during the event or before it, to properly instruct the students. Demonstrations are usually carried out by classroom teachers while the students watch or observe. This is usually demonstrated on a graph board or a white board.

There are other instances where only a few students, particularly the brightest, are permitted to demonstrate after the teacher has completed his or her demonstration. This should be encouraged because it will increase their interest in the lesson and help them retain the abilities they have learned. Because most students forget what they hear or read, the demonstration method is beneficial. It may be necessary to exhibit just an actual object, model, photograph, or diagram of an event at times. It usually entails a procedure in which the students must complete a series of phases, one after the other to arrive at a conclusion. It is practical and necessary and it is a true learning experience in which students are given actual models or apparatus to control to obtain a desired result. It normally includes the employment of practically all of the sense organs in the demonstration process.

Teachers should use demonstration approaches to guarantee that learners observe correct procedures the first time they undertake a new assignment. Because learners learn best when they practice a skill right after they're taught it, facilitators should teach students to practice Rigid Motion right after they are taught it. Using demonstration as a teacher necessitates patience. This is because the students do not all operate at the same level. When there are both slow and quick learners in a class, the demonstration approach becomes one of the most commonly used methods of skill training. It entails performing each task one at a time, using specific physical procedures whenever possible. It is also necessary to organize the demonstration so that each step is performed in the correct order and that all steps are included.

The Procedure of Demonstration Method

According to Presmeg (2013), the first stage in the demonstration technique is to determine the instructional need and design the objective (s). The next step is to carefully arrange all demonstration-related activities, as well as to prepare learners, the environment, and the material. Before starting the demonstration, double-check that the illustration, equipment, and other required materials are all ready and functional.

The following phase is to describe briefly what new skill or motor control is being taught, then gently demonstrate the skill or motor control so that all pupils understand the intricacies. Give appropriate verbal explanations to pique the pupils' interest. After each step, check to see if the pupils have understood the meaning, content, and explanations. If they haven't completed any of the steps, have them do so again. Involve students in carrying out tasks within the demonstration as much as possible.

Finally, if there is any error in the process of executing the tasks, modify and correct the pupils, and assign a demonstration assignment to take the learners through all of the stages involved in the demonstration (Roel & Reddy, 2013).

Advantages of the Demonstration Method

It encourages learners' critical thinking, concept building, and generalization study. It aids in the correction of facts, concepts, information, principles, and abilities, as well as the development of creative thinking in students. It is an extremely successful educational strategy for introducing new abilities Bilgici, (2011). This is because it holds the learner's attention for the duration of the lesson, especially when the arrangement is linear and orderly.

The learners' aims become clearer when they apply the demonstration technique. Students are aware of what they are supposed to study, making learning easier because their attention is directed in the proper direction. This strategy has an impact on both good and bad students. It allows students to gain knowledge through first-hand sources. It is also delivered at a pace that allows everyone in the class to keep up (Hiebert, 2009).

Learners usually reinforced their learning by repeating the exercises. Students acquire trust in the teacher. This is because people choose teachers who demonstrate what they preach. This strategy establishes a direct connection between theory and practice. It gives students a solid foundation on which to apply what they've learned. More importantly, it teaches students how to be skilled observers.

Disadvantages of the Demonstration Method

Because demonstration methods focus activities on the teachers, learners have fewer opportunities to explore new ideas and solve issues on their own. When students are not offered any activities, they become passive learners. It reduces learners' active participation. It becomes more difficult to impose such competence on students when complex tasks are involved.

It's difficult to prove a student's comprehension. This is especially true because it focuses on the psychomotor rather than the cognitive area. It is possible that if the underlying ideas are not verbally explained, learning will become more difficult.

Summary of the Reviewed Literature

The literature review looked at the CAI theoretical and conceptual framework, the model of CAI the types and characteristics of CAI. The review dwelled on the benefit of CAI and the problems associated with Computer Assisted Instruction.

The literature reviewed Geometry and Transformation Geometry. The advantages and disadvantages of computer-assisted instruction in the learning of Mathematics were also reviewed in this section. GeoGebra and its effect on Mathematics were also reviewed in this section as well as the benefits of GeoGebra in the teaching of Mathematics. Factors which impede the implementation of computer-assisted instruction were also reviewed in this chapter.

CHAPTER THREE

RESEARCH METHODS

Overview

The purpose of this study was to examine the impact of GeoGebra on the performance of Junior High School 2 students in Mathematics. This chapter presents the methodology of the study. First, the design of the study is presented and this is followed by research questions, hypotheses, sample of the study, variables of the study and data collection instruments. Then, data collection and data analysis procedures are explained. Finally, limitations of the study are discussed.

Research Design

The study adopted the Solomon Four-Group quasi-experimental design. Research of an empirical interventional study used to estimate the impact of an intervention on the target population without random assignment. The study sought to compare the academic achievements of the control group and the experimental group. Quasi-experimental research shares similarities with the traditional experimental design or randomized controlled trial but it specifically lacks the element of random assignment to treatment or control. The Solomon four group is a strong design because it assures equality of groups, even in a quasi-experimental design. Additionally, the researcher can determine whether or not the administration of a pre-test is affecting the change in the dependent variable as opposed to the actual intervention (Jason, 2018).

The Solomon-Four group design is illustrated in table 1

Table 1: Solomon-Four Group

	Pre-test	Treatment	Post Test
Group E1(Boys)	O1	X	O2
Group C1(Girls)	03	Y	04
Group E2(Girls)	No Test	X	05
Group C2(Boys)	No Test	Y	06

Solomon-Four Group, Non-equivalent control group design as indicated in Figure 2, the notations are EI= Experimental group 1, C1= Control Group 1, E2= Experimental Group 2, C2= Control Group 2, O2, O4, O5, O6= Post-test, O1, O3= Pre-test, X= Treatment (computer-aided instruction), Y= No treatment (conventional methods).

In 1949, Richard Solomon developed the Solomon four-group design research method. It is occasionally used in social science, psychology, and medicine. It can be used if the pre-test raises concerns about treatment sensitization.

The four groups have four different experiences:

1. Pre-test, treatment, post-test
2. Pre-test, no treatment, post-test
3. Treatment, post-test
4. No treatment, post-test

To measure the treatment's success, make comparisons between groups 1 and 3 and groups 2 and 4.

This design includes two additional control groups to reduce confounding variables and allow the researcher to assess if the pre-test affects the participants.

Despite being substantially more complex to set up and assess, this design style combats many of the internal validity issues that affect research. It enables the researcher to maintain complete control over the variables and verify that the pre-test has no bearing on the final results.

The Solomon four-group test is a two-group pre-test-post-test design with just a post-test control. By mixing tested and untested groups with treatment and control groups, the researcher may ensure that confounding variables and extraneous factors have not influenced the results.

The pre-test, treatment and post-test are given to the first group (A); only the treatment and post-test are provided to the second group (B); the pre-test, no treatment, and post-test are given to the third group (C); and only the post-test is given to the fourth group (D). The Solomon four-group design has several advantages over a traditional two-group pre-test–post-test design, including less confounding and the ability to determine if changes in the dependent variable are due to a pre-test–treatment interaction effect.

Participants and Sampling Procedures

In this study, sampling was done at four levels. First, the Form 2 class was selected purposively. Form two students were selected due to the fact that they were expected to have covered some prerequisites in Geometry from the Form 1 Mathematics content. The total population of Sunflower School was 524, the total population of Crown Prince Academy was 553, the total population of God's Grace School was 623 and the total population of Saint Theresa's

School was 924. The total population for all form twos in the four schools was 320. Further at this level, major topics that are fundamental in Geometry are covered hence the topic rigid motion as well. Also, it was expected that the students had settled in the school as opposed to form one classes and hence had already acquired basic computer knowledge. Form three classes were not used in the study as they are examination classes

The participants in this study were 80 Form Two students from four Junior High Schools in Accra with computer laboratories. A total of 20 students in form two (N=20) were selected from each school

These participants constituted the total population for the study. The participants were in four intact groups. Group EI included 20 students; Group E2 consisted of 20 students; Group C1 consisted of 20 students and Group C2 comprised 20 students.

Four Junior High Schools were purposively sampled from the 15 Junior High Schools with computer laboratories within my catchment area within the Accra Metropolis. Purposive sampling was used to select schools with similar academic levels as possible because the research was a comparative study. Since the computer laboratory was a key resource that was required for CAI lessons, only schools with such facilities were sampled. The assignment of the four schools (groups) to either experimental or control conditions was done using simple random sampling. Random sampling gives every school from the target population a known and equal probability of selection (Thomas, 2022)

Data Collection Instrument

The main instrument for data collection was test. Mathematics Achievement Test (MAT) was used to collect data on students' academic achievement. Two assessment tests were used: the pre-test and the post-test. The pre-test achievement tests were used to measure the students' achievement in Geometry before exposure to the treatment (CAI). The post-test was used to measure the students' achievement in Geometry after the treatment.

The pre-test and post-test achievement tests were constructed by a panel of qualified and experienced teachers and under the supervision of two specialists each in Mathematics education. Both pre-test and post-test Mathematics Achievement Tests contained multiple choice questions, short-answer questions, and sentence completion with scores awarded to each question and a total score of 30 marks.

Validation of Instrument

The validation was determined by the expert judgement of the supervisor, the head of Mathematics Department of Sunflower School and a Mathematics teacher from Crown Prince Academy. The judgement was sought to guarantee that each of the items in the instrument measured was it was supposed to measure.

Mathematics Achievement Test (pre-test)

This consisted of ten (10) items borrowed from past B.E.C.E. questions on the topic of Rigid Motion. It was used as a pre-test for the first experimental group 1 and the first control group (WAEC, 2018)

Mathematics Achievement Test (post-test)

This instrument was similar to the pre-test, it was administered to the four groups in the study after the experiment.

Validity

Validity refers to the extent to which inferences made on the basis of numerical scores are appropriate, meaningful and useful to the sample (McMillan and Schumacher, 2001). Validity also checks whether the instruments provide an adequate sample of items that represent that concept (De Vos et al, 2003).

In this study, both construct and content validity were used in this study to check if the test really measured the concepts that the researcher assumed it measured. The Initial suggestions and input from the verification exercise from the supervisor led the researcher to reframe, add and delete some existing questions. For example, it was suggested that the inclusion of question on enlargement with a scale factor was not part of rigid motion, this suggestion resulted to deletion of questions on enlargement with a scale factor. These steps were included in the process in ensuring that the research findings are meaningful and reflected students' perceptions.

Reliability

The reliability of a test or instrument refers to the extent to which it consistently measures what it is supposed to measure (Cresswell, 2010). To ensure reliability of the data collected in this study, the contents of the written test went through verification from an independent body. The pilot test of the instruments was carried out by administering the pre-test items. The test was conducted twice on the same set of students covering two weeks and the data gathered were analyzed.

The goal was to find out the correlation coefficient of the four set of pilot tests. Pearson's correlation between the four set of pilot study was analyzed. It showed a positive Pearson Product Moment correlation of 0.825. This figure is quite high, which suggested a strong relationship. Hence, the instruments were considered reliable and appropriate to collect the relevant data to answer the research questions for the study.

A colleague who is knowledgeable in the line of mathematics education ascertain the degree to which the contents of the test items and interview were in harmony with the intended purpose.

Intervention

GeoGebra is an interactive Mathematics software suite that is used to learn and teach science and Mathematics. Points, vectors, segments, lines, polygons, conic sections, inequalities, implicit polynomials and functions are all built in GeoGebra which can be used to support the teaching and learning of Mathematics. GeoGebra can hold variables for numbers, vectors, and points, calculate function derivatives and integrals and execute commands such as finding the roots of a number. GeoGebra can be used by teachers and students to help them formulate and prove geometric conjectures.

This research contained two control groups and two experimental groups, which serve to reduce the influence of confounding variables and allowed the researcher to test whether the pre-test itself affects the subjects. There are four different groups, divided into a treatment group and a control group.

In the Solomon four-group design, the participants in the study are randomly assigned to four different groups: Group E1, experimental group one was taken through intervention with pre-test and post-test. Group C1, Control group one was also taken through pre-test and post-test with no intervention. Group E2 was taken through intervention with a post-test and finally, Group C2 took a post-test with no intervention as shown in figure 2.

The experimental group was made up of students who were tutored using computer-assisted instruction (Geogebra). The difference was that students used GeoGebra, a computer instruction program that included the textbook, assignments and tutorials to help their learning. In the experimental group, a customized computer package was created to aid teaching and learning.

The ADDIE instructional development model was used to build the product. Analysis, design, development, implementation, and assessment are all processes in the Computer Assisted Package (CAP). The analysis step clarifies the instructional problem, specifies the instructional goals and objectives, recognizes the learning environment, and identifies the "gaps" between the desired results or behaviours and the learner's existing knowledge and skills. At the design stage, the instructional designer is responsible for choosing an instructional strategy, learning objectives, evaluation tools, activities, contents, subject material analysis, lesson preparation, and media selection.

The design stage is meticulous and methodical. In the development step, instructional designers build and put together the content pieces (materials, resources, technologies, assessments, and so on) that were generated in the design stage. At this moment, CAP was designed and implemented. In light of the feedback, it was re-evaluated and revised. Formative and summative evaluations were used during the evaluation stage. Summative assessments verified the adequacy of the supplied materials in fulfilling the course objectives and gave chances for user feedback. Formative evaluations were undertaken at each level of the ADDIE process.

Each computer instruction was supported by 10 to 15-item graded post-test questions. The test instruments comprised Free-response questions, multiple-choice questions, matching questions, and sentence completion. Each question had a maximum of three attempts during the assessment. Upon submission, the results of the achievement test are displayed.

If a student received a maximum score of 60%, he or she might proceed to the next lesson; otherwise, the exam had to be retaken. If a student fails the lesson on all three attempts, the lesson must be repeated. Three times each item might be attempted. This motivated pupils to recognize and remedy their mistakes as soon as possible, to achieve a perfect score on each evaluation. The instructor may examine the number of attempts on each assignment, the grade, the time spent, and the answers to particular questions for each student using the computer-assisted tool.

The researcher trained four Mathematics teachers one from each of the selected schools. The training was conducted in the school's computer laboratory since GeoGebra is a computer-assisted instruction tool. The training guide was shown in Appendix E

Pre-test items were developed using PowerPoint and Ispring (computer instruction tool) and administered on a computer. The pre-test was validated by colleague Mathematics teachers and educational technology experts and finally administered to the students to measure their entry behaviour. This is shown in Appendix A

There were three lessons. The lessons covered reflection transformation, rotation transformation and translation transformation. The package was used for the experimental group. The sequence of text display, question and answer options, and immediate feedback were provided until all three lessons were covered. The computer package was face and content validated by educational technology, Mathematics, and computer specialist. The content of the package was validated with a reliability coefficient of 0.84 using Kuder Richardson (KR-20).

Each lesson ended with ten post-test items. The main menu of the package consisted of an introduction, students' registration, a list of lessons 1, 2, and 3 and an exit button. It adopted the drill and practice modes of CAI in administering test items. Upon completion of each lesson, post-tests were conducted to determine the differences between the two groups. The post-test items are shown in Appendices B and C.

Data Collection Procedure

A pre-test and post-test item consisting of ten multiple-choice questions was administered to measure their entry behaviour and understanding of rigid motion since they had previously been introduced. Those in the control group wrote a paper-based text whilst those in the experimental group wrote a computer-based test consisting of ten test items. Instructors graded the pre-test and post-test of both groups. The researcher recorded the number of responses to the pre-test score, and post-test score in

SPSS.

Data Processing and Analysis

After the administration of the Mathematics post-test to the four groups, the test for every student in the four groups was marked and scored out of 40 marks. The Mathematics achievement test of the experimental group was taken on their computers and the result was displayed immediately after the test. The quantitative data was then recorded into four different categories and analyzed as per group using both descriptive and inferential statistics using SPSS. The descriptive statistics included computing means and standard deviations. Descriptive statistics were used to describe the data.

The t-tests, Analysis of Variance (ANOVA) was run to determine the statistical significance and difference between the group means. The sample t-test was used to determine the statistically significant difference between the pre-test scores of the control groups and the experimental group. The ANOVA test was performed to determine the difference in the means of the post-test scores of the control groups and the experimental groups of the four groups. The statistical significance of the hypothesis was tested at $\alpha = 0.05$.

Logical and Ethical Considerations

The data-gathering approach verified that existing data collection policies from schools were followed. The heads of schools were granted permission to conduct research. Consent to conduct research was secured from the District Education Office using this information, as well as a letter of introduction from the University. Permission to visit schools was sought from the heads of all the sampled schools using the endorsed documents.

The researcher was introduced to the Mathematics department heads in each of the participating schools, who then introduced the researcher to the Mathematics teachers. Before participating in data collection, the teachers were informed about the purpose of the research.

The researcher reassured the participants that the information was collected solely for research purposes and would be treated with the highest level of confidentiality.

Chapter Summary

This chapter described the research design, locale, sample size and sampling techniques, research instruments and administration of the instruments. It also described the reliability and validity of the research instruments and the ethical considerations for the study. The next chapter describes the methods of data analysis, presentation, interpretation and discussion of the research findings.

CHAPTER FOUR

RESULTS AND DISCUSSION

Introduction

This chapter presents the results and discussion of data obtained from the written test administered to students. The study aimed to investigate the impact of GeoGebra software on junior high school students' ability to understand rigid motion. A detailed analysis and discussion of the findings of the written test are presented.

The results of the study were based on the following research questions;

1. What is the difference in students' performance between the control group and the experimental group?
2. How does GeoGebra affect students understanding of rigid motion?
3. How does GeoGebra influence the performance of students in terms of gender?

The study included four groups: two Experimental groups and two Control groups as shown in Table 2.

Table 2: Shows the four groups and the number of participants in each group

Group	Category	Number of Participants
Group 1	Experimental Group (E1)	N = 20
Group 2	Control Group (C1)	N = 20
Group 3	Experimental Group(E2)	N = 20
Group 4	Control Group(C2)	N = 20

Research Question 1: What is the difference in students' performance between the control group and the experimental group?

To find out the significant difference in students' performance in solving rigid motion questions, the researcher designed an initial test (pre-test) aimed at establishing the learners' entry behaviour and initial knowledge of the intended learning areas. The test which was marked out of 30, therefore, tested knowledge of rigid motion (rotation, reflection and translation vector) and in particular the topics at the form two level.

Table 3: Descriptive statistics of student's sample pre-test scores

	N	Minimum	Maximum	Sum	Mean	Std. Deviation	Variance
Control Group 1	20	3.00	8.00	117.00	5.8500	1.53125	2.345
Control Group 2	20	3.00	7.00	97.00	4.8500	1.18210	1.397
Experimental Group 1	18	2.00	7.00	84.00	4.6667	1.57181	2.471
Experimental Group 2	15	3.00	7.00	70.00	4.6667	1.17514	1.381
Valid N (listwise)	14						

In the pre-test, the maximum score was 8 (80%) and the minimum score was 2 (20%) for the full group of pupils. The participants' overall performance in the pre-test suggested that they have trouble answering rigid motion questions. Only 33.3% of students passed with a pass value of 5 (50 %), indicating their difficulty in solving rigid motion questions. A variance of 2.345 means that there is a more spread of data in relation to the mean of 5.85 in the control group 1 compared to control group 2 which has a variance of

1.397 with a mean value of 4.85.

Students struggled with rigid motion, such as rotation, reflection, and translation vector, according to a critical analysis of their answers to the pre-test questions.

Generally, the students demonstrated they had problems in the area of rigid motion as described below:

Furthermore, the students were aware of the fact that the translation transformation is a concept of replacement, but they made mistakes on the issue of replacement direction (e.g. along the x-axis or y-axis) while translating a given point in the coordinate system.

Research Question 2: How does GeoGebra affect students understanding of rigid motion?

To respond to the second objective, the study sought to compare the scores of students in the pre-test and the post-test results. The students' scores were categorized into 2 major groups; namely, their scores when the GeoGebra was used (post-test score) and when the traditional method was used (pre-test). The students by using GeoGebra were allowed to explore the dynamic geometry environment and eventually apply the learnt ideas in the post-test. This was done by form 2 science classes in the rigid motion topics which include rotation, reflection and translation by a vector. Some of the activities the students were engaged in were captured and represented in this report as evidence of the GeoGebra use.

Table 4: Means of Sample Pre-test and Post-Test Scores

Paired	N	Mean	Std. Deviation	Std. Error Mean
Pre-Test	20	5.9	1.5	.34240
Post-Test	20	6.7	1.1	.24170

From Table 3, the results indicated that the average scores were higher for the Post-test scores as compared to the pre-test. The pre-test produced (M=5.9, SD=1.5) as against the post-test (M=6.7, SD=1.1) and with 95% confidence level there is an increase in students' rigid motion achievement after the instruction with GeoGebra software.

Research Question 3: How does GeoGebra influence the performance of students in terms of gender?

The goal of the study was to see if there was a significant difference in students' Mathematics achievement when rigid motion was combined with Geogebra in terms of gender. Table 5 shows the independent sample t-test of MAT of the groups in terms of gender.

Table 5: Descriptive and Independent Sample T-Test of MAT Pre-treatment scores in MAT by Gender

Groups	Gender	N	Mean	Std. Deviation	Std. Error Mean	sig
Control Group 1	Male	11	5.0909	1.44600	.43598	.731
	Female	9	4.8889	1.05409	.35136	.723
Control Group 2	Male	9	4.4444	1.13039	.37680	.209
	Female	8	5.1250	.99103	.35038	.206
Experimental Group 1	Male	11	5.2727	1.10371	.33278	.452
	Female	8	4.8750	1.12599	.39810	.455
Experimental Group 2	Male	8	5.2500	1.66905	.59010	.593
	Female	8	4.8750	.99103	.35038	.595

The t-test analysis shows that the MAT pre-test mean scores for male and female students were not significantly different, $p > 0.05$. This implied that the male and female students' sample pre-test scores were similar on MAT measure before the exposure to the treatment.

Table 6: Levene's Test of Equality of Error Variances for Sample Pre-Test Scores

		Levene Statistic	df1	df2	Sig.
Pre-Test Score	Based on Mean	.574	1	18	.458
	Based on Median	.544	1	18	.470
	Based on Median and with adjusted df	.544	1	15.222	.472
	Based on trimmed mean	.620	1	18	.441

A significant level ($P > 0.05$) indicates that there is an assumption of homogeneity of variance with 95% confidence level. The variances are equal across sample.

The Experimental groups received the treatment (CAI), while the Control groups received no treatment. All four groups took a Mathematics Achievement Test (MAT) at the end of the treatment period. Descriptive statistics was used and the findings are shown in Table 5

Table 7: Descriptive Statistics of Overall Post-Test Scores in MAT

Variable	Group	Mean (Max = 20)	N	Std. Deviation	Skewness
MAT Post-Test	Experimental Group 1	25.60	20	3.360	-0.474
	Control Group 1	16.07	18	4.298	0.234
	Experimental Group 2	25.59	18	4.145	-0.423
	Control Group 2	14.71	19	4.959	0.424

From Table 7, it is apparent that the average MAT post-test scores of the Experimental groups were relatively higher than those of the Control groups. For instance, the mean scores for Experimental Groups 1 and 2 were 25.60 and 26.59 respectively while Control groups 1 and 2 mean scores were 16.07 and 14.71 respectively. This indicates that students who were taught using Computer Assisted Instruction (GeoGebra) performed better than the students who were taught using Conventional Instructional Methods. To establish whether there was a significant difference between the group means, the One-Way ANOVA test was performed on MAT Post-test scores and the results obtained were as shown in Table 8.

Table 8: One-Way ANOVA of MAT Sample Post-Test Scores

		Sum of Squares	df	Mean Square	F	Sig.
Experimental Group 2	Between Groups	1.962	1	1.962	1.721	.020
	Within Groups	17.097	15	1.140		
	Total	19.059	16			
Control Group 2	Between Groups	.584	1	.584	.486	.049
	Within Groups	21.616	18	1.201		
	Total	22.200	19			

The results in Table 6 show that the difference in Mathematics achievement post-test mean scores of the students between the Experimental and Control groups was significant with F (1.721), P < 0.05.

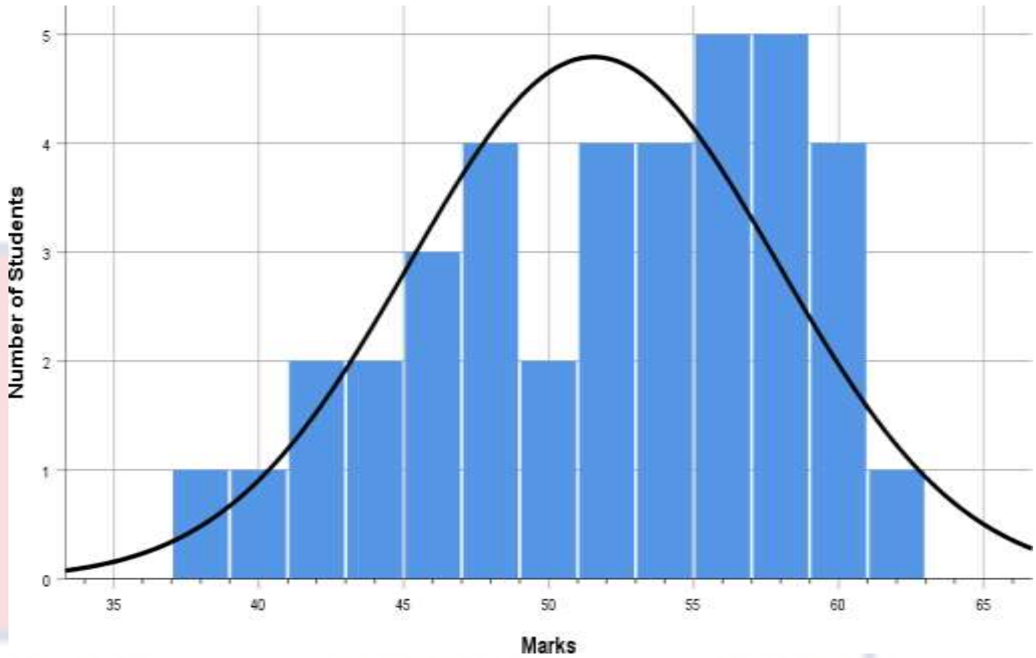

Figure 2: Histogram and normal curve of post-test marks of the experimental group

Figure 2 shows a distribution of marks obtained by the experimental group in their post-test. The distribution which is slightly skewed to the left indicates that most of the marks obtained in the experimental group are greater than the mean mark (that is 51.55). This implies that several students scored marks above the mean mark.

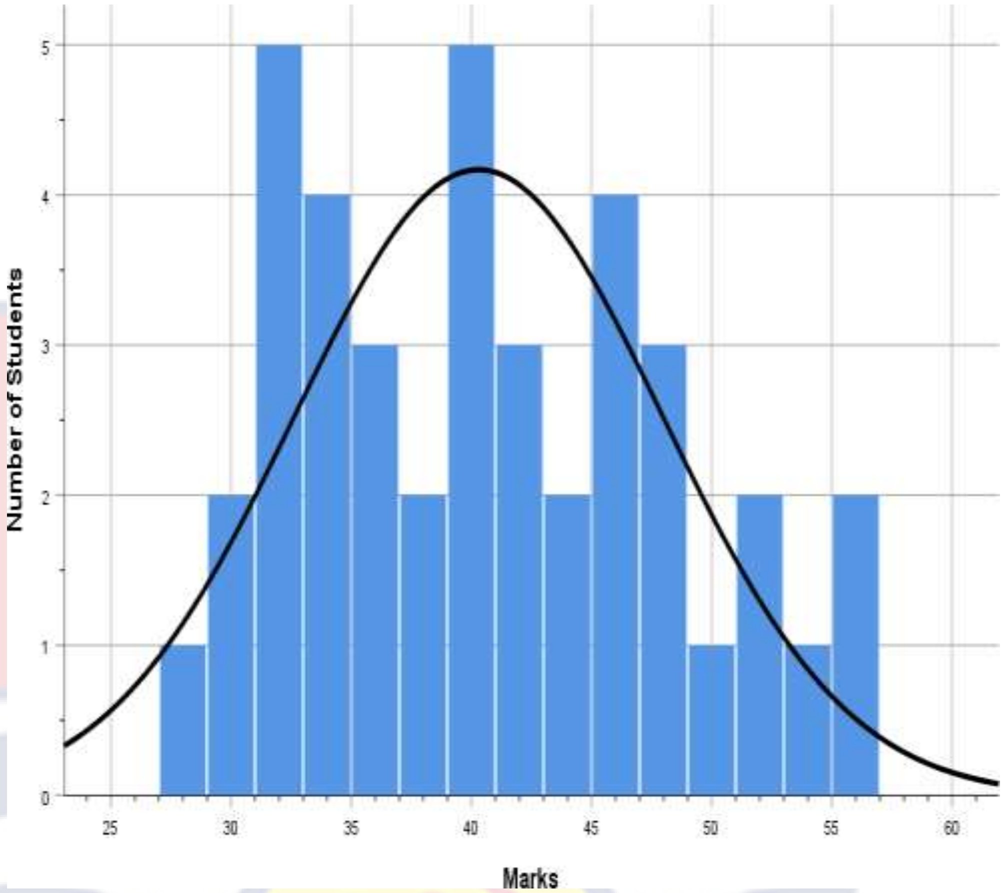

Figure 3: Histogram and normal curve of post-test marks of the control group

Figure 3 shows a distribution of marks obtained by the control group in their post-test. The distribution which is slightly skewed to the left indicates that most of the marks obtained in the control group are greater than the mean mark (that is 42.55). This implies that several students scored marks below the mean mark.

Students' level of Academic Achievement before Treatment

The aim of pre-testing the groups was to ascertain whether the students selected to participate in the Experimental group and Control group had comparable academic characteristics. Experimental group 1 (E1) and Control group 1 (G1) students were exposed to Mathematics Achievement Test (MAT) pre-test before the application of treatment. Table 9 shows the descriptive statistics and t-test analysis of the two groups.

Table 9: Descriptive and Independent Sample t-test of Pre-treatment scores in MAT

Group	N	Mean (Max-40)	SD	Df	t-value	Sig
Experimental Group 1	40	23.23	3.750	88	1.314	0.192
Control Group 1	45	23.23	4.125			

The t-test analysis reveals that the MAT pre-test mean scores of both the Experimental group and Control group were not significantly different at 0.05 alpha level ($t(88) = 1.314$, $p > 0.05$). Therefore, the groups were deemed similar on MAT measure and had comparable characteristics, hence homogenous with a 95% confidence level. A similar test was done based on gender achievement and the results are shown in Table 10.

Table 10: Levene's Test of Homogeneity of Variance for Sample Pre-Test in MAT

		Levene Statistic	df1	df2	Sig.
Pre-Test Score	Based on Mean	.498	4	11	.738
	Based on Median	.498	4	11	.738
	Based on Median and with adjusted df	.498	4	10.000	.738
	Based on trimmed mean	.498	4	11	.738

A significant level ($P > 0.05$) indicates that there is an assumption of homogeneity of variance with 95% confidence level. The variances are equal across sample. There was homogeneity of variances, as assessed by the Levene's test for equality of variances, for competence, $p > .05$.

Academic Achievements of Students in Mathematics

The first study objective sought to determine whether teaching rigid motion with GeoGebra is more effective than the traditional teacher-led mode of instruction. To collect data on Academic achievement, a pre-test was administered to Experimental Group 1 (E1) and Control Group 1 (C1). Both experimental groups (group l and group 3) were exposed to the treatment condition for three weeks. Control Group 1 and Control Group 2 were taught using the regular teacher-led mode of instruction over the same Period after which a post-test was administered to the four groups.

Table 11: Pre-Test Means Scores of the Control Group and the Experimental Group

Learning Method	N	Mean	SD	Df	T-Value	Sign
Experimental Group 1	34	19.06	16.89	64	0.096	0.446
Control Group 1	32	18.64	19.50			

Table 11 shows the mean score by experimental and control groups. The difference between the mean scored by the two groups was not statistically significant at α = 0.05 significant level using t- value. It also shows that a sign of 0.446 was greater than 0.05, an indication that the groups were homogeneous and thus suitable for the study.

Table 12: Levene's Test of Homogeneity of Variance for Sample Post-Treatment in MAT

		Levene Statistic	df1	df2	Sig.
Post-Test Score	Based on Mean	.428	4	11	.738
	Based on Median	.238	4	11	.729
	Based on Median and with adjusted df	.448	4	10.000	.638
	Based on trimmed mean	.428	4	11	.738

A significant level (P > 0.05) indicates that there is an assumption of homogeneity of variance with 95% confidence level. The variances are equal across sample.

Percentage Comparison of Post-Test Marks

By calculating the percentage equivalent of the post-test results, the findings of the post-test results were also examined. According to the results, the experimental group's mean mark percentage value, which was 79.31%, was higher than the control group, which was 62.30%. The results of the percentage comparison of the post-test scores are displayed in Table 9

Table 13: Percentage Comparison of Post-Test Marks

Group	Mean Mark	Percentage
Control	40.30	62.30
Experimental	51.55	79.31

It may be inferred from Table 13 that pupils who utilize the software perform better than their peers who did not. This finding is consistent with that of Tay and Wonkyi (2018), who hypothesized that GeoGebra aids in raising math proficiency in student learning. The results confirm those of Yaratan (2014), who found that technology improves pupils' academic performance. From the study's results, it can be concluded that GeoGebra improves student performance compared to the conventional mode of instruction. This is indicative that there was a significant difference between the result of the MAT between the control group and the experimental group.

Students' Understanding of Rigid Motion After Treatment

This study also assessed the attitudes of students towards the use of GeoGebra in the teaching and learning of Rigid Motion. A questionnaire of 10 items was used to solicit information regarding students' attitudes toward the use of GeoGebra after intervention. Students responded to the statements using a 5-point Likert scale: Strongly Agree, Agree, Not Sure, Disagree and Strongly Disagree.

The study assessed students' understanding Rigid Motion with the use of the GeoGebra software. Question items on the students' questionnaire particularly sought information on whether GeoGebra helped students to understand rigid motion

Table 6 displays the findings of students' responses on the conceptual understanding of GeoGebra.

Table 14: Students Understanding of Rigid Motion

Statement	Response									
	Strongly Disagree		Disagree		Not Sure		Agree		Strongly Agree	
	N	%	N	%	N		N	%	N	%
Learning Mathematics with GeoGebra helps me to work independently	0	0	0	0	0	0	32	40	20	25
Learning Mathematics with GeoGebra was fun and interactive	0	0	0	0	0	0	27	34	32	40
Learning Mathematics with GeoGebra helps me to easily understand Rigid Motion	0	0	0	0	0	0	5	31	34	43
Learning Mathematics with GeoGebra was very interactive.	0	0	0	0	0	0	32	40	35	44
Assessment response in Learning Mathematics with computer-assisted instruction is quick	0	0	0	0	1	1.25	28	35	31	39

Source: Field Work, 2021.

The findings of students' understanding of rigid motion showed that all the students that used GeoGebra agreed that GeoGebra enhanced their understanding of rigid motion. The students confirmed that the GeoGebra helped them visualize various orientations of diagrams showing an reflection, rotation and translation. All the students also acknowledged that the GeoGebra helped them to draw various orientations of diagrams.

Discussion of the Results

The purpose of this study was to investigate the impact of GeoGebra software on Junior High School Students' ability to understand rigid motion. The findings of hypothesis one show that the experimental group that was taught GeoGebra significantly outperformed the control group in terms of student achievement. These outcomes were consistent with those of (Zengin, Furkan & Kutluca, (2012) who found that teaching Mathematics with the aid of computers enhances student learning. Many things contributed to GeoGebra's supremacy, including students' ability to comprehend how objects move during rotation and translation. These and other characteristics of GeoGebra make it a special educational tool for enhancing the traditional approach to teaching rigid motion in Mathematics.

According to the findings of hypotheses two and three, there is statistically no significant difference in achievement between male and female students who are taught GeoGebra. This suggests that both male and female students benefited equally from the teaching strategies.

The study of the t-test findings on the performance of students taught using GeoGebra vs the traditional style of instruction (talk-and-chalk) revealed a substantial difference in achievement in the student's favour when taught with GeoGebra. In comparison to their pre-test scores, the pupils' average scores increased after being introduced to GeoGebra.

This supports the findings of Santagata, (2015). showing student motivation and achievement levels rise when teachers effectively incorporate technology into the learning process. This discovery may have resulted from the fact that GeoGebra allowed students to check the accuracy of their work and the validity of their approaches during the post-test. The ability to review one's work is very important for assessing achievement levels.

Because GeoGebra is dynamic, students had the chance to go back and review their work during the post-test but they were unable to do so during the pre-test. GeoGebra makes it possible for instant remediation and re-teaching to get learners back on track with the course (Velichova, 2011). Due to the time and space requirements of creating numerous diagrams on the chalkboard, the conventional style of teaching could only cover a small number of instances.

When learning with GeoGebra, students spend less time creating diagrams (sketches) and performing computations, giving them more opportunities to investigate the properties of various geometric forms. All of these elements might have influenced the participants' exceptional performance in the post-test.

When computer technology, such as GeoGebra, is incorporated into the teaching and learning process, it is almost impossible to have passive students. With GeoGebra, inactive pupils become active explorers, and the teacher's job is to oversee and lead students' activities. The mathematical ideas and methods that children acquire through GeoGebra are more enduring and better ingrained in their cognitive structures, making them simpler to apply Velichova, (2011).

This study has shown that incorporating GeoGebra into instruction and learning improves students' performance. Numerous studies have demonstrated the positive motivational effects of GeoGebra on students learning (Gambari, 2013), including increased participation in class activities, better attention in class, enjoyment of learning activities, self-confidence in learning abilities, and recommendations for this teaching and learning approach.

Additionally, GeoGebra provides an opportunity for learners' cognitive development. These help and encourage learning, comprehension, thinking, mental imagery, noticing particulars, internalization, and recall. These results seem remarkable given that visualization can play a significant role in modern Mathematics education (Matinez, 2017). In this regard, Gomez (2012) emphasized that GeoGebra can give students numerous opportunities to visualize mathematical procedures and develop an intuitive worldview.

Additionally, their opinions align with those of high school students who participated in the study by Martin (2013) using GeoGebra-developed activities and apps. The Junior high school students reported that they use GeoGebra willingly and enthusiastically. The program enhances visualization and offers a discovery-based learning environment, enabling them to recognize the connections between mathematical concepts. The information they previously memorized can be retained more easily when used with GeoGebra.

Conclusion

The study looked at how learners' teaching and learning f rigid motion could be improved in Junior High School. The solution to the performance issue appears to be cutting-edge technology that uses computer applications to support the teaching of rigid motion. GeoGebra improved student performance, increased their retention and was more gender-neutral in teaching rigid motion.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

Introduction

The purpose of this study was to establish the utilization of GeoGebra software as a teaching and learning tool in geometry and its impact on student achievement in some selected Junior High Schools in the Greater Accra Metropolis. This chapter contains a summary of the findings, conclusions and recommendations based on the findings. Areas of further research have also been suggested. The presentation is based on the research objectives. Tables were mainly used to present the findings, while standard deviation, mean scores and t-tests were used to discuss the results. The study aimed at achieving the following objectives:

To explore students' understanding of Rigid Motion before teaching with GeoGebra software (instructional tool).

To establish whether the use of GeoGebra could significantly enhance the teaching and learning of Rigid Motion in Mathematics.

To explore gender differences in students' achievement after GeoGebra has been used to teach and learn Rigid Motion

Summary and Findings of the Study

The results of hypothesis one reveals that there is significant difference in the students' achievements between the control group and the experimental group. These results agreed with findings of Yuksel (2015) and Wang, (2017) who found that students taught using GeoGebra performed better than their counterparts taught with the conventional method. The superiority of GeoGebra to other methods may be attributed to several factors, which includes learners' ability to visualize the 3D object, receive immediate feedback, self-paced learning, reinforcement, principles of mastery learning, associate learning and step by step learning.

The findings also suggest that GeoGebra instructional model has superiority over the conventional method of teaching rigid motion. This could be attributed to the assertion of Abimbade (1997) who said that instructional model enhances visual imagery, stimulates learning and assists the teacher to properly convey the topic content to the learners to achieve better performance.

The study also revealed there was a significant difference in achievement between the treatment group and the control group, with the treatment group performing better the control group. The GeoGebra software improved students' understanding of rigid motion and their ability to solve problems. These findings also revealed the use of GeoGebra increased students' interest in geometry.

Recommendations for Policy and Practice

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 teachers to GeoGebra as an innovative way to teach rigid motion will be most helpful in raising the performance of Junior High School students. This introduction could be done through workshops and seminars organized by Ghana Education.
2. Integrating the use of computers and interactive educational software like GeoGebra into the Mathematics curriculum of Junior High School

could also help teachers guide students to understand of geometric concepts and improve students' ability in solving mathematics problems.

3. This will help to improve students' performance significantly.
4. Interactive educational software and computers could be incorporated into teaching and learning activities. This will help make learning mathematics more interesting to students. This could be done by providing resource materials such as educational applet devices, computers and mathematical instruments.

Suggestions for Further Research

Based on the findings of this study, the study recommends further research as follows:

1. This research focused on the application of GeoGebra to the teaching and learning of rigid motion. Other computer applications that can be used to aid the teaching and learning of rigid motion should be investigated. It would be interesting to see if combining multiple computer applications could improve rigid motion instruction and learning.

2. The study focused on how to learn rigid motion using GeoGebra software. Another study could be conducted to see if GeoGebra can be used in other areas of Mathematics in Ghana's Junior High School curriculum, such as algebra and statistics. It would be interesting to see how well children perform in these areas when taught with GeoGebra.

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APPENDICES

APPENDIX A

PRE-TEST EXAMINATION

This test is part of research on your ability to solve the rigid motion of transformation geometry problems. Data gathered will be used for purposes of research only and will be treated with confidentiality. Your cooperation will be highly appreciated. Please respond to all the questions as honestly as possible. Thank you.

PART A: Pre-Test

Gender: (Please tick one)

Male ☐ Female ☐

Please select the appropriate answer to each of the following questions

1. Point A (1,3) is rotated about the origin of the coordinate plane anticlockwise 90^o. Find the imageA^1.
   A. (-3 – 1)
   B. (– 3, 1)
   C. 3, -1)
   D. (3, 1)

2. Point B (-7, 3) is reflected in line x = 0. Find the coordinates of the image of B^1.
   A. (7, 3)
   B. (– 7, -3)
   C. (- 7, 3)
   D. (-7, -3)

3. The Point P (x, y) is mapped onto P' (6, 8) under a translation by the vector (2, 3). Find the coordinates of P.
   A. (9, 15)
   B. (4, 5)
   C. (- 3, -1)
   D. (- 9, -15)

4. Find the coordinates of the point Q (– 3, – 7) under rotation through 180^0about the origin.

A. (3, 7)
B. (– 7, 3)
C. (7, 3)
D. (– 3, 7)

5. G’ (–4, 6) is the image of G under a translation by the vector (-5, -7) What is thecoordinate of G?

A. (- 9, -1)
B. (– 1, -13)
C. (1, 13)
D. (9, 1)

6. The points (5,1) are reflected in the x-axis. Find the coordinates of the final image

A. (5, – 1)
B. (– 5, 1)
C. (–5, – 1)
D. (1, 5)

A transformation is given by $\begin{pmatrix} x \\ y \end{pmatrix} \rightarrow \begin{pmatrix} 2x-7 \\ -3y \end{pmatrix}$

7. Find the image of (–2,–3) under this transformation.

A. (–11,9)
B. (–11, -6)
C. (–11, – 9)
D. (–1, –6)

8. The point P (-3, 4) is reflected in the line y = 2. Find the image of P.

A. (– 3, 0)
B. (–3, 4)
C. (3, 4)
D. (7, 4)

9. What transformation is represented by the mapping? $\begin{pmatrix} x \\ y \end{pmatrix} \rightarrow \begin{pmatrix} -x \\ y \end{pmatrix}$

A. Reflection in the y-axis

B. Reflection in the x-axis

C. 90^0 clockwise rotations about the origin

D. 90^0anticlockwise rotation about theorigin

10. In reflection, the line of reflection can also be referred to as

A. Line of rotation

B. Angle of reflection

C. Mirror line

D. Mirror plane

SOLUTION

PART A – PRE-TEST MARKING SCHEME

1. B	6. C
2. A	7. B
3. B	8. B
4. A	9. A
5. C	10. C

Total Marks = 20

THEORY: SECTION B

(i) Using a scale of 2cm to 1 unit on both axes, draw two perpendicular axes OX and OY on a graph sheet.

(ii) Mark on the same graph sheet the x-axis from -5 to 5 and the y-axis from -6 to 6

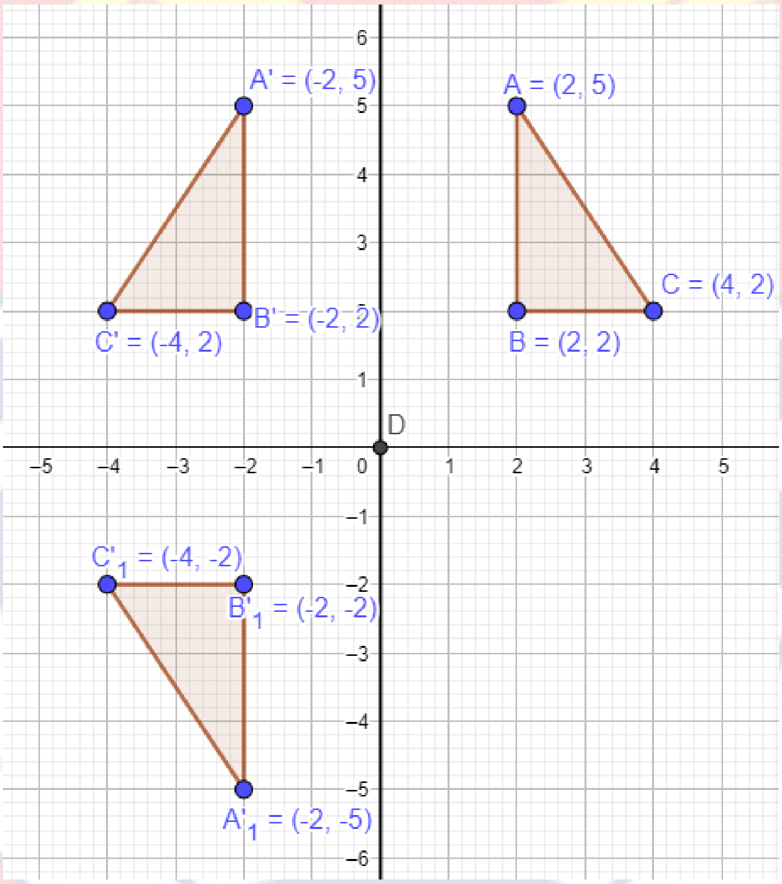
(iii) Plot the points A(2,5), B(2,2) and C(4,2). Join the points A, B and C to form a triangle ABC

(iv) Using the y-axis as a mirror line, draw the image triangle $A_1B_1C_1$ of the triangle ABC such that $A \rightarrow A_1$, $B \rightarrow B_1$ and $C \rightarrow C_1$. Write down the coordinates of A_1, B_1 and C_1

(v) Draw the image triangle $A_2B_2C_2$ of triangle ABC under anticlockwise rotation of 180^o about the origin where $A \rightarrow A_2$, $B \rightarrow B_2$ and $C \rightarrow C_2$. Write down the coordinates of A_2, B_2 and C_2

Solution

Marking Scheme (10 Marks)



iv. Reflecting (x, y) in the y-axis

$$\begin{pmatrix} x \\ y \end{pmatrix} \rightarrow \begin{pmatrix} -x \\ y \end{pmatrix}$$

$$\Rightarrow \quad OA\begin{pmatrix} 2 \\ 5 \end{pmatrix} \rightarrow OA_1\begin{pmatrix} -2 \\ 5 \end{pmatrix}, \quad \therefore A_1(-2, 5)$$

$$\Rightarrow OB\begin{pmatrix} 2 \\ 2 \end{pmatrix} \rightarrow OB_1\begin{pmatrix} -2 \\ 2 \end{pmatrix}, \quad \therefore B_1(-2, 2)$$

$$\Rightarrow OC\begin{pmatrix} 4 \\ 2 \end{pmatrix} \rightarrow OC_1\begin{pmatrix} -4 \\ 2 \end{pmatrix}, \quad \therefore C_1(-4, 2)$$

∴ Plot and join $A_1(-2,5)$, $B_1(-2,2)$ and $C_1(-4,2)$ as the image of triangle ABC under a reflection in the y-axis as shown above.

v. Rotating (x, y) through 180° about the origin

$$\begin{pmatrix} x \\ y \end{pmatrix} \rightarrow \begin{pmatrix} -x \\ -y \end{pmatrix}$$

$$OA\begin{pmatrix} 2 \\ 5 \end{pmatrix} \rightarrow OA_2\begin{pmatrix} -2 \\ -5 \end{pmatrix}, \quad \therefore \; A_2(-2,-5)$$

$$OB\begin{pmatrix} 2 \\ 2 \end{pmatrix} \rightarrow OB_2\begin{pmatrix} -2 \\ -2 \end{pmatrix}, \quad \therefore \; B_2(-2,-2)$$

$$OC\begin{pmatrix} 4 \\ 2 \end{pmatrix} \rightarrow OC_2\begin{pmatrix} -4 \\ -2 \end{pmatrix}, \quad \therefore \; C_2(-4,-2)$$

∴ Plot and join $A_2(-2,-5)$, $B_2(-2,-2)$ and $C_2(-4,-2)$ as the image of triangle ABC under a rotation through 180° about the origin as shown above.

APPENDIX B

POST-TEST EXAMINATION FOR FORM 2 STUDENTS

REFLECTION

This test is part of research on your ability to solve the rigid motion of transformation geometry problems. Data gathered will be used for purposes of research only and will be treated with confidentiality. Your cooperation will be highly appreciated. Please respond to all the questions as honestly as possible. Thank you

PART A: Post-Test

Gender : (Please tick one)

Male ☐ Female ☐

Please select the appropriate answer to each of the following questions

1. Reflection is the ____ image of the shape.

A. Translated

B. Rotated

C. Mirror

D. Dilated

2. If the x-coordinates remain the same, but the y-coordinates are transformed into opposite signs, the reflection is over ____.

A. Origin

B. X-axis

C. Y-axis

D. None of these

3. The original image in the reflection method is called

A. Pre-image

B. Image

C. Post image

D. None of these

4. Reflection is one of the types of

A. Rotation

B. Transformations

C. Translation

D. None of these

5. The reflected image is also called
A. Pre-image
B. Image
C. Post image
D. None of these
6. Reflection symmetry is also called
A. Rotational symmetry
B. Mirror symmetry
C. Translational symmetry
D. None of these
7. The axis or imaginary line that passes through the centre of the shape is called
A. Translation
B. Line of symmetry
C. Rotation
D. None of these
8. Circle has ___ lines of symmetry.
A. Ten
B. One
C. Infinite
D. None of these
9. Reflect in the x-axis can also be referred to as reflection in the line X = 0.
A. True
B. False

APPENDIX C

POST-TEST MARKING SCHEME-PART A

1. C	6.D
2. B	7. B
3. A	8. B
4. B	9. C
5. B	10A

Total Marks = 20

SECTION B

(a) Using a scale of 2cm to 1 unit on both axes, draw perpendicular lines OX and OY on a graph sheet.

(b) On this graph sheet, mark the x-axis from –5 to 5 and the y-axis from –6 to 6

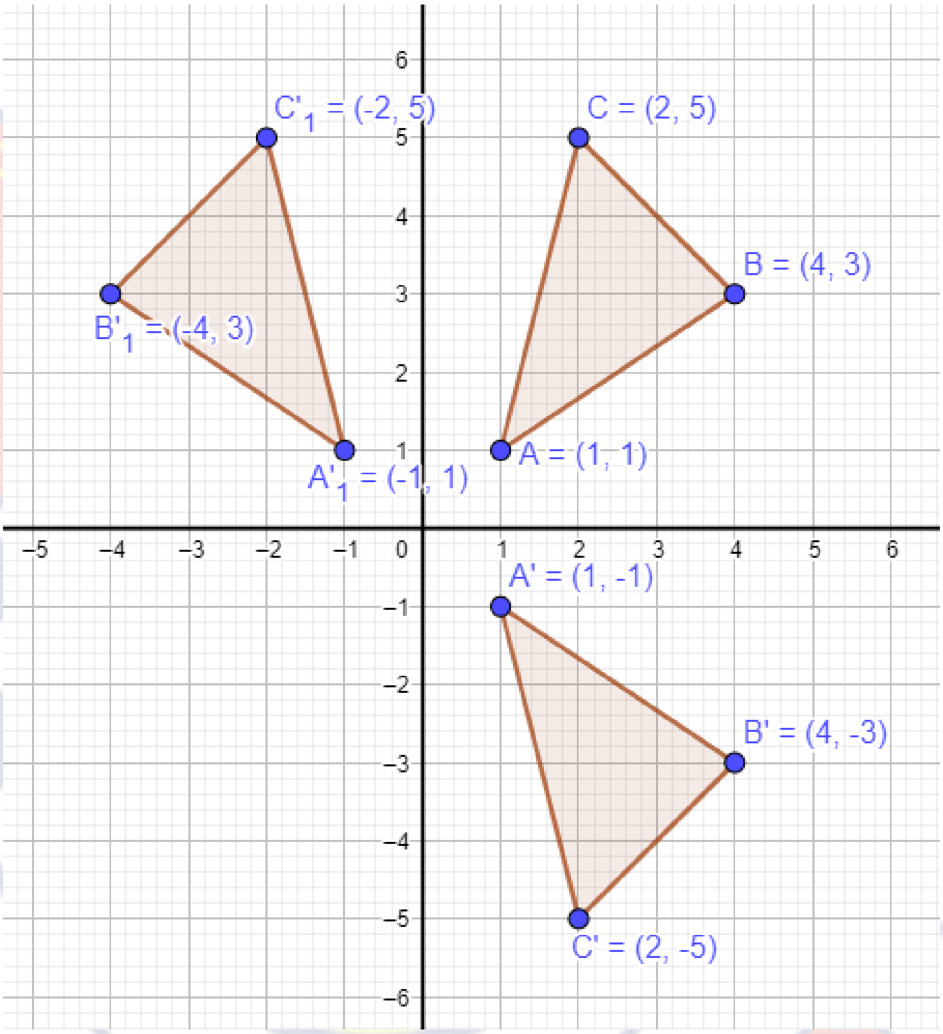
(c) Plot on the same graph sheet the points A(1,1), B(4,3) and C(2,5). Join the points A, B and C to form a triangle.

(d) Using the y-axis as the mirror line, draw the image $A_1B_1C_1$ of the triangle ABC, such that $A \rightarrow A_1$, $B \rightarrow B_1$ and $C \rightarrow C_1$. Write down the coordinates of A_1, B_1 and C_1.

(e) Using the x-axis as the mirror line, draw the image $A_2B_2C_2$ of triangle ABC where $A \rightarrow A_2$, $B \rightarrow B_2$ and $C \rightarrow C_2$.

Solution

Marking Scheme (10 Marks)



c. Reflecting (x, y) in the y-axis

$$\begin{pmatrix} x \\ y \end{pmatrix} \to \begin{pmatrix} -x \\ y \end{pmatrix}$$

$$OA\begin{pmatrix} 1 \\ 1 \end{pmatrix} \to OA_1\begin{pmatrix} -1 \\ 1 \end{pmatrix}, \quad \therefore A_1(-1, 1)$$

$$OB\begin{pmatrix} 4 \\ 3 \end{pmatrix} \to OB_1\begin{pmatrix} -4 \\ 3 \end{pmatrix}, \quad \therefore B_1(-4, 3)$$

$$OC\begin{pmatrix} 2 \\ 5 \end{pmatrix} \to OC_1\begin{pmatrix} -2 \\ 5 \end{pmatrix}, \quad \therefore C_1(-2, 5)$$

∴ Plot and join $A_1(-1,1)$, $B_1(-4,3)$ and $C_1(-2,5)$ as the image of triangle ABC under a reflection in the y-axis.

d. <u>Reflection in the x-axis</u>

$$\begin{pmatrix} x \\ y \end{pmatrix} \rightarrow \begin{pmatrix} x \\ -y \end{pmatrix}$$

$$OA\begin{pmatrix} 1 \\ 1 \end{pmatrix} \rightarrow OA_2\begin{pmatrix} 1 \\ -1 \end{pmatrix}, \quad \therefore A_2(1,-1)$$

$$OB\begin{pmatrix} 4 \\ 3 \end{pmatrix} \rightarrow OB_2\begin{pmatrix} 4 \\ -3 \end{pmatrix}, \quad \therefore B_2(4,-3)$$

$$OC\begin{pmatrix} 2 \\ 5 \end{pmatrix} \rightarrow OC_2\begin{pmatrix} 2 \\ -5 \end{pmatrix}, \quad \therefore C_2(2,-5)$$

∴ Plot and join $A_2(1,-1)$, $B_2(4,-3)$ and $C_2(2,-5)$ as the image of triangle ABC under a reflection in the x- axis

APPENDIX D

POST-TEST EXAMINATION FOR FORM 2 STUDENTSROTATION

This test is part of research on your ability to solve the rigid motion of transformation geometry problems. Data gathered will be used for purposes of research only and will be treated with confidentiality. Your cooperation will be highly appreciated. Please respond to all the questions as honestly as possible. Thank you

PART A

Gender: (Please tick one)

Male ☐ Female ☐

Please select the appropriate answer to each of the following questions

1. The points (5,1) are rotated 90^0. Find the coordinates of the final image

A. (5, – 1)
B. (– 5, 1)
C. (–5, – 1)
D. (-1, 5)

2. In rotation, pre-images are rotated in ……….. if the direction of rotation is not stated

A. Clockwise
B. Linearly
C. Anticlockwise
D. dilation

3. A rotation is a transformation that turns a figure about a fixed point called the

A. centre of rotation
B. centre of origin
C. midpoint
D. middle section

4. Point P (3, - 1) is rotated about the origin through an angle of 270^0 in aclockwise direction. Find the image of P.

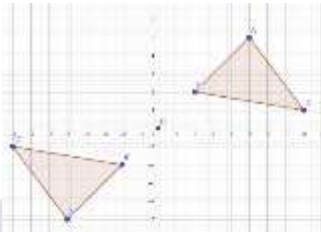
A. (3, 1)
B. (1, 3)
C. (– 1, 3)
D. (– 1, – 3)

5. The number of times the figure coincides with itself when it rotates through 360° is called

A. Order of symmetry
B. Line of symmetry
C. Point of symmetry
D. None of these

6. The rotation of one of the axes of a coordinate system is called

A. Basic rotation
B. Elemental rotation
C. Both A and B
D. None of these
7. The order of rotational symmetry of the rectangle is
A. One
B. Two
C. Three
D. Four
8. The amount of rotation measured in degrees is called
A. Point of rotation
B. Degree of rotation
C. Angle of rotation
D. None of these
9. The point about which the object is rotated is called
A. Point of reflection
B. Point of rotation
C. Point of translation
D. None of these
10. Identify the type of rotation shown in the picture below



Rotation 90^0 anticlockwise about the origin
A. Rotation 180^0 anticlockwise about the origin
B. Rotation 270^0 anticlockwise about the origin
C. Rotation 360^0 anticlockwise about the origin

POST-TEST MARKING SCHEME-PART A (ROTATION)

1.D	6. C
2. C	7. B
3. A	8. C
4. B	9. B
5. A	10. B

Total Marks = 30

SECTION B

Using a scale of 2cm to 2 units on both axes, draw two perpendicular axes OX and OY on a graph sheet. On the same graph sheet, mark the x-axis from –8 to 8 and the y-axis from –8 to 8

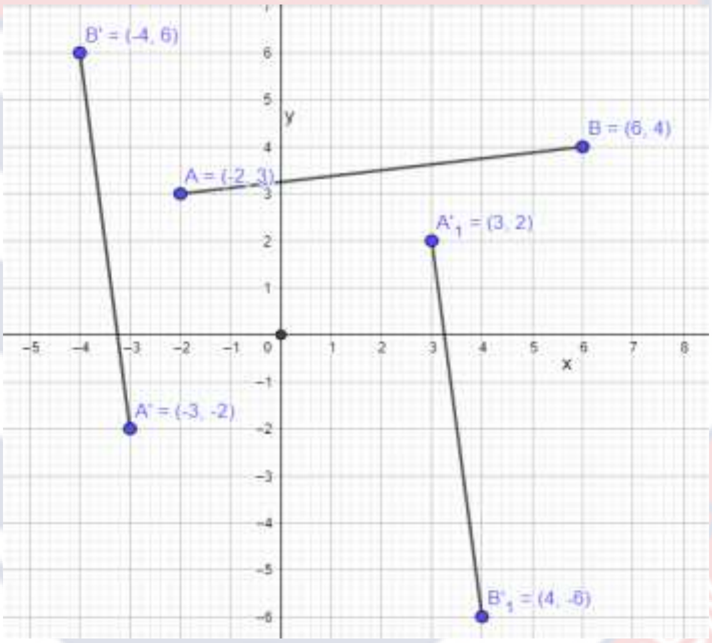
(i) Plot P(-2, 3) and Q (6, 4). Join PQ

(ii) Draw the image P_1Q_1 of PQ under an anticlockwise rotation through 90^o about the origin, where $P \to P_1$ and $Q \to Q_1$. Indicate all the coordinates.

(iii) Draw the image P_2Q_2 of PQ under a clockwise rotation through 90^o about the origin where $P \to P_2$ and $Q \to Q_2$. Indicate all the co-ordinates

Solution

Marking Scheme (10 Marks)



ii. Rotating (x, y) about the origin through 90°anticlockwise

$$\begin{pmatrix} x \\ y \end{pmatrix} \to \begin{pmatrix} -y \\ x \end{pmatrix}$$

$$OP\begin{pmatrix} -2 \\ 3 \end{pmatrix} \to OP_1\begin{pmatrix} -3 \\ -2 \end{pmatrix}, \quad \therefore P_1(-3,-2)$$

$$OQ\begin{pmatrix} 6 \\ 4 \end{pmatrix} \to OQ_1\begin{pmatrix} -4 \\ 6 \end{pmatrix}, \quad \therefore Q_1(-4,6)$$

∴ Plot and join $P_1(-3,-2)$ and $Q_1(-4,6)$ as the image of line segment PQ under a rotation about the origin through 90° anticlockwise

ii. Rotating (x, y) about the origin through 90°clockwise

$$\begin{pmatrix} x \\ y \end{pmatrix} \rightarrow \begin{pmatrix} y \\ -x \end{pmatrix}$$

$$OP\begin{pmatrix} -2 \\ 3 \end{pmatrix} \rightarrow OP_2\begin{pmatrix} 3 \\ 2 \end{pmatrix}, \quad \therefore\ P_2\,(3, 2)$$

$$OQ\begin{pmatrix} 6 \\ 4 \end{pmatrix} \rightarrow OQ_2\begin{pmatrix} 4 \\ -6 \end{pmatrix}, \quad \therefore Q_2\,(4, -6)$$

∴ Plot and join P2(3,2) and Q2(4,-6) as the image of line segment PQ under a rotation about the origin through 90° clockwise

APPENDIX E

POST-TEST EXAMINATION FOR FORM 2 STUDENTS

TRANSLATION

This test is part of research on your ability to solve the rigid motion of transformation geometry problems. Data gathered will be used for purposes of research only and will be treated with confidentiality. Your cooperation will be highly appreciated. Please respond to all the questions as honestly as possible. Thank you

PART A

Gender : (Please tick one)

Male ☐ Female ☐

Please select the appropriate answer to each of the following questions

1. The point (2,3) is first reflected in the straight-line y=x and then translated through a distance of 2 units along the positive direction x-axis. The coordinates of the transformed point are

   A. (5,4)

   B. (2,3)

   C. (5,2)

   D. (4,5)

   Use the translation

   $$(x, y) \to (x + 5, y - 9).$$

2. What is the image of B (2,5)?

   A. B′(6,−3)

   B. B′(−1,−1)

   C. B′(7,−4)

   D. B′(−3,−1)

3. A transformation in which a graph or geometric figure is picked up and moved to another location without any change in size or orientation.

   A. Translation

   B. Rotation

   C. Reflection

   D. Dilation

4. Determine where X' would be if you translated X (2, 4) 3 units to the left and 9 units down.
   A. (-4, 4)
   B. (-10, 2)
   C. (-4, -5)
   D. (-1, -5)
5. Write the rule for this translation:

Slide 3 up and 2 right
   A. (x, y)---->(x + 3, y + 2)
   B. (x, y)-----> (x+2, y + 3)
   C. (x, y)----> (x - 2, y + 3)
   D. (x, y)---->(x + 3, y + 3)
6. Which vectors translate a figure to the right? Select ALL that apply.
   A. (-3, 9)
   B. (2, -10)
   C. (-5, -6)
   D. (4, 1)
7. Find A', the image of A(3, 5), after a translation with vector (-7, 4)
   A. (10, 1)
   B. (-4, 9)
   C. (-10, -1)
   D. (4, -9)
8. What are the coordinates of R', the image of R(-1, 4), after a translation of 2 units right and 3 units down?
   A. (-3, 1)
   B. (3, 7)
   C. (-1, 7)
   D. (1, 1)
9. When a shape is translated in the coordinate plane, it has undergone a rigid transformation. Which of the following are true statements about the image of a shape after a translation? Select all that apply.
   A. The size of the shape is the same.
   B. The orientation of the shape is the same.
   C. A translation is in simple terms a flip.

D. Each point moves the same distance in the same direction.

10. Find A', the image of A(3, 5), after a translation with vector (4, 4).

A. (7, 9)

B. (9, 9)

C. (-10, -1)

D. (4, -9)

POST-TEST MARKING SCHEME-PART A (TRANSLATION)

1.A	6.D
2. B	7. B
3. A	8. D
4. D	9.A
5. B	10. A

Total Marks = 20

SECTION B

(i) Using a scale of 2 cm to 1 unit on both axes, draw two perpendicular axes O*x* and O*y* on a graph sheet.

(ii) Mark on the same graph sheet, the *x*-axis from -5 to 5 and the *y*-axis from -6 to 6.

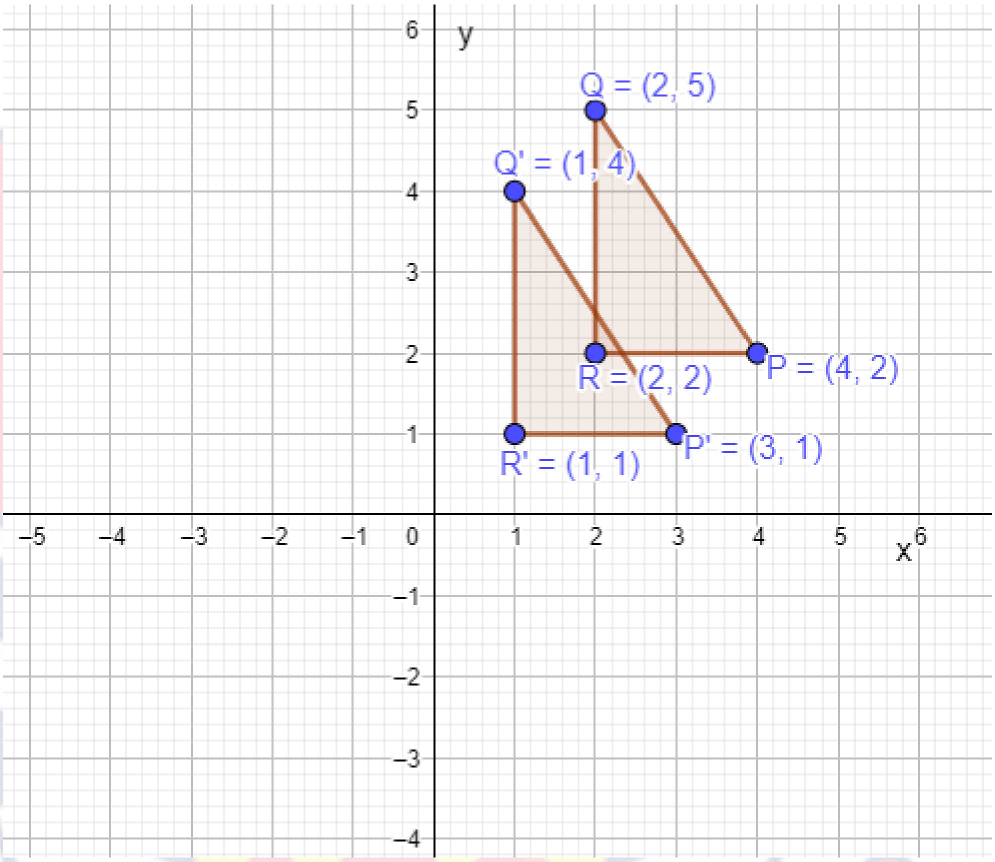
(iii) Plot the points *P*(4, 2), *Q*(2, 5) and *R*(2, 2). Join the points *P*, *Q*, and *R* to form a triangle *PQR*

(iv) Translate triangle *PQR* by the vector $\begin{pmatrix} -1 \\ -1 \end{pmatrix}$ such that $P \rightarrow P_2$, $Q \rightarrow Q_2$, $R \rightarrow R_2$

(v) Label the vertices of triangle $P_2Q_2R_2$

Solution

Marking Scheme (10 Marks)



Translating PQR by vector $\begin{pmatrix}-1\\-1\end{pmatrix}$

Translating (x, y) by vector $\begin{pmatrix}a\\b\end{pmatrix}$

$$\begin{pmatrix}x\\y\end{pmatrix} \to \begin{pmatrix}x+a\\y+b\end{pmatrix}, \quad OP\begin{pmatrix}4\\2\end{pmatrix} \to OP_2\begin{pmatrix}4+-1\\2+-1\end{pmatrix} = \begin{pmatrix}3\\1\end{pmatrix}, \quad \therefore\ P_2\,(3, 1)$$

$$OQ\begin{pmatrix}2\\5\end{pmatrix} \to OQ_2\begin{pmatrix}2+-1\\5+-1\end{pmatrix} = \begin{pmatrix}1\\4\end{pmatrix}, \quad \therefore Q_2\,(1, 4)$$

$$OR\begin{pmatrix}2\\2\end{pmatrix} \to OR_2\begin{pmatrix}2+-1\\2+-1\end{pmatrix} = \begin{pmatrix}1\\1\end{pmatrix}, \quad \therefore\ R_2\,(1, 1)$$

∴ Plot and join $P_2(3, 1)$, $Q_2(1, 4)$ and $R_2(1, 1)$ as the image of triangle PQR under a translation by the vector $\begin{pmatrix}-1\\-1\end{pmatrix}$

APPENDIX F

STUDY CONTRIBUTION: TRAINING GUIDE ON GEOGEBRA

Students were taken through the introduction by Gerritstols manual for GeoGebra. Geometry activities customized from the Ghanaian curriculum are used for practice. Some of the many activities are documented here.

TRAINING GUIDE ON THE USE OF GEOGEBRA IN FORM 2 MATHEMATICS GEOMETRY TOPICS IN THE GHANAIAN CURRICULUM

STEP1. DRAWING BASIC SHAPES

Instruction

Click on the polygon shape and click to draw the shape of the triangle as shown in the figure below.

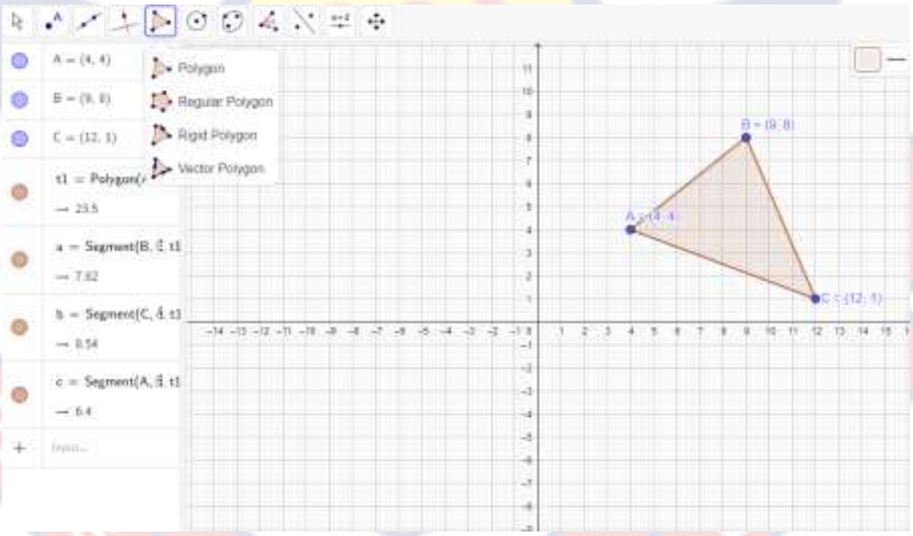


Figure 4: Drawing shapes of triangle

DRAWING A REGULAR POLYGON

Right Click on the polygon tool

Click on Regular Polygon from the drop-down menu

Right-click on the polygon

Click on settings and select the number of sides of the regular

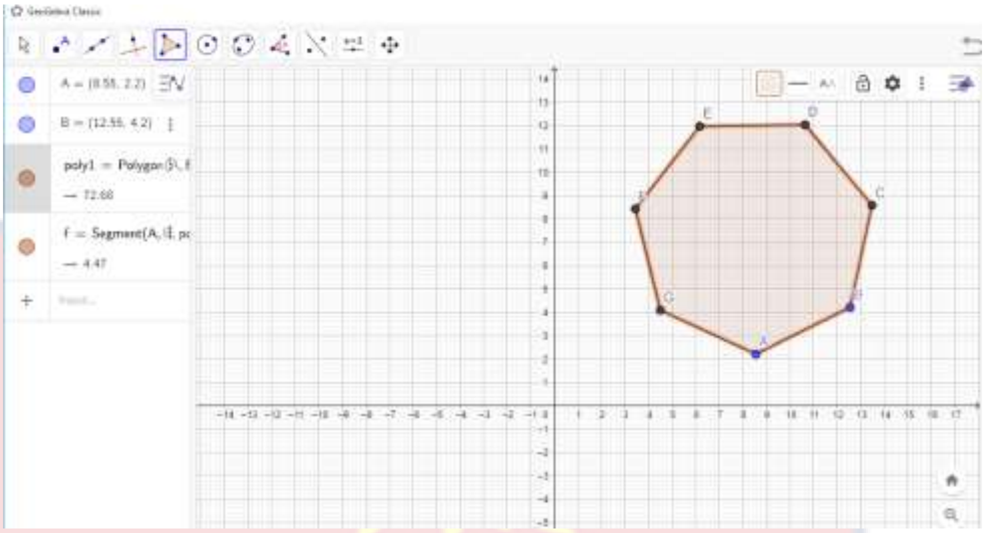


Figure 5: Drawing the shape of a polygon

REFLECTION IN THE X-AXIS

Draw the object using the line tool or the polygon tool

Draw your line of reflection (y=0)

Click on reflect about the line.

Select the object you want to reflect.

Then, click on a mirror line to reflect the object

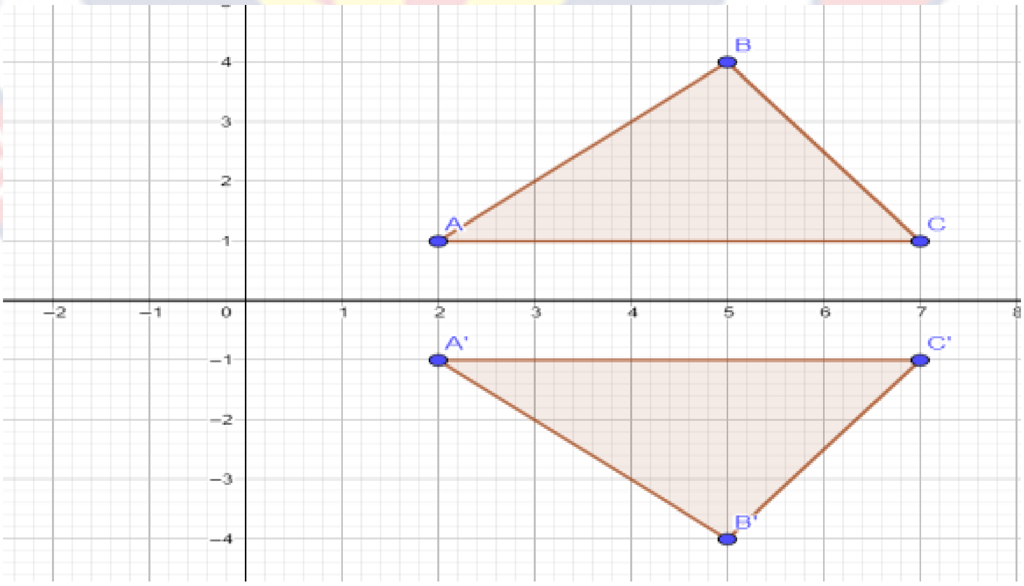


Figure 6: Reflection in the x-axis

Reflection in the y-axis

Draw the object using the line tool or the polygon tool

Draw your line of reflection (x=0)

Click on reflect about the line.

Select the object you want to reflect.

Then, click on a mirror line to reflect the object

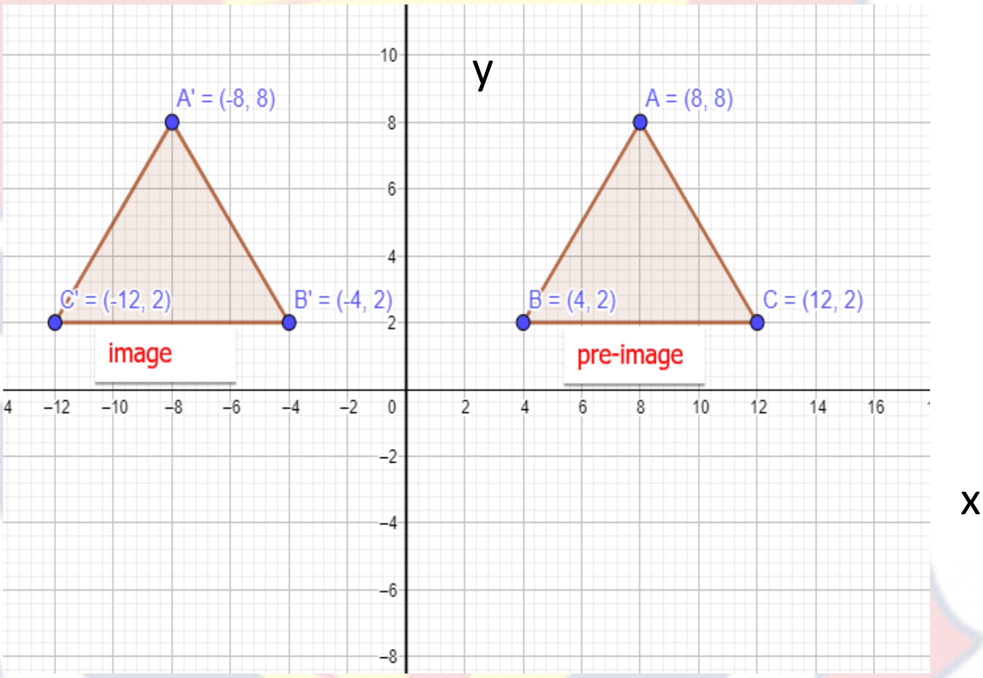


Figure 7: Reflection in the y-axis

ROTATION 90^0 ANTICLOCKWISE ABOUT THE ORIGIN

Draw the preimage by using the polygon tool.

Choose a point and create the center of rotations

Click on the select tool to deselect select

Choose rotate around point on the GeoGebra Menu

Click on the image to rotate

Click on the center of rotation and choose the angle of rotation

Click Ok and the image will be formed as shown on

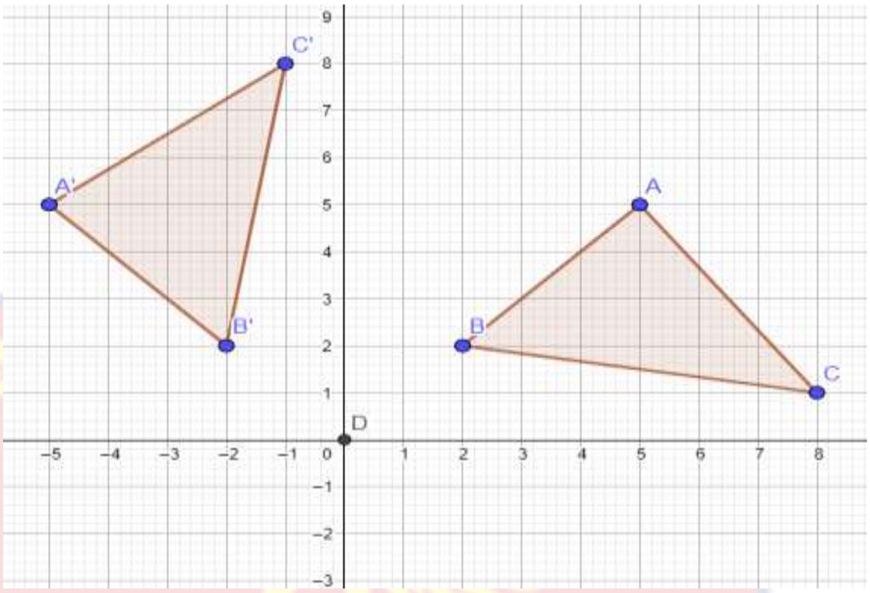


Figure 8: Rotation 90 degrees anticlockwise about the origin

ROTATION 180^{0} ANTICLOCKWISE ABOUT THE ORIGIN

Draw the preimage by using the polygon tool.

Choose a point and create the centre of rotations

Click on the select tool to deselect select

Choose rotate around point on the GeoGebra Menu

Click on the image to rotate

Click on the centre of rotation and choose the angle of rotation

Click Ok and the image will be formed as shown on

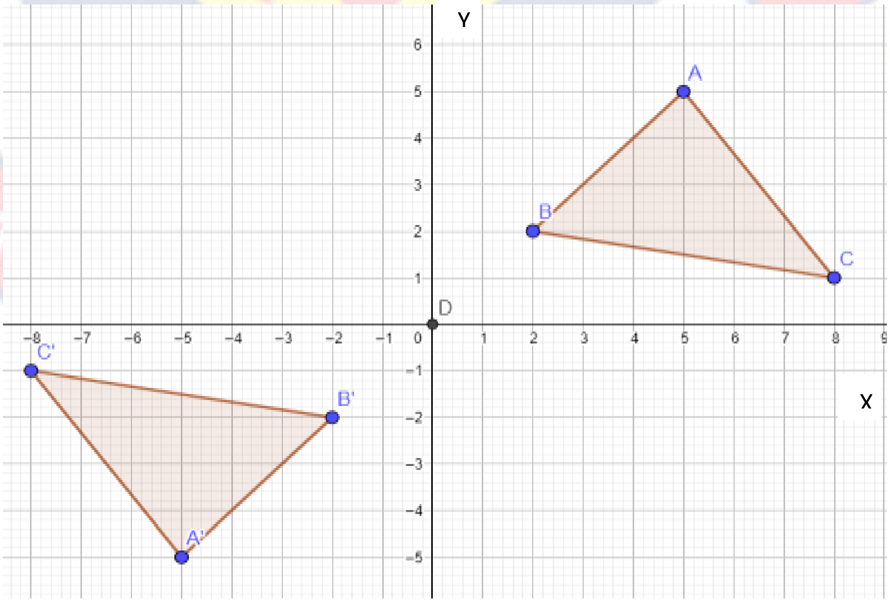


Figure 9: Rotation 180 degrees about the origin

TRANSLATION OF A POINT BY A VECTOR

Draw the object using the polygon tool

Click on the point tool to create a point in the origin (0, 0)

In the input bar type in the coordinates for the translation

Now click on a vector to show the direction of the vector

Click n translate by a vector

Click on the object and click on the vector to translate the object

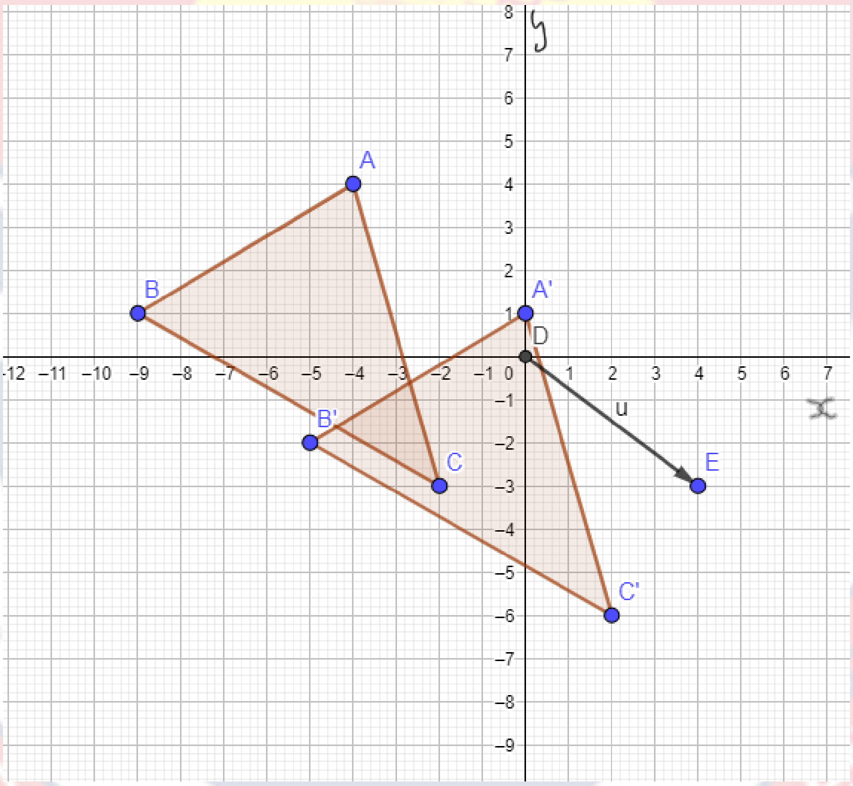
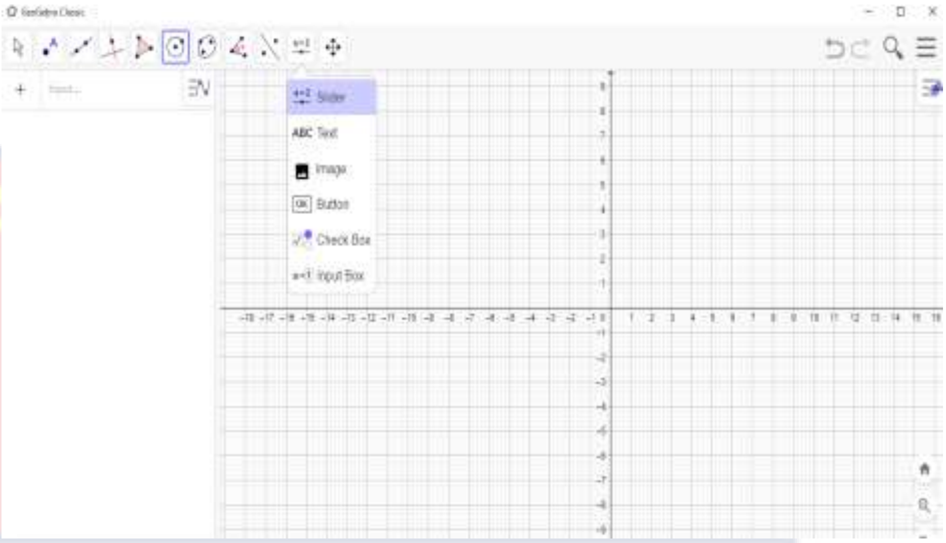
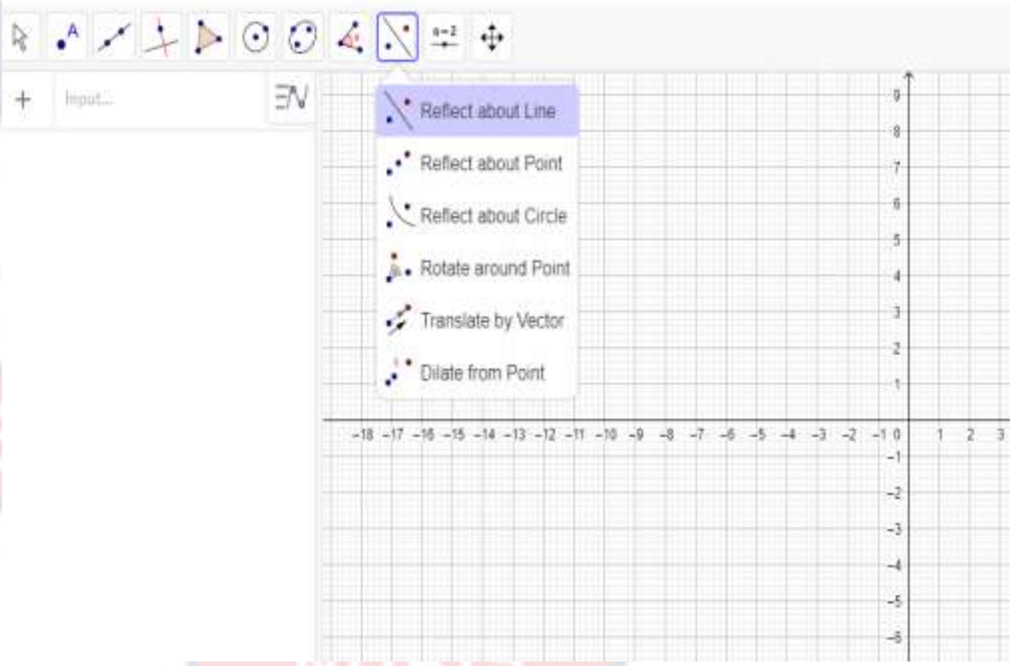


Figure 10: Translation by a Vector

SOME USEFUL FEATURES IN GEOGEBRA GIVE A DROP-DOWN MENU OF ITSFUNCTIONS



GEOGEBRA FORMS OF REFLECTION AND ROTATION



APPENDIX G

PERMISSION TO CONDUCT PILOT STUDY

The headmaster

Crown Prince Junior High School

Accra

Dear Sir

REQUEST FOR PERMISSION TO CONDUCT A PILOT STUDY AT YOURSCHOOL

I am currently a student at the University of Cape Coast, pursuing a Master of Education Degree in Information Technology.

As part of the condition for my studies, I am conducting research titled Effect of GeoGebra on Junior High School Students' Ability to Use Rigid Motion in doing Transformation Geometry.

As part of the research, I need to conduct a written test with your Form 2 Science students. This investigation will not in any way distract the normal teaching and learning at the school as the investigation will only be done immediately after normal school hours. I assure you that all information obtained during the investigationwill be treated confidentially and will only be used for academic purposes.

Thanks for your co-operation

Yours faithfully,

……………….

Collins Mbrah

APPENDIX H

PERMISSION TO CONDUCT RESEARCH STUDY

The headmaster

Sunflower School

P.O. Box 25 Accra

Dear Sir,

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY AT YOURSCHOOL

I am currently a student at the University of Cape Coast pursuing a Master's degree in Education.

As part of the condition for my studies, I am conducting research titled "Effect of using GeoGebra software in teaching and learning Rigid Motion in Junior High School".

As part of the research, I need to conduct an interview and written test with your Form2 Science students. This investigation will not in any way distract the normal teachingand learning at the school as the investigation will only be done immediately after normal school hours. I assure you that all information obtained during the investigationwill be treated confidentially and will only be used for academic purposes.

Thanks for your co-operation

Yours faithfully,

……………….

Collins Mbrah

APPENDIX I

PERMISSION TO CONDUCT RESEARCH STUDY

The headmaster

God's Grace Junior High School

P.O. Box 25 Accra

Dear Sir,

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY AT YOUR SCHOOL

I am currently a student at the University of Cape Coast pursuing a Master's degree in Education.

As part of the condition for my studies, I am conducting research titled "Effect of using GeoGebra software in teaching and learning Rigid Motion in Junior High School".

As part of the research, I need to conduct an interview and written test with your Form2 Science students. This investigation will not in any way distract the normal teachingand learning at the school as the investigation will only be done immediately after normal school hours. I assure you that all information obtained during the investigationwill be treated confidentially and will only be used for academic purposes.

Thanks for your co-operation

Yours faithfully,

……………….

Collins Mbrah

APPENDIX J

PERMISSION TO CONDUCT RESEARCH STUDY

The Headmaster

Saint Theresa's School

P.O. Box 25 Accra

Dear Sir,

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY AT YOUR SCHOOL

I am currently a student at the University of Cape Coast pursuing a Master's degree in Education.

As part of the condition for my studies, I am conducting research titled "Effect of using GeoGebra software in teaching and learning Rigid Motion in Junior High School".

As part of the research, I need to conduct an interview and written test with your Form2 Science students. This investigation will not in any way distract the normal teachingand learning at the school as the investigation will only be done immediately after normal school hours. I assure you that all information obtained during the investigationwill be treated confidentially and will only be used for academic purposes.

Thanks for your co-operation

Yours faithfully,

……………….

Collins Mbrah

SECTION A: STUDENT'S ATTITUDE TOWARDS MATHEMATICS

RESPONSE OF EXPERIMENTAL GROUP BEFORE TREATMENT

Please rank using the following scales

1 = Strongly Disagree 2 = Disagree 3 = Not Sure 4 = Agree 5 = Strongly Agree

CODE	STATEMENT	SCORE				
		1	2	3	4	5
1.	Learning Mathematics with GeoGebra helps me to work independently	0	0	0	23	15
2.	Learning Mathematics with GeoGebra was fun and interactive	3	5	2	28	29
3.	Learning Mathematics with GeoGebra helps me to easily understand Rigid Motion	5	2	0	8	10
4.	Learning Mathematics with GeoGebra was very interactive.	2	0	0	30	12
5.	Assessment response in Learning Mathematics with computer-assisted instruction is quick	3	0	0	20	30
6.	I think CAI made the understanding of Rigid Motion easy for me	0	0	0	35	25
7.	I think GeoGebra made me understand rigid motion better	3	5	2	20	25
8.	I think learning Mathematics supplemented by CAI maintained my attention span throughout the lesson	5	0	0	10	12
9.	I think it is comfortable learning Mathematics with CAI	0	0	0	15	12
10.	Learning Mathematics with CAI allows me to review the lesson at any time even after the lesson	2	0	0	25	30

SECTION B: STUDENT'S ATTITUDE TOWARDS MATHEMATICS RESPONSE OF EXPERIMENTAL GROUP AFTER TREATMENT

Please rank using the following scales

1 = Strongly Disagree 2 = Disagree 3 = Not Sure 4 = Agree 5 = Strongly Agree

CODE	STATEMENT	SCORE				
		1	2	3	4	5
1.	Learning Mathematics with computer-assisted instruction helps me to work independently	0	0	0	40	31
2.	Learning Mathematics with CAI was fun and interactive	0	0	0	40	25
3.	Learning Mathematics with computer-assisted instruction helps me to easily understand	0	0	0	35	30
4.	Learning Mathematics with CAI was very interactive.	0	0	0	30	31
5.	Assessment response in Learning Mathematics with computer-assisted instruction is quick	0	0	1	31	30
6.	I think CAI made the understanding of Rigid Motion easy for me	0	0	0	35	28
7.	I think GeoGebra made me understand rigid motion better	0	0	0	35	25
8.	I think learning Mathematics supplemented by CAI maintained my attention span throughout the lesson	0	0	0	30	28
9.	I think it is comfortable learning Mathematics with CAI	0	0	0	28	28
10.	Learning Mathematics with CAI allows me to review the lesson at any time even after the lesson	0	0	1	30	38