UNIVERSITY OF EDUCATION, WINNEBA

IMPACT OF USING GEOGEBRA SOFTWARE IN TEACHING AND LEARNING RIGID MOTION ON SENIOR HIGH SCHOOL STUDENTS IN GHANA

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DECLARATION

Student's Declaration

I, JAMES TETTEH ASARE hereby declare that except for reference to other people's work which have been duly cited, this thesis is the outcome of my own research work and it has neither in whole nor part been presented elsewhere.

Signature: …………………..………………

Date: ……………………………….……

Supervisor's Declaration

I hereby declare that the presentation of this thesis was supervised in accordance with the guidelines for the supervision of thesis laid down by the University of Education, Winneba.

Supervisor's Name: Professor D.K. Mereku

Signature: …………………..………………

Date: ……………………………….……

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DEDICATION

This work is dedicated to my daughter Lilian Asare, son Prosper Asare and my wife Patience Elinam who have eagerly waited for this achievement.

ACKNOWLEDGEMENT

I wish to express my sincerest gratitude to my supervisor Professor D.K. Mereku without whose support this study could not have been carried to completion. His constructive criticism and encouragement kept me going.

I thank the Headmaster of New Juaben Senior High school, Mr. Wilson for permitting me to conduct the research in the school.

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 giving me wisdom and knowledge to complete this work successfully.

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ABSTRACT

GeoGebra is a free computer application software that provides an algebra view, geometry view, spreadsheet view and an input bar. This study looked at if this instructional tool can be used to enhance the teaching and learning of rigid motion in senior high schools in Ghana. The objectives of this study were to assess the applicability of GeoGebra in the teaching and learning of mathematics in secondary schools in Ghana. The difference in performance of students when taught using the traditional method and when taught with the help of this innovation was the main objective of the study. However, the students' problem in answering rigid motion questions and their views about the use of the innovation was also assessed before and after the intervention respectively. The design adopted for this study was a mixed methods design of qualitative and quantitative approaches. The instruments for data collection were test items and interview. The independent variable in this study was the uptake of technology in this case GeoGebra in the teaching of mathematics, while dependent variable is the achievement of students in rigid motion. The population was the students in the New Juaben Senior High School. The data obtained was analyzed with the help of descriptive and inferential statistics for the uptake of technology. The study found out that uptake of technology was slow at the early adopter's stage of adoption among mathematics teachers. Further, there was a clear indication that GeoGebra would help improve the students' understanding of concepts in mathematics and hence improve performance. The study concludes that GeoGebra is useful in improving performance of secondary school students in rigid motion if teachers are well trained using the guides indicated in this study. It also developed a prototype GeoGebra manual for Ghanaian mathematics teachers using GeoGebra. The study recommends that GeoGebra be used in teaching and learning of rigid motion in Ghanaian secondary schools. The findings of this study will be useful to scholars of Mathematics Education, Mathematics teachers, students and the schools administration.

CHAPTER ONE

INTRODUCTION

1.0 Overview

This chapter is an introductory section of the study. It presents the general background to the study, statement of the problem, purpose of the study, research questions, significant of the study, scope and delimitation and organization of the study.

1.1 Background to the Study

Currently, students' interest to study mathematics and ability in mathematics is declining. The mass failure in mathematics examinations is real and the trend of student's performance has been on the decline (Adolphus, 2011). This has also been confirmed by WAEC chief examiner's report on the league of WASSCE (May-June) results in core mathematics from 2011 to 2015 as shown in Table 1.

Table 1 May-June core mathematics results of WASSCE (2011-2015)

YEAR	2011	2012	2013	2014	2015
Number of candidates	65,005	77,882	149,612	77,884	64,268
Percentage passed	43.8	49.4	36.6	32.4	24.0

Mathematics educators have put in effort aimed at identifying the major problems associated with secondary school mathematics. Despite the noble efforts put in by mathematics educators to identify the major problems associated with secondary school mathematics, the problem of poor achievement in mathematics has continued to rear its head (Adolphus, 2011).

Mathematics is one of the important subjects that constitute the core curriculum in most countries throughout the world. The subject occupies a privileged position in the school curriculum since the ability to cope with it improves one's chances of social advancement. According to Adolphus (2011) the place of mathematics in the life of any nation cannot be overemphasized because it is linked with the place of development in the nation.

In Ghana, students are admitted into the tertiary institution based on their performance in the West Africa Secondary School Certificate Examination (WASSCE.). A student who wants to enter into the tertiary institution must obtain at least grade "C6" or better in Mathematics among other subjects in the WASSCE. A pass in mathematics in the Senior Secondary School Certificate Examination (SSSCE) or the West African Senior Secondary Certificate Examination (WASSCE) is a basic requirement for admission into the tertiary institutions in Ghana. This is required irrespective of the program of study the student wishes to pursue. Hence the study of mathematics in Ghanaian schools. This implies that students who lack mathematical competence will find many doors leading to a productive as well as successful future closed. Therefore, Mathematics acts as a critical filter denying or giving access to many students to continue their education at the tertiary institutions, hence it must be of national interest.

The secondary school educational policy in Ghana entails six years secondary school study. Thus, three years Junior High and three years Senior High. During this period, students are required at the third year of study to sit for an external examination. At both phases of learning, mathematics is one of the examinable subjects and it is compulsory for all third-year students. At both levels of study the mathematics syllabus includes Geometry. However, indication emanating from the report compiled by the chief examiner of the West Africa Examination Council (West Africa Examination Council, 2011, 2012, 2014 and 2015) revealed that students' performance in geometry in the West Africa Secondary School Certificate Examination (WASSCE) was very poor. This evidence leaves much to be desired. The report pointed to the fact that students lack the understanding of basic concepts of plane geometry which in turn affects their ability to find unknown angles. Hence, their poor performance.

Students' poor performance in mathematics may be linked to the phenomenon of mathematics anxiety. Mathematics anxiety is the feeling of helplessness in an individual in relation to doing mathematics (Uusimaki & Nason, 2004). This anxiety may occur in both teachers and learners. Teachers may lack confidence in their own abilities of suffered mathematics anxiety during their in-service training.

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 senior high school 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. Also, this approach to teaching and learning Geometry lay more emphasis on how much a student can remember and less on how well the student can think and reason, and it makes the teacher dominate the classroom and turns students to mere listeners (Mereku, 2010). The method used in teaching by teachers is very necessary as this affects the interest of students in the subject. Supporting this, Emaikwu (2012) reported that teaching method affects the response of students and determines whether they are interested, motivated and involved in a lesson in such a way as to engage in learning. This study sought to intervene, and investigate how technologically oriented teaching methods could improve student achievement.

The factors that are responsible for students' performance and achievement in mathematics are teacher factor, student factor and environmental factor. The teacher factors includes subject mastery, instructional techniques and strategies, classroom management, communication skills, and personality. The student factor comprised of study habits, time management, attitude and interest in mathematics; the environmental factor includes issues such as parents' values and attitudes, classroom settings, and peer group. This study sought to explore the extent to which technology-inspired instructional techniques and strategies impact on student achievement in mathematics. The factors that influence students' attitudes towards Mathematics are the teaching materials used by teachers, classroom management, teacher content knowledge and personality, relating the topics with real life situation (Yilmaz Altun & Olkun, 2010)

A number of technology tools are available such as interactive whiteboards, calculators, Geometers Sketchpad and GeoGebra. However, this study will discuss in detail the use of GeoGebra software to conduct learning of rigid motion in mathematics. The effect of technology usage in Mathematics classrooms on students' performance has drawn the attention of Mathematics educators to the need to utilize technological software in Mathematics classrooms. In view of this, the Mathematics Association of Ghana (MAG) has made a remarkable step towards the use of ICT in the teaching and learning of Mathematics which will be an effective tool for social transformation (Suleman, 2012). The Association is of the view that teaching and learning Mathematics with technology will aid students to visualize, think, reason, analyse and articulate logically. The use of the computer makes it suitable for teachers to design lessons which make learners become more interested and eager to study and enjoy Mathematics (Suleman, 2012).

Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances student's learning (NCTM, 2000). Furthermore, confirmation from Bos (2009) show that teachers who make use of educational technology comprehensively in their Mathematics instruction environment do build high confidence in pedagogical technology skills and focus their lessons on a student-centred approach which turn to improves students' performance in Mathematics. Previous researches proved that use of ICT in teaching will enhance the learning process and maximizes the students' abilities in active learning (Finger & Trinidad, 2002; Jorge, C. M. H., Gutiérrez, E. R., García, E.G., Jorge M. C. A., & Díaz, M. B., 2003; Young, 2003; Jamieson-Proctor, R., Albion, P., Finger, G., Cavanagh, R., Fitzgerald, R., Bond, T., & Grimbeek, P., 2013).

In this rapidly changing environment, education should change as quickly as the technology does. According to Fluck (2010), the future of Information, Communication and Technology (ICT) should play as a transformation role in education rather than integration into existing subject areas. The transformative view of ICT in education requires us to examine what new ways of pedagogies and curriculum are appropriate for a new generation working with new tools

The traditional talk-and-chalk teacher-centred type of teaching, which assumes that students are passive recipients of knowledge, has lost its lustre among technologically savvy youths (Chimuka, 2017). It is one's belief that the integration of information technology (IT), GeoGebra in particular, into the teaching and learning of secondary school mathematics can serve as a scaffold on which changes and developments in curriculum can be better managed (Mwingirwa, 2012). Many research studies showed that Information and Communication Technology (ICT) is useful as a supportive tool in the teaching and learning environment. In the mathematics classroom setting, the use of ICT can motivate students and teachers to perform better in calculations, analyses of data, exploration of mathematical ideas and concepts and the association of these ideas and concepts with real life examples, thus resulting in permanent and effective learning in mathematics and further mathematics achievement (Saha, Ayub & Tarmizi, 2010; Yemen, 2009).

In this study, the researcher looked specifically at the mathematical content of rigid motion in the Senior High School syllabus and experimentally explored the effect of integrating GeoGebra in teaching the topic on Senior High School students' achievement. The intention was to investigate whether it is worthwhile to integrate GeoGebra into the teaching and learning process in order to narrow the instructional and knowledge gap, seemingly created by the teacher factor (teaching aids).

Rigid motion of the plane is a motion which preserve distance. This consists of translation, reflection, and rotation. Rigid motions (translation, reflection, and rotation) preserve the distance between vertices of any polygon. Thus, rigid motions are transformations that create congruent figures. In contrast, dilations do not preserve distance and thus it creates similar figures. The idea that all points in the plane move can be shown using technology; thus, students are able to see that there is a direct relationship between transformations and the distance from the segments and the points that make up the line of reflection point of rotation or direction of transformation of figure being transformed (Hollebrands, 2004).

1.2 Statement of the problem

Research indicates that students have difficulties in understanding the concepts and variations in performing transformations (Akay, 2011; Yazlık, 2011; Ada & Kurtulus, 2010; Acquah & Alhassan, 2018; Gürbüz, 2008; Zenigami & Okzaki, 2008; Rollick, 2009). Given recommendations from mathematics educator and researchers about the importance of geometry in mathematics, we might expect to observe the teaching of the concepts being taken serious in the senior high schools. However, in Ghana, senior high school students are faced with varieties of difficulties relating to geometry and for that matter rigid motion of transformation geometry hence their performance in the topic continue to decline (WAEC, 2012). There are many possible reasons for this, which the traditional talk-and-chalk teacher-centred type of teaching, which assumes that students are passive recipients of knowledge is not in exception (Chimuka, 2017). The traditional method of teaching makes the teacher dominate the classroom and turns students to mere listeners (Mereku, 2010) and (Emaikwu, 2012).

Many research studies showed that Information and Communication Technology (ICT) is useful as a supportive tool in the teaching and learning environment. It is the researcher's belief that the integration of information technology (IT), GeoGebra in particular, into the teaching and learning of geometry and for that matter rigid moton in the senior high school mathematics can serve as a scaffold on which changes and developments in curriculum can be better managed to enhance students' performance.

The study focused the “Impact Of Geogebra On Senior High School Students’ Ability To Use Rigid Motion In Doing Transformation Geometry”. The study was motivated by the West Africa Examinations Council (WAEC) chief examiners reports of 2011, 2012, 2014, and 2015 which revealed that students’ performance in geometry in the West Africa Secondary School Certificate Examination (WASSCE) was very poor as compared to other areas of mathematics.

1.3 Purpose of the study

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 West Africa Secondary School Certificate Examination (WASSCE) 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 student’s performance (Ada & Kurtulus, 2010). Also GeoGebra can provide a frame work on which geometry instructions can be structured and taught in schools (Ada & Kurtulus, 2010). However, this claim has not been comprehensively investigated in Ghana. Hence it deserves some exploration and investigation with students. The purpose of this study is to find out if the use of GeoGebra as an instructional tool will have any effect on students’ achievement in rigid motion of transformation geometry.

1.4 Objectives of the study

The research objectives in this regard are as follows:

- Find out the difficulties Senior High School student have in solving rigid motion questions.

- Find out the effect of teaching rigid motion using GeoGebra on SHS students' achievement?
- To find out the view of students about GeoGebra in the learning of rigid motion.

1.5 Research questions

The above purpose were realized by pursuing answers to the following

1. What difficulties do students have in solving rigid motion questions?
2. What is the effect of teaching rigid motion using GeoGebra on SHS students' achievement?
3. What are the views of students about using GeoGebra in learning rigid motion?

1.6 Significance of the study

Improving mathematics results in secondary schools in Ghana is a contemporary problem to which practical solutions are yet to be found. Ghanaian students have over the years experienced varieties of difficulties in the learning of transformation geometry. This study has sought to contribute in this regard by exploring alternative teaching and learning methods, especially for topics traditionally regarded as problematic to both teachers and students, such as rigid motion.

Geometry is a key mathematics component that is required in all applied physical sciences; its understanding through the use of technology, helps students to develop insights into an understanding of today's technological world. Teaching and learning methods that incorporate technology are important to developing countries like Ghana, in order to catch up with the rest of the developed world.

The significant of the study is as follows:

- It will introduce Senior High students to the usefulness and impact of technology (GeoGebra software) on the teaching and learning of rigid motion. . This will go a long way to provide useful information for teachers, school administrator and curriculum developers on how to ease teacher' difficulties in the teaching of transformation geometry in the classroom by using mathematical software to simplify the teaching and learning processes .
- It will add to the list of existing literature on the usefulness of technology in teaching mathematics, especially in the Ghanaian context.
- It will serve as a means of assessment of the technology integration in educational practices which is necessary in 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 National Education Ministry and to teacher educators in training mathematics teachers.

1.7 Delimitation of the study

Delimitations describe the scope of the study or establish parameters or limits for the study. Geometry and for that matter transformation geometry have many aspects but the study was delimited to only rigid motion. Again, there are many software of teaching mathematics but the study was delimited to the GeoGebra software. Lastly, there many Senior High Schools in the New Juaben Municipal in the Eastern Region of Ghana but the population of the study was derived from students in New Juaben Senior High School.

1.8 Layout of the study

Chapter one

The background to the research problems and the research statement are discussed in this chapter. The purpose of the study, the research questions and the significance of the study are also highlighted.

Chapter two

This chapter reviews the relevant literature on geometry and transformation geometry with special focus on how students learn geometry and the difficulties they have during learning.

Chapter three

This chapter provides a detailed description and explanation of the research design, the research instruments and how these instruments were developed. Descriptions of the population sample, how the research instruments were administered, the validity and reliability of these instruments and steps taken to analyze both the written test and interview were discussed in this chapter.

Chapter four

This chapter focused on the analysis and interpretation of data obtained from both the written test and the interview administered to students.

Chapter five

A presentation of the summary of findings and recommendations of the study are unveiled in this chapter.

CHAPTER TWO

LITERETURE REVIEW

2.0 Overview

This chapter reviewed the literature of the study that investigated the impact of integration of GeoGebra software on Senior High School students' mathematical attainment on rigid motion of transformation geometry. The theoretical and conceptual framework of the study is discussed in Section 2.1 and 2.2 respectively. The literature on technology in teaching and learning of mathematics is discussed in Section 2.3. What geometry and transformation geometry entails is discussed in Section 2.4 and 2.5 discussed research related to transformation geometry. Research related to the effect of GeoGebra on mathematics is discussed in section 2.6 and 2.7 summarized the chapter.

2.1 Theoretical Framework

Technology acceptance depends on how it is perceived, how the participants create and share the information with one another, the period and how conducive the environment is. Hence, this study was guided by Diffusion Innovation Model (DIM) adopted by Rogers. Diffusion is the process by which an innovation is communicated through a certain channel over time among the members of social systems (Rogers, 1995). DIM is a theory that seeks to explain how, why, and at what rate new ideas and technology spread through cultures. It explains four main elements that influence the spread of a new idea. These elements include; Innovation, Communication channel, Time and Social system.

2.1.1 Innovation

"An innovation is an idea, practice, or project that is perceived as new by an individual or other unit of adoption" (Rogers, 2003). An innovation may have been discovered a long time ago, but if individuals perceive it as new, then it may still be an innovation for them. According to Rogers (2003), an innovation is without consequences hence there is the need for individuals to know about its advantages and disadvantages to make them aware of all its consequences.

2.1.2 Communication channels

The second element of the diffusion of innovations process is communication channels. For Rogers (2003), communication is “a process in which participants create and share information with one another in order to reach a mutual understanding” (p. 5). Rogers states that “a source is an individual or an institution that originates a message. A channel is the means by which a message gets from the source to the receiver” (p. 204).

Diffusion is a very social process that involves interpersonal communication relationships” (Rogers, 2003, p. 19). This means that, interpersonal channels are more powerful which can easily create or change strong attitudes held by an individual

2.1.3 Time

According to Rogers (2003), attention is not given to time aspect most behavioral research. He argues that including the time dimension in diffusion research illustrates one of its strengths. The innovation-diffusion process, adopter categorization, and rate of adoptions all include a time dimension.

2.1.4 Social systems

The social system is the last element in the diffusion process. Rogers (2003) defined the social system as “a set of interrelated units engaged in joint problem solving to accomplish a common goal” (p. 23). Diffusion of innovations takes place in the social system, hence it is influenced by the social structure of the social system. Rogers

(2003), claimed that structure is “the patterned arrangements of the units in a system” (p. 24).

The diffusion process determines the success or failure of any new product in the market. The theory notes the part played by attitude of people when it comes to adapting to new technology. Rogers theory advocates that innovations diffusion is a process that takes time to occur and that it takes place in five stages. The five stages are:

2.1.5 Knowledge

According to Roger’s model the knowledge about the new technology is very important. In this study the knowledge of the students and teachers about ICT is important. The knowledge is found through the teachers and students being introduced to resources like computers, internet, relevant computer software, availing a conducive computer laboratory, having a technician in the school and the teachers being qualified in computer use.

2.1.6 Persuasion and decision

Persuasion is important as it gives rise to the willingness to attend to the innovation. The teachers and students will now be able to attend selectively to various aspects of the context within the innovation. Both the teachers and the students will require an active participation rather that listening or attending. More complete, responding would be indicated by students willing to engage in various activities involving ICT. In this study it involved teachers being able to use computers in the teaching process. The students should be involved in the use of computer programs, internet and participation in computer practice. The constraints that affect these activities were investigated.

2.1.7 Implementing and confirming

At the implementing level, teachers and students judge an activity as to its worthiness and tend to do so consistently enough so that the pattern is recognized and is acceptable to others. After becoming convinced of the validity of the activity, the student expresses commitment to the activity. At the confirmation stage, ideas are internalized and become increasingly interrelated and prioritized. The students and teachers become organized into a value system. The valued ideas are arranged to foster their consistency.

Diffusion Innovation Model states that the five main factors that influence an individual's decision to adopt or reject an innovation include:

i. Relative advantage- this refers to how improved an innovation is over the previous methods. This is applicable to this study as the researcher will be interested in finding out how the teaching using GeoGebra compares to teaching using the pen paper methods of teaching geometry in secondary school mathematics.

ii. Compatibility- this refers to the level of compatibility that an innovation has to be assimilated into an individual's life. This is in line with the third research objective that seeks to establish activities in GeoGebra that can be used to aid the teaching of areas perceived to be difficult to teach.

iii. Complexity or simplicity- this deals with how complicated or difficult it is to use. This further determines how willing the individuals will be to use the invention.

iv. Trialability- this refers to how easily an innovation may be experimented. Also, trialability is positively correlated with the rate of adoption. The more an innovation is tried, the faster its adoption is.

v. Observability- this is the extent that an innovation is available and visible to the users. A less complicated innovation is more likely to be adopted.

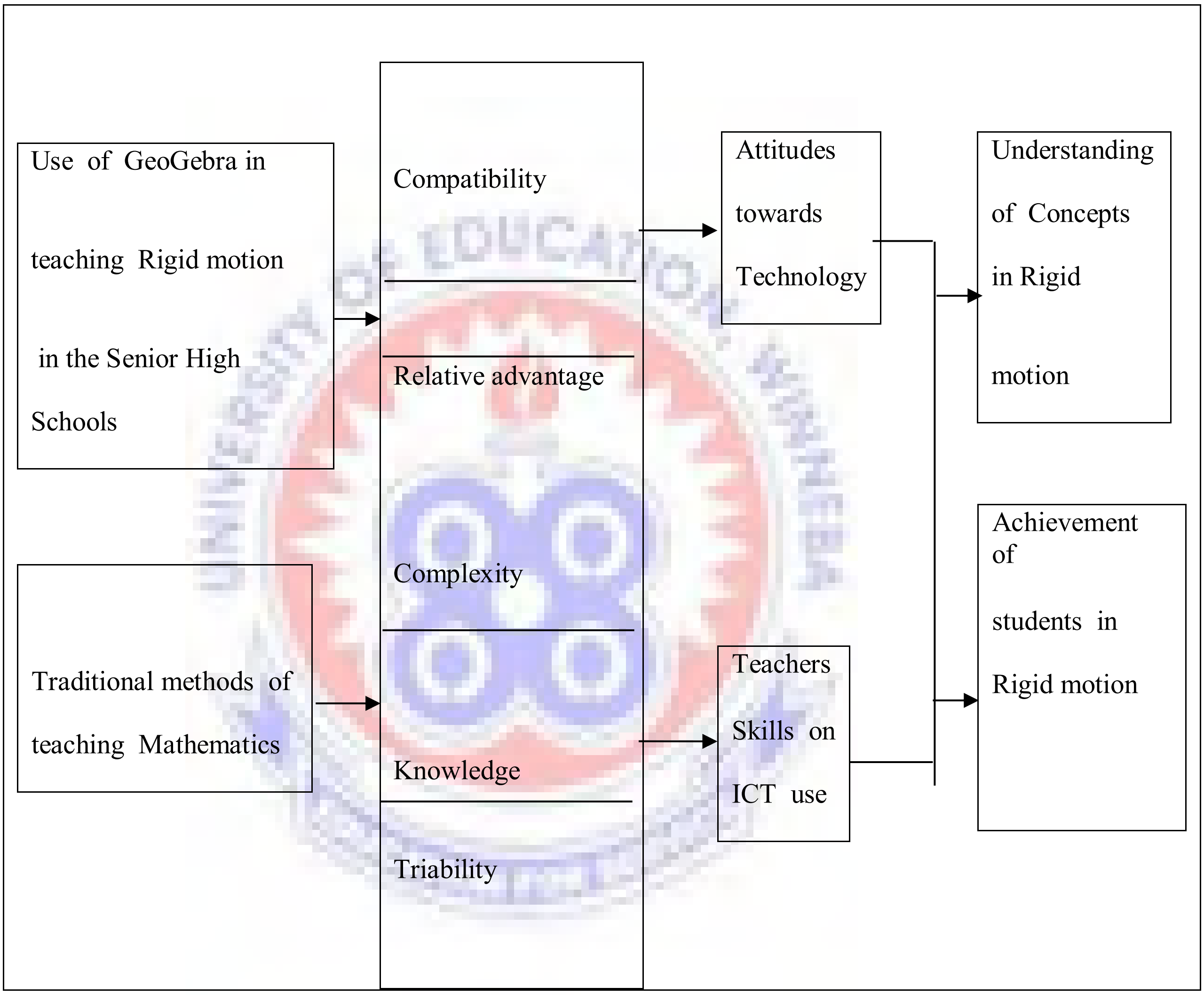
vi. GeoGebra, which is a recent innovation, was investigated by this study. The study assessed the applicability of Diffusion Model in the Ghana senior high school mathematics curriculum. The study tried to establish if this application was in line with the Rogers model of implementing technology. The study compared the performance of students using the computer app (GeoGebra) and their performance using the traditional method of teaching.

2.2 Conceptual Framework

The use of new computer application is influenced by some intervening factors such as compatibility, complexity, trailability, social factors and most important the relative advantage of the innovation. The perception that technology is either easy or difficult to adopt depends on compatibility and complexity. The interaction of these factors will influence the decision of whether to use or not to use the resource.

Whether students would understand the concept of rigid motion to enhance their achievement depends on their attitude towards the technology (GeoGebra software) and the teachers' skills use in ICT. For learning to take place, students need to be actively engaged with the explored concepts or objects – whether abstract or concrete (Liang & Sedig, 2010). According to Engel & Green (2011), Technology is used appropriately when it is an active, integral part of the mathematical teaching process.

The contention of this study in using ICT (GeoGebra) to enhance the teaching and learning of mathematics was that these technologies might impact on learning leading to improved understanding. This study tried to intervene by introducing GeoGebra to enhance students' rigid motion achievement.



(Source: Researcher's consolidated ideas from DIM, and variables of the study)

Figure 1: Conceptualized Framework of the Study.

2.3 Technology in teaching and learning of mathematics

The formidable problem currently facing mathematics education in Ghana is the need to improve the students' performance in mathematics. Mathematics is acknowledged by most people as essential and useful (Khatoon & Mahmood, 2011). Its usefulness ranges from social, aesthetic, utility, and communication. Mathematics acts as a pivot in providing a means of studying other disciplines such as sciences, technology, geography and economics. Mathematics provides a basic relevant skill in studying other subjects without which we may have problems (Khatoon & Mahmood, 2011). Almost all of mathematics syllabi clearly states that a mathematics course is designed to enable the learners acquire attitudes and knowledge that will be relevant to his or her life after school. It also aims at fostering a positive attitude towards appreciating the usefulness and relevance of mathematics to a modern society. Great emphasis is placed on the application to real life situation and practical approaches to the teaching and learning of the subject, a fact which can be seen from mathematics books in primary schools and secondary schools (Mwingirwa, 2012). Mathematics has been pointed as a subject area that demands practice, if the objectives of teaching the subject are to be achieved. Mathematics does not examines only what a student knows but also how fast and accurately the student can express it without making errors, hence the reason why mathematics examinations are strictly timed.

One of the major goals in mathematics education is to ensure the success of all students in understanding the subject matter. Mathematics is seen as one of the challenging and problematic subjects in the education. Never the less, it is one of the most important areas of science, given that mathematical skills and knowledge are important in everyday activity, and there are also many mathematical applications in other subjects and sciences. Hence, mathematics is a subject which should be taken seriously. Teachers should focus on fostering the students' understanding of mathematical concepts and they should provide a quality education environment for them. Many students find it difficult to engage with mathematical concepts. For learning to take place, students need to be actively engaged with the explored concepts or objects – whether abstract or concrete (Liang & Sedig, 2010).

We live in a technology-driven world. Technology is everywhere around us: billboards, grocery stores and in the palms of our hands. Research study has proved that when teachers integrate technology appropriately into the learning process, student motivation and student achievement levels increased (Engel & Green, 2011). Technology is used appropriately when it is an active, integral part of the mathematical teaching process.

The use of technology in the classrooms in today's world is believed to have a positive effect on students' success and their attitudes towards mathematics lessons (Ramadan & Hüseyin, 2014). In a mathematics classroom, the strategic use of technology strengthens mathematics teaching and learning (Dick & Hollebrands, 2011). Findings from a number of studies have shown that the strategic use of technological tools can support both the learning of mathematical procedures and skills as well as the development of advanced mathematical proficiencies, such as problem solving, reasoning, and justifying (e.g., Gadanidis & Geiger, 2010; Nelson, Christopher, & Mims, 2009; Pierce & Stacey, 2010; Roschelle, et al., 2009, 2010; Suh & Moyer, 2007). Integrating ICT into our everyday teaching and learning can provide creative opportunities for supporting students' learning and fostering the acquisition of mathematical knowledge and skills (Hohenwarter & Hohenwarter, 2009).

According to the National Council of Teachers of Mathematics (NCTM, 2011), it is essential that teachers and students have regular access to technologies that support and advance mathematical sense making, reasoning, problem solving, and communication. Yanik and Porter (2009) argue that the integration of technology in teaching and learning of mathematics “has increased incredibly and gained recognition and acceptance as an instructional tool in school mathematics both at the elementary and at the secondary level” (p. 3). The integration of ICT is an essential agenda of the government of Ghana to raise standards in schools and promote teachers’ and students’ access, skills and knowledge to new technologies. The application of ICT in education is one of primary concerns for educators all over the world. This increase in use also brought drastic changes to the type of technologies used in mathematics education. Overhead projection technology has changed from slide projectors or overhead projectors (which are still in use) to data projectors, video machines and digital video disc (DVD) players. The internet also gives students and teachers online learning material. The use of technology generally has been an integral part of the teaching of Mathematics for decades, but not in every classroom. However, initially it has been for a minority of well-resourced elite schools. Today more teachers and students have access to computers, interactive whiteboards, and the internet, and more educational software packages have become available. Technology is here to stay and Mathematics teachers need to make effective use of technology in their teaching. Today in most developed and developing countries technology is being used extensively in classrooms (Ramadan & Hüseyin, 2014).

Many studies have shown the advantages of using technology in classroom instruction. Technology can be used as a tool for establishing meaningful projects to engage students in critical thinking and problem solving. Technology can be used to restructure and redesign the classroom to produce an environment that promotes the development of higher-order thinking skills (Kurt, 2010). Technology also increases student collaboration. Collaboration is a highly effective tool for learning. Students cooperatively works together to either create projects or they can learn from each other by reading the work of their peers (Keser, Huseyin, & Ozdamli, 2012).

A study by MacBride and Luehmann (2011) gives another aspect of incorporating technology in the mathematics classroom. A high school mathematics teacher integrated an online blog for his Pre-Calculus class. Each day a student was responsible for uploading a blog post about that day's class activities. Students were required to respond to each other's posts. Because the blog was mostly maintained by students, the only posts the teacher wrote were concerning online resources for remediation and enrichment. For this class, the blog served as a means of reflection – the new age journal (MacBride & Luehmann, 2011). MacBride and Luehmann reported that the students were happy to see how other students responded to their blog posts.

Shirley and colleagues (2011) conducted a research study on the implementation of Connected Classroom Technology. This technology allows students' work to be projected on a classroom monitor through their calculators. The researchers followed 7 teachers during the school year. The teachers received the necessary equipment to implement Connected Classroom Technology in their classrooms. The researchers conducted interviews with the teachers via telephone periodically throughout the school year. They also scheduled classroom observations. The teachers reported they were able to monitor students' work, give feedback in a quicker time span, and make sure each student was on task (Shirley et al., 2011). Because of this benefit of the technology, they noticed more student participation and an increase in student achievement. Teachers could immediately see if a student was misunderstanding a concept because of the use of CCT in the classroom. Remediation and re-teaching happened immediately to get students back on track in the lesson (Shirley et al., 2011). This allows students to see their mistakes and how to fix them as soon as they make them. In classrooms where CCT was used, students tended to score higher on given assessments because of its benefits.

A study was conducted to examine the experiences of pre-service teachers implementing technology in math lessons. The study shows a positive effect on student learning in mathematics. The pre-service teachers noted that the internet provided math activities at different levels, which gave students an opportunity to choose the level they are comfortable working. Findings showed that students were engaged during the math lessons using technology and students were able to discuss what they learned the following day. The teachers were surprised by the students' recall of the lesson. Some students who participated in the lessons believed that the computer helped them understand what the teacher was saying about the lesson. Technology can be used as a way to create a hands-on and meaningful math lesson (Herron, 2010).

Another study found that integrating technology and peer-led discussions of literature can produce increased student engagement and motivation. Technology used in these small group discussions of literature includes wikis, online literature circles, and online book clubs. With these technologies, students were able to connect with readers from other schools, states, and even other countries. This type of technology is an assessable and motivational way to expose students to other ideas and cultures. These online literature discussions have the ability to create a sense of community and foster positive social interaction (Coffey, 2012).

Improvement of student performance in mathematics is largely determined by how effective their teachers are in delivering content to them. Martinovic and Manizade (2013) believe that technology should be used as a partner in the geometry classroom. To support their claim, these authors presented technology-based geometric activities to pre-service teachers, with the aim of promoting pre-service teachers' mathematical reasoning. They found positive results in which these teachers were able to explore carefully structured activities and engage technological skills that enabled them to develop and evaluate geometric conjectures. The study recognized technology as an important part of developing pre-service teachers' professional integrity.

Many studies have also focused on the use or integration of dynamic geometry systems (DGS) in the teaching of specific mathematical topics. Strausova and Hasek (2013) investigated dynamic visual proofs using DGS. Their view is that pictures and diagrams play an important role in the process of understanding various mathematical features, and that an appropriate picture or diagram can be used as visual proof of a geometric property or theorem. They argue that non-verbal proofs (proofs without words) are more attractive and acceptable to students than classical proofs. They presented examples of dynamic visual proofs created by dynamic geometry software to secondary school mathematics teachers and students. However, they do acknowledge the weakness of dynamic visual proofs using DGS because in general they do not capture the chain of thought leading to the proof, but focus only on the result.

Karaibryamov, Tsareva and Zlanatov (2012) carried out a study on optimization of courses in geometry by using DGS known as 'Sam' (mathematical software). In this study, a new approach to the teaching of synthetic geometry in schools and universities with the help of DGS was used. Their aim was to optimize the teaching process. They reported that their new approach increased the benefits of DGS in the teaching and learning of geometry, especially optimising the education process by saving time involved in drawing, generalizing large groups of problems, and stimulating and helping investigations.

Foster and Shah (2015) explored the process of game-based learning in the classroom through the use of the play, curricular activity, reflection, discussion (PCaRD) model. They carried out a mixed-methods study at high school with control and experimental groups, where they implemented three games with the PCaRD model for a period of one year. Pre- and post-assessments were administered in order to measure achievement gains and motivational changes. Their results indicate that PCaRD aided student learning, and motivated them to learn. They also claimed that PCaRD provided teachers with an adaptive structure of integrating games with their teaching process.

Among many scholars who have investigated the effectiveness of mathematical software is Ertekin (2014). His study sought to investigate the effects of teaching analytical geometry using the software Cabri 3D on teacher trainees' ability to write the equation of a given special plane, identify the normal vector of a plane and draw the graph of the plane. The software was used with the intention to improve the trainee teachers' geometric and algebraic competences. The results of this study indicated that students instructed with the software were significantly more successful than those who did not use it, in terms of identifying the equations of special planes and their normal vectors and drawing their graphs.

Swallows (2015), in a case study report titled: 'The year-two decline: Exploring the incremental experiences of a 1:1 technology initiative', reported that 1:1 (one-to-one) technology initiatives result in favourable results in the first year, but in subsequent years results decline. This case study's finding suggests that enthusiasm for the use of technology declines over time, resulting in diminishing favorable outcomes with its continued use.

Perjesi-Hamori (2015) based on her experiences in teaching numerical methods to university students and, using the computer algebraic system (CAS) called Maple, argued that the use of CAS Maple enabled students with limited mathematical skills to understand more complex tasks, such as solutions of multivariate interpolations and regressions, or those of partial differential equations. This study is another success story of technology integration with the teaching of mathematics. A similar study by McAndrew (2015) used CAS calculators to teach and explore numerical methods to third-year pre-service teachers. It was shown from the study that CAS calculators, although very low-powered compared to standard computer-based numerical systems, are also quite capable of handling textbook problems, and as such provide a very accessible learning environment.

Vajda (2015) used computer algebra software to introduce the classical Chebyshev polynomials as extremal polynomials. The use of computer algebra in this study is reported to have made the exploration of extremal polynomials easy and enjoyable for students. Yet another study that used computer technology to introduce a topic was that conducted by Soon (2015) introducing queuing theory through simulations. In the study, the researchers discussed the role that simulations can play in a classroom to create real-world learning experiences for students. Mathematical principles governing queues are very challenging to students, especially at the introductory stage. Real data was collected from queues at automated teller machines (ATMs) and at cinema ticketing counters, and was used to model activities involving queues. The study found that students were able to understand basic probability theory and statistical concepts, such as the Poisson process and exponential distribution, without the need to know all about classical queuing theory.

Some technologies that can be used in the classroom include, but are not limited to: interactive whiteboards (Promethean, SMART, and Active Boards), electronic tablets, e-readers, iPods, Geogebra, Maple, Geometer's Sketch Pad, computer algebra systems, Desmos, electronic voting devices, screen casting tools, pen casts, podcasts, etc. (Ramey, 2012).

2.4 Geometry and transformation geometry

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. A solid shape on the other hand is bounded by surfaces which may not wholly be represented on a plane surface. There are many types of geometry found in the field of mathematics. This includes Euclidean, Non -Euclidean, Dynamic, Transformational, Projective, Vectors, Applied and Menstruation geometry. According to Mashingaidze (2012), Transformation can be divided into two areas, isometries and non-isometries. Isometries include Translation, Reflection and Rotation. Whereas non-isometries include enlargement, Shear and Stretch.

Transformation geometry was first mentioned in the seminar named Erlangen program by Christian Felix Klein in 1872. He defined geometry as the shapes of which properties remain stable under the transformations (Burton, 2011). A transformation on the plane is one-to-one correspondence from the plane onto itself (Dodge, 2012). According to these definitions, isometric transformations, which keep the properties in geometry, came into prominence (Zembat, 2013). Namely, according to Klein's thought, the properties kept in the interpretation of the transformations should be studied (Yavuzsoy Köse, 2013). Transformation geometry is a kind of transforming process and it could be said that it is a function (Zembat, 2013a, 2013b; Yavuzsoy Köse, 2013; Hollebrands, 2003). Here the domain is a geometric shape or an object; function is the movement of transformation; and the image set is the activated shape of the initial shape according to the parameter taken. Students conceptualized transformations as "physical motions" (Edwards, 2003)

2.4.1 Reflection Transformation

One of the most important application fields in actual life of reflection within the content of mathematics is the concept of symmetry. Symmetry is an important tool to understand the nature and the environment and is used in many fields ranging from art to architecture (Aksoy & Bayazit, 2009). Symmetry has two different meanings. The first meaning which geometric and algebraic patterns make up and the meaning of balance and ratio used in the association of the parts within a whole in harmony. The second meaning is associated with the order of symmetry, harmony, aesthetics, beauty and perfection (Yavuzsoy Köse, 2013). According to Conway, Burgiel and Strauss (2008) by using symmetry the mysterious world of mathematics can be shown with visual objects, its artistic aspect could be explored and also its visual beauty could be revealed.

Reflection transformation is also the basis of the comprehension of the topics in Analytic geometry. The reflection of any geometric shape is made up by intersecting lines from every angle on the shape and projecting these angles on the other side of the axis. Thus, the projected geometric shape and the reflected according to axis are of equal length and they are the same in basic properties, but different in terms of location and direction.

2.4.2 Translation Transformation

Translation transformation is the image taken according to the described function in a straight line and in the same direction of a vector or a geometric object. Namely, it is function that matches the plane with another by means of one to one correspondence (Zembat, 2013). The movement of a geometric shape or an object from one place to another in a specific rotation and direction is called translation transformation (Aksoy & Bayazit, 2009).

In the conceptualising and naming translation transformation mathematically, three properties could be utilized. The first one is that translation transformation keeps the internal dynamic that is edge length, angles and direction of a geometric shape. The second is that the properties of every point on geometric shapes are the same as among the matched points after the transformation. Therefore, some specific points of a geometric shape are not applied to translation transformation and the image of every point under this transformation is found. Thirdly, translation transformation with the zero vector matches the geometric object on the plane with itself (Zembat, 2013).

2.4.3 Rotation Transformation

Rotation transformation is the function that fixes every one of the points on the plane with another point on the plane. Martin (1982) describes rotation transformation as a function that covers and one to one correspondences all points on the plane with the help of a central point and angle with the points on the plane. Rotation transformation keeps angles and distances which are the dynamics of the plane.

In the interpretation of solids, one of the subjects of geometry, rotation transformation is used. A student who sees that when a right triangle is rotated 360° around one of the legs, a cone is obtained, when a rectangular is rotated 360° around one of its lines, a cylinder is obtained and when a semicircle is rotated 360° around its diameter, a sphere is obtained can be able to learn solids conceptually (Aksoy & Bayazit, 2009).

2.5 Research on transformation geometry

In a study conducted by Akay (2011), he/she investigated the impact of the peer instruction method on the success of 8th grade students in transformational geometry and their attitude toward mathematics. The study was conducted during the 2009-2010 academic year. The sample was comprised of 112 8th grade students of a public school in Küçükçekmeçe, İstanbul. One of the two classes that the researcher was teaching was randomly assigned as the experimental and the other as the control group. The students in the experimental group received instruction in transformational geometry by means of the peer instruction method, while those in the control group received instruction in the traditional method. At the end of the study, it was found that the peer instruction method had a positive impact on students' success in transformational geometry and their attitude toward mathematics.

Differently, Yazlık (2011) conducted a study to investigate whether geometry instruction using the Cabri Geometry Plus II software had any impact on 7th grade students' learning outcomes in the topic of rotation geometry in math education and to examine students' attitudes toward the Cabri Geometry Plus II software. This study was carried out during the 2010-2011 academic year with 7th grade students. Over a period of six class lessons, the rotation geometry topic was taught by using the Cabri Geometry Plus II software in the experimental group comprised of 66 students, and in the traditional way in the control group comprised of 69 students. At the end of the study, it was found that utilizing the dynamic geometry software program Cabri in teaching rotation geometry had increased the success level of the students. In addition, according to the results of the survey on the experimental group students' attitude toward the Cabri program, it was found that the Cabri program enabled students in the experimental group to learn transformational geometry more effectively and permanently. The experimental group students recommended the Cabri program to the primary school students. They stated that the Cabri program increased their motivation to solve problems and that they could use this program in their self-studies in other subjects. Overall, it was found that the experimental group students had a positive attitude toward the Cabri program.

Ada & Kurtulus (2010) investigated students' misconception and errors in transformation geometry. The study analysed students' performance in two - dimensional transformation geometry and explored the mistakes made by the students taking the analytical geometry course given by researchers. The subject of the study included 126 third -year students of mathematics in the university. Data were collected from seven examination questions. The result of the analysis showed that these students did not understand how to apply rotational transformation. The mostly mistake observed showed that the students seemed to know the algebraic meaning of translation and also of rotation but they did not seem to understand the geometric meaning of these concepts. In a similar study, Hollebrands (2003) investigated the nature of students understanding of geometric transformations, which included translation, reflections, rotation and dilations, in the context of the technological tool, the Geometer's Sketchpad. The researcher implemented a seven-week instructional unit on geometry transformations within an Honors Geometric class. Students' conceptions of transformations as functions were analyzed. The analysis suggested that students' understanding of key concepts including domain, variable and parameters, and relationships and properties of transformation were critical for supporting the development of deeper understandings of transformations. Aktaş & Ünlü (2017) also conducted a similar study to investigate the challenges and the common mistakes the 8th grade middle school students encounter about the transformation geometry. The study was conducted using mixed method designs with 125 8th grade students. At the end of the study, it was observed that the students understood that the translation transformation is a movement of replacement, but they had difficulty in the topics such as the direction of the transformation and the position of the shape within the transformation. It was detected that the students had difficulty in identifying the equation of the axis of symmetry for the images of the shapes under reflection, confused the rule that the points intersecting with the symmetry of the shape within the reflection should intersect with the image under transformation and they made mistakes since they couldn't explore the relationship between symmetry axis in regular polygons and sides. They had problems in finding and practicing the angle of rotation about rotational transformation and also. In the study, learning environments were recommended towards overcoming these challenges for teachers and course book writers and imp roving conceptual information and the skill to practice these concepts.

Acquah & Alhassan (2018) to assess the challenges of Ghanaian pre-service teachers' in their learning of geometric transformation concepts and perception of factors inhibiting the development of their mathematical knowledge for teaching. The study employed the use of survey method using sample size of 200 pre-service teachers selected from Colleges of Education (CSE) in Eastern region of Ghana. Descriptive statistics was used to analysed the data which was selected by the use of questionnaire. Findings from the study showed challenges of pre-service teachers were as a result of factors such as lecture approaches adopted by mathematics tutors in the teaching of geometric transformations, inadequate exercises on geometric transformation concepts taught to consolidate their understanding; and poor nature of assessment task given on geometric transformations. Further findings made with regards to difficulties of pre-service teachers in their learning of geometric transformation concepts were: reflection of figure in other mirror lines apart from (x=0, y=0, y= -x, y=x), rotation of figure with different centre apart from the origin and multiple transformations.

Also in a study by Glass (2001), entitled "Students' Reification of Geometric Transformations in the Presence of Multiple Dynamically Linked Representations", Glass aimed to make transformational geometry meaningful by defining it within a dynamic environment. At the end of the study, Glass found that the students participating in the study made sense of and configured first translation, then reflection and finally rotation. It was stated that students knew that the shape and the corner points of its symmetry were at an equal distance to the symmetry line. Furthermore, it was observed that an environment with dynamically linked representations made it easier for students to learn reflection.

In a similar study conducted by Aktas and Unlu (2017) conducted a research on Understanding of Eight Grade Students about Transformation Geometry: Perspective on Students' Mistake. The subject of the study was 125 8th grade students. At the end of the study, it was observed that the students understood that the translation transformation is a movement of replacement, but they had difficulty in the topics such as the direction of the transformation and the position of the shape within the transformation. A misconception was developed for the reflection by confusing the similarity with the congruence property of the shapes. It was detected that the students had difficulty in identifying the equation of the axis of symmetry for the images of the shapes under reflection, confused the rule that the points intersecting with the symmetry of the shape within the reflection should intersect with the image under transformation and they made mistakes since they couldn't explore the relationship between symmetry axis in regular polygons and sides. They had problems in finding and practicing the angle of rotation about rotational transformation and also. In the study, learning environments were recommended towards overcoming these challenges for teachers and course book writers and imp roving conceptual information and the skill to practice these concepts.

In another research, Gürbüz (2008) aimed to determine the elementary school teachers' qualifications on the sub learning strands like transformational geometry, geometric objects, patterns and tessellations as well. Firstly, it was found that participant teachers were better at the sub learning strand called transformational geometry (79%) than the other sub learning strands such as geometric objects (56%), patterns and tessellations (56%). On the topics of reflection (84%) and translation (84%) they had the same qualification rate, unlike the rotation topic (68%), which was lower. As for gender difference, female primary school teachers (57%) surpassed their male counterparts (33%) on the sub learning strands such as transformational geometry, geometric objects, pattern and tessellations.

2.6 Effect of GeoGebra on Mathematics

GeoGebra is a community-supported open-source mathematics learning environment that integrates multiple dynamic representations, various domains of mathematics, and a rich variety of computational utilities for modeling and simulations. Invented in the early 2000s, the aim of GeoGebra was to implement in a web-friendly manner the research-based findings related to mathematical understanding and proficiency as well as their implications for mathematics teaching and learning. One can easily download the software on (http://www.geogebra.org) and consequently use it in teaching. A mathematically competent person has the ability of coordinating various representations of a mathematical idea in a dynamic way and further gain insight into the focal mathematical structure (Bu, 2011). This therefore, makes GeoGebra very important to teachers of mathematics as they have the relevant competence in mathematics. According to Diković (2009), in comparison to a graph calculator, GeoGebra is more user-friendly. GeoGebra offers easy-to-use interface, multilingual menus, commands and help. Besides, encourages students` projects in Mathematics, multiple presentations and experimental and guided discovery learning. GeoGebra is also noted for its friendly interface and its web accessibility making it attract tens of thousands of visitors across the world that includes class room mathematics teachers and mathematics educators. There has been an expansion of GeoGebra internationally which has been attributed to online GeoGebra Wiki, global and local professional conferences.

In the fields of learning sciences and instructional design there have been several highlights by researchers on the theoretical and practical implications of mental models and conceptual models involving complex human learning (Milrad, et al, 2003). Pierce & Stacey, (2011), reported on how dynamic geometry can be used in supporting students' investigation of real-world problems in the middle and secondary grades. It was found that dynamic models of real-world scenarios, was helpful to students making mathematical conjectures in addition to enhancing their understanding of the mathematical concepts. Furthermore, the multiple features involved in dynamic modeling have been found to contribute to improving students' general attitudes toward mathematics learning. Burke and Kennedy explore the use of dynamic GeoGebra models and simulations in building a bridge between students' empirical investigations and mathematical formalizations. Their approach to abstract mathematics illustrates the didactical conception of vertical mathematization, a process by which mathematical ideas are reconnected, refined, and validated to higher order formal mathematical structures (Gravemeijer & van Galen, 2003). They aim to provide model-based conceptual interventions that support students' development of valid mental models for formal mathematics, an important practice that typically receives inadequate treatment in upper-division mathematics courses. Novak, Fahlberg-Stojanovska, and Renzo present a holistic learning model for learning mathematics by doing mathematics—building simulators with GeoGebra to seek deep conceptual understanding of a real-world scenario and the underlying mathematics (Alessi, 2000). They illustrate their learning model with a few appealing design examples in a setting that could be called a mathematical lab, where science and mathematics mutually define and support one another in sense-making and mathematical modeling.

Viewed from the theoretical perspective of RDM, GeoGebra affords a variety of digital resources that allow learners to mathematize realistic problem situations, invent and experiment with personally meaningful models using multiple representations and modeling tools, and further proceed to formulate increasingly abstract mathematical ideas.

McClintock, Jiang, & July, (2002) conducted a 4-year study on a group of 24 low socioeconomic, seventh grade minority students to determine if the use of GSP can assist in moving students' Van Hiele levels to a higher level. The researchers were at the time interested in determining what role the dynamic geometry environment could play in the development of students' 3-D visualization. Through the use of Geometers Sketchpad (GSP) directed activities, observations of the students, interviewing the students at regular intervals and assessments, the students' Van Hiele levels increased on average of two levels. At the outset of the McClintock et al (2002) study, the students were tested and the results determined that the students displayed 28 varying Van Hiele levels. When the students were re-tested at the end of the study, the result showed an average of two Van Hiele levels increase. The authors attributed the students' growth to the use of GSP through guided discovery activities (2002). That study is important to the field of mathematics education because it shows that, through the use of technology, particularly GSP, minority students increased their understanding of geometric concepts by increasing their Van Hiele levels of understanding. This study, however, differs from the McClintock et al. (2002) study on the basis that the researcher was interested in investigating the effect of the use of GeoGebra on form two students geometry students' achievement, including interaction with gender, and not just the students' Van Hiele levels. However, the McClintock et al (2002), study did not have a control group which is similar to the present study.

A study by Myers (2009) investigating The Effects of the Use of Technology in Mathematics Instruction on Student Achievement is very similar to this study although Myers' study used Geometers Sketchpad (GSP) while this study focuses on GeoGebra. Myers' study focused on achievement in mathematics in general, whereas the current study focuses on achievement in transformation geometry. The findings of Myers' study revealed "a significant difference in the FCAT mathematics scores of students who were taught geometry using GSP compared to those who used the traditional method."

A study in Turkey conducted at Dicle University and Kahramanmaras Sutcu Imam University involved 51, 10th grade students using GeoGebra to learn trigonometry, in particular, the graphing of trigonometric functions. The students' test scores showed that students who used the software learned the material better than students who did not use the software. Note that the treatment students were given a one hour introduction to the GeoGebra software prior to beginning the GeoGebra lessons. Students in both the treatment and control groups took a pre-test and post-test and both groups did better on the post test. However, there was a significant difference between the treatment and control groups with the treatment group scoring better on the post-test than the control group. This indicates that instruction with GeoGebra can be more effective than traditional teaching methods. As stated by the researchers, "computer assisted instruction as a supplement to constructivist instruction is more effective than constructivist teaching methods" (Zengin, Furkan, Kutluca, 2012). The findings in this study are consistent with the study by Ross and Bruce (2009), Reis (2010), and Tatar

(2012) which found that the impact of utilizing mathematical learning software had a positive effect on enhancing student learning and understanding.

GeoGebra has also shown to be successful in the teaching of integers and addition and subtraction of integers to 6th graders. This study involved two homogeneous classes each including 12, 6th grade students. In this study, the treatment students used GeoGebra to learn about integers and the control students experienced traditional teaching methods. The study, conducted at Istanbul University, found that the treatment class was more successful than the control class. Researchers claimed that students exposed to the traditional teaching method failed to understand the material at the desired level because the traditional teaching method appeals only to the auditory learning modality. However, success at the desired level was reached for students who used GeoGebra because it appeals to more learning modalities. "With the application of GeoGebra, more intelligences of students are aimed to be reached at, thus success is to be higher" (Reis, 2010). Researchers found that GeoGebra helped students conceptualize the operations in addition and subtraction and students who learned the integers with the software had a more permanent learning than the students who did not use GeoGebra (Reis, 2010). The researchers agree that making more use of GeoGebra in mathematics teaching is a factor in effective mathematics teaching and permanent learning.

Nazihatulhasanah and Nurbiha (2014) conducted a research on "The effects of GeoGebra on students' achievement "in order to investigate the effectiveness of using GeoGebra software on Mathematics learning among students in Malaysia. This study applied quasi-experimental research design using quantitative method. The sample consisted of Form 4 students at a secondary school in Malaysia of 62 participants where

32 students formed the control group and another 30 students were in the experimental group. The instrument used in this study is the performance tests; pre -performance test and post-performance test and also a set of questionnaire in which Mann-Whitney U test was use to analyse the data. The pre - achievement test was used to determine the achievement level of achievement by students in both groups. Post -performance tests used to measure the students' achievement after using GeoGebra software. The results the Mann-Whitney U test indicate that there are significant differences between the mean scores of students in the post -test for the GeoGebra. Based on this findings, the researcher concluded that GeoGebra is very helpful in the mathematics classroom teaching and more effective than traditional teaching method. In a similar study by Royati, Ahmad and Rohani (2010) on "The Effects Of Geogebra On Mathematics Achievement: Enlightening Coordinate Geometry Learning" to examine the effects of using a free-software called GeoGebra in the learning of Coordinate Geometry among students classified as high visual-spatial ability students (HV) and low visual-spatial ability students (LV). This researchers used the quasi-experimental study with a population of 60 students out of which 53 of them were randomly selected. The total number of students in the experimental group was 27 students whilst the control group was 26 students. The instrument for data collection was an achievement test which was analysed using Independent samples t-test. The results of the study indicated that there was a significant difference between the means of the students' scores on the posttest in favor of the GeoGebra group. The findings showed that computer assisted instruction as a supplement to traditional classroom instruction is more effective than traditional instruction alone. The findings of this study are consistent with the study by Hennessy, Fung and Scanlon (2001), Hannafin and Foshay (2008), Ahmad Fauziet. al. (2010) and Ahmad Tarmiziet. al. (2010) which found positive impact of utilizing mathematical

learning softwares thus enhancing students learning and understanding. This clearly demonstrates the instructional effectiveness of GeoGebra as compared to the traditional construction tools.

This study compared the relationship between scores of students who learnt transformation geometry using GeoGebra with the scores of students who learnt using traditional method.

CHAPTER THREE

METHODOLOGY

3.0 Overview

In order to provide answers to the research questions, this chapter provides a description and explanation of the research design in section 3.1. The population of the study is discussed in 3.2. Section 3.3 talked about sample and sampling procedure. The research instruments were highlighted in section 3.4 and piloting was discussed in section 3.5. The validity and reliability of these instruments are discussed in section 3.6. Data collection procedure is discussed in section 3.7. Lastly, this chapter culminates with a summary of the design and methodology.

3.1 Research Design

The term “design” has often been used in relation to the planning and conducting of experiments (Mugenda, 2008). A mixed method design comprising of both qualitative and quantitative research designs was used for this study. Creswell (2009) indicates that since the problems addressed by social and health science are complex, use of either qualitative or quantitative methods by themselves is inadequate to address the complex problems. Teddlie and Tashakkori (2009) concur that the mixed method research provides better inferences and minimizes unimethod bias. Mixed method is the best paradigm of research because it eschews the use of metaphysical concepts that has caused much endless discussion and debate and also presents a very practical and applied research philosophy (Bryman, 2012, Teddlie and Tashakkari, 2009, Regmi, 2010). The type of mixed method used was sequential explanatory. A sequential explanatory design consists of first collecting quantitative data and then collecting qualitative data to help explain or elaborate on the quantitative results (Plano Clark, 2011).

This study was aimed at investigating the applicability of GeoGebra in the teaching of senior high school Mathematics in the Ghanaian curriculum. The study established the topic Rigid Motion of Transformation Geometry in senior high school mathematics and adopted an activity that would enhance it teaching.

3.2 Population

Population refers to the collection of individuals or regions that are to be investigated in a statistical study (Mugenda and Mugenda, 1999). The population of the study comprised of students in the New Juaben Senior High School. Although there are other schools in the Municipal, the study focused on New Juaben Senior High School since the researcher himself teaches in that school so as to reduce cost.

3.3 Sample and Sampling Procedure

In this study, sampling was done at two 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. 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.

Looking at the time frame for the study, there was the need to use students (a class) with high achievement level to test the new instructional tool (GeoGebra) hence Purposive sampling was used to select the two science classes in form 2. Simple random sampling was then used to select 45 students.

Students partaking in the interview were selected based on their performance in the Post-test. There were a total of 10 students that were preliminary selected. These students were then assembled and given an overview of the interview. The reason for this was to ensure that every participant (student) that will be finally chosen for the interview must be willing and not forced to participate in the interview. Finally, only six volunteers were interviewed. See Appendix F for the interview overview.

A similar study carried out in Turkey by Demirbilek and Özkale (2013) in 2013 which 46 participants were used. The control group consisted of 24 students and the experimental group consisted of 22 students. The research was implemented by using GeoGebra software in the Mathematics course. While the experimental group was exposed to a lecture method with GeoGebra software, the control group was exposed to a traditional lecture for four weeks. The study recommended further research using different set of students. This current study used a sample of 45 students with the aim of comparing the findings and making recommendations although in a different country. Besides, this study used the same group for both the pre-test and post-test so as to minimize other intervening factors between the control and experimental group.

3.4 Research Instruments

This study was done using various research instruments; the pre-test examination for the sampled students were administered in order to establish the learners' level of knowledge and their difficulties in answering questions on geometric transformation, specifically rigid motion in order to address the first research question. To answer the second research question, Post-test was done after exposure to rigid motion using GeoGebra for the same group to establish if there was a statistically significant difference in their performance before and after using GeoGebra.

A total of 10 students who performed better in the post-test were preliminary selected to find out their view about GeoGebra in learning transformation geometry in order to address the third research question. These students were selected so as to find out what engineered their performance. The students were then assembled and given an overview of the interview. The reason for this was to ensure that every participant (students) that will be finally chosen for the interview must be willing and not forced to participate in the interview. Finally, only six volunteers were interviewed.

3.5 Pilot Study

Shuttleworth (2010) defines pilot study as, "standard scientific tool for 'soft' research allowing scientists to conduct a preliminary analysis before committing to full-blown study". A pilot study is often described as a smaller version of the proposed study and is conducted to refine the methodology (Hallway & Jefferson, 2007). A pilot study helps to identify possible problems in the proposed study and allows the researcher to revise the method and instrument before the actual study is conducted (De Vos, Strydom, Fouche and Deport, 2005).

To increase the validity of this study, the test questions were first piloted to determine whether it elicited the intended responses (Hallway and Jefferson, 2007). The pilot study involved form 2 science students from a different school not meant for the actual study. The aim of the pilot study was to give the researcher an insight on whether the intended questions to be given to students would yield the desired data that would be needed to answer the research questions. The class and age group of students in the pilot study and that of the final group study were the same. In order to determine to what extent they understood the question and to decide whether some of the contents of the questions should be reconstructed or not, the researcher decided to assess the time they took to complete the task and other difficulties such as language, meaning, and choice they have to make (Thomas, 2003).

3.6 Reliability and Validity

3. 6 .1 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 and interview went through verification from an independent body. The pilot test of the instruments was carried out by administering the pretest items, followed by interview items, posttest items and interview items to the form three science class in Koforidua Secondary Technical

Senior High School in the Koforidua Municipal. The test was conducted twice on the same set of students covering two weeks and the data gathered were analyzed.

Pearson correlation was used to calculate the correlation coefficient. The goal was to find out the correlation coefficient of the two set of pilot tests. Pearson's correlation between the two 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 colleagues 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.

3. 6 .2 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 provides an adequate sample of items that represent that concept (De Vos et al, 2003).

In this study, both construct and content validity was used in this study to check if the test and interview questions really measured the concepts that the researcher assumed it measured. The Initial suggestions and input from the verification exercise from professional colleagues and 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. See appendix A for the test questions. These steps were included in the process in ensuring that the research findings are meaningful and reflected students' perceptions.

3.7 Data Collection

The first step towards data collection was to hold familiarization meetings with the students and the head of department to brief them on the intention of the study and also make them aware that the data collected would be used only for the purpose of the study.

3.7.1 Written Test

Data was then collected in the following procedure; a pretest examination was administered to the sampled students to assess them in the area of rigid motion and their challenges in answering rigid motion questions. See Appendix A and B for the pretest questions and the marking scheme respectively. Their challenges were identified through the errors they made in answering the questions. This enabled the researcher to address the research question one and for that matter to respond to the first objective of the study. Secondly, the sampled students were taught using GeoGebra as an instructional tool. The intervention process took place for two weeks. See Appendix E for the intervention outline. After the process of intervention by the researcher the post-test was administered to assess the learned concepts. See Appendix C and D for the post-test questions and the marking scheme respectively.

The written test was conducted before and after the intervention. the Pre-test was meant to discover the difficulties students have in solving rigid motion questions and also to establish the learners' entry behavior and initial knowledge of the intended learning areas of study. The questions were marked out of 30.

3.7.2 Interviews

Interviews are one of the most important tools of qualitative research. When properly used, researchers often get better responses from interviews than other data gathering devises like the questionnaire (Cutis et al, 2000).

The researcher believes that the interview technique will give room for an in depth probing that would provide a better knowledge of the participant's views and thinking processes about the use of GeoGebra in learning rigid motion. See Appendix F for the interview guide and questions.

Interview data was obtained from six students. The interview was administered immediately after school hours for duration of two hours a day and it lasted for three days. The interview protocol consisted of three main questions and related follow-up questions. The purpose of the inteviews was mainly to seek the views of the participants about the use of GeoGebra as an instructional tool. The interview responses were transcribed using themes.

3.8 Data Analysis

The study produced both quantitative data and qualitative data, showing scores of students in the in the pre-test and the post-test.

Achievement test scores was analyzed using inferential statistics. Specifically, the t-test was executed using the Statistical Package for Social Sciences (SPSS) software. The t-test was used to test for statistical significance difference between the pre-test and post-test scores of the participants. This was done primarily by comparing the mean score of the pre-test and post scores.

Descriptive statistics (percentages, mean and standard deviation) was used for the analysis of scores. Students' interview responses was transcribed and analyzed to answer the third research question.

3.9 Summary

A sequential explanatory mixed method design comprising of both qualitative and quantitative research designs was used for this study. The population comprised of students in the New Juaben Senior High School for which 45 students in the form 2 science classes were sampled for the study.

The instruments for the study were achievement test and interview guide which were analysed using descriptive and inferential statistics to address the research questions.

CHAPTER FOUR

RESULTS AND DISCUSSION

4.0 Overview

This chapter presents the results and discussion of data obtained from both the written test and the interview administered to students. The aim of the study was to investigate the impact of GeoGebra software on senior high school students' ability to use rigid motion in doing transformation geometry. A detailed analysis and discussion of findings of the written test and interviews are presented.

The three research questions that guided the study are:

1. What difficulties do students have in solving rigid motion questions?
2. What is the effect of teaching rigid motion using GeoGebra on SHS students' achievement?

3. What are the views of students about using GeoGebra in learning rigid motion?

4.1 Research question 1: What difficulties do students have in solving rigid motion questions?

In order to find out the difficulties students have in solving rigid motion, the researcher designed an initial test (pre-test) aimed at establishing the learners' entry behavior 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 form two level.

It is evident that students had an average uniform entry behavior as the mean of this test was 13.6 as shown on Table 2.

Table 2: Descriptive statistics of Pre-test and Post-test scores

	N	**Minimum**	**Maximum**	**Mean**	**Std Deviation**
Pretest score	45	2 (6.7)	26 (86.7)	13.6 (45.7)	5.9 (20.1)
Posttest score	45	16 (53.3)	30 (100)	25.0 (83.3)	3.9 (12.9)

Percentages in parenthesis

For the entire set of students, the maximum score was 26 (86.7%) and minimum score was 2 (6.7%) in the pretest. The general performance of the participants in the pretest revealed that, they have difficulties in answering rigid motion question. The pass mark of 15 (50%) revealed that only 33.3% of the students passed hence their difficulties in solving rigid motion questions.

Critical analysis of the participants' answers to the pre-test questions revealed that students had difficulties in rigid motion that is rotation, reflection and translation vector.

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

The first problem the students demonstrated was finding the object point when the translation vector and the image are given, example is pre-test objective Question 5 (see box 1).

G' (–4, 6) is the image of G under a translation by the vector $\begin{pmatrix} -5 \\ -7 \end{pmatrix}$ What is the coordinate of G?

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

Box 1

It was observed that only 5 (16.7%) out of the 45 participants had the answer correct. The students added the translation vector to the image instead of subtracting. Furthermore, the students were aware of the fact that the translation transformation is a concept of replacement, but they made mistakes on issue of replacement direction (e.g. along the *x*-axis or *y*-axis) while translating a given point in the coordinate system.

Secondly, the students had problem of reflecting a point in the line $y=k$, example is pre-test objective Question 8 (see box 2).

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)

Box 2

It was observed that about 39 (87.7%) of the students had the answer wrong. The students reflected the point in the y-axis (x=0) hence had the image as (3,4).

The students also had problem of rotating an object about point outside the origin, example is pre-test subjective question number 2(iii) (see box 3).

The image $\Delta A_2B_2C_2$ ΔABC under an anticlockwise rotation of 90^0 about the point (– 2, 2) where $A \longrightarrow A_2$, $B \longrightarrow B_2$, $C \longrightarrow C_2$;

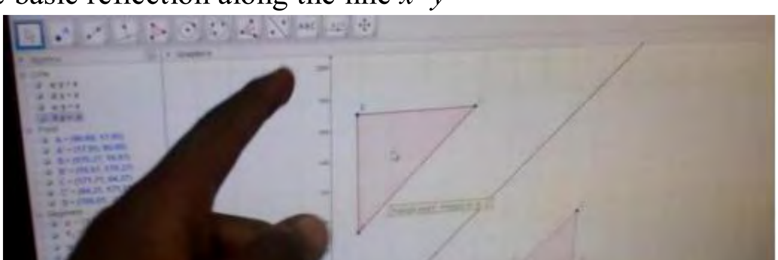
Box 3

It was observed that only 5(11.1%) of the participants had the answer correct. The other participants who attempted that question rotated the points about the origin (0,0).

4.2 Research Question 2: What is the effect of teaching rigid motion using GeoGebra on SHS students' achievement?

To respond to the second objective, the study sought to compare scores of students in the pre- test and the post-test examinations involving rigid motion. The students' scores were categorized into 2 major groups; namely, their score when the GeoGebra was used (post-test score) and that when the traditional methods of learning was used (pre-test). The students by using GeoGebra were allowed to explore in 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. Images from the experimental classroom activities are as shown in Figure 2: a and b.

a. Simple basic reflection along the line x=y



b. A rotation of a figure with the origin as the center of rotation at an angle of 90°

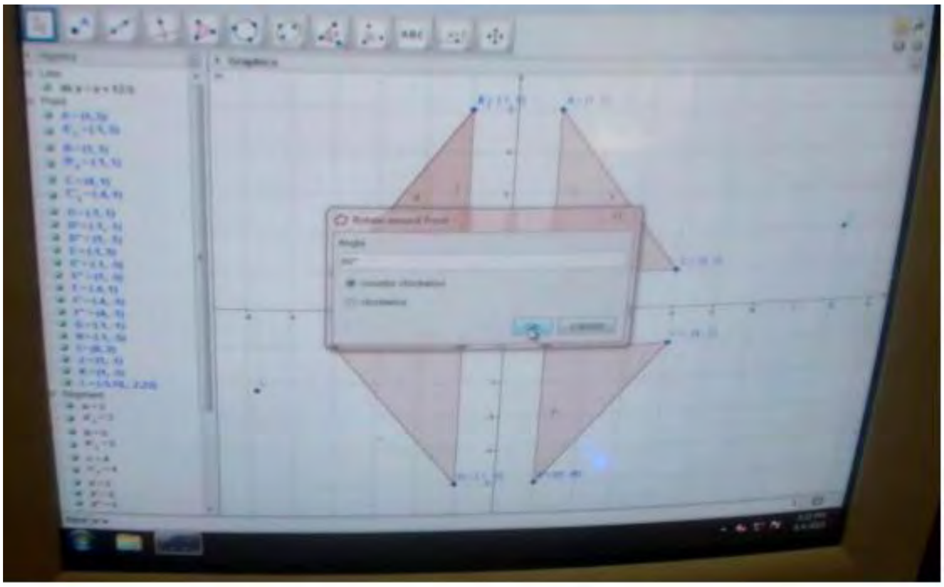


Figure 2: Experimental classroom activities

Table 3: means of Pre-test and Post-test

Paired	Mean	Number	Std Deviation
Pre-Test	13.6	45	5.9
Post-Test	25.0	45	3.9

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=13.6, SD=5.9) as against the post-test (M=25.0, SD=3.9), there is therefore an increase in students' rigid motion achievement after the instruction with GeoGebra software.

To find out if the difference in means is significant, paired sample T-test was conducted as shown in Table 4

Table 4: Paired T-Test analyses of means

	Mean	**Std Deviation**	**T**	**Df**	**Sig (2-tailed)**
Pre-Test& Post Test	-1.1	5.8	-13.1	44	0.0000

A paired-samples t-test in Table 4. indicated a test statistics of -13.1 and a p-value of 0.000 with 44 degree of freedom. The two-tailed p-value of 0.000 is far less than the conventional 0.05 level of significance. There is therefore enough evidence to conclude that, there is a significant difference between students' pre-test and post-test mean scores. The results suggested that the GeoGebra software increased students' rigid motion achievement. Specifically, the result suggested that when students are instructed with GeoGebra their performance in rigid motion and for that matter mathematics will increase. This result is consistent with the study by Ramadan and Hüseyin, (2014) which indicated that, the use of technology in the classrooms in today's world is believed to have a positive effect on students' success and their attitudes towards mathematics lessons.

4.3 Research Question 3: What are the views of students about using GeoGebra in learning rigid motion?

Research question three sought to seek the views of the students on their learning experiences using the GeoGebra software as compared to the traditional approach. Refer to Appendix F for sample of the posttest interview items.

4.3.1 Interview data indicated students' general view about GeoGebra in learning rigid motion. According to the data obtained from students, responses were divided into some themes. The common responses we:

- I have not used any software in learning mathematics before
- The GeoGebra software aided me to answer the questions correctly
- It was because I was actively involved
- It is a very effective software
- I wish it would be used in teaching other mathematics topics.

All participating students in the interview said they never used any software in learning mathematics. For example, there is no computers in the participating students' schools. Students have too many problems in learning rigid motion in transformational geometry due to lack of concrete material and technological materials. One of the students expressed his/her view as follows:

> "There is only a board and a board marker in the school as material. In rotation, I have to draw a coordinate system and also a shape first. When I rotate the shape, I have to draw the coordinate system again. It takes too much time. I can work on just two or three questions in the lesson. This many questions, is certainly not enough in rotation.

When the participants were asked whether or not the GeoGebra software aided their rigid motion achievement, they explained that GeoGebra enhanced their understanding of rigid motion concepts. All six participants asserted that GeoGebra was able to build a connection between mathematics concepts and the physical representations within their minds which in turn motivated them to learn rigid motion of transformation geometry. One of the students expressed his/her view as follows:

> The GeoGebra software aided me to answer the questions correctly; it was because I was actively involved in the lesson; it is a very effective method. The GeoGebra software enabled me to build a connection between the concepts and

> the physical representations within my minds which in turn motivated me to learn rigid motion of transformation geometry.

Based on the participants' achievement in rigid motion by the use of the instructional tool, all six participants suggested that GoeGebra software and for that matter Technology is used as an instructional tool in learning of mathematics.

4.4 Discussion

This section discusses the findings of this study in relation to the impact of GeoGebra software on senior high school students' ability to use rigid motion in doing transformation geometry.

Some mistakes such as matching the based point with a different point as shape while finding the image of a closed shape under translation were made during the pre-test. The reason why the participants could not take the image of the based point under translation could result from the fact that they could not isolate these transformations were isometry. In the study of Portnoy, Grungmeter and Graham (2006), they mention about the fact that the isometric properties of translation, reflection and rotation could not be isolated by the students. Isometric properties are finding the remaining properties after these transformations. For instance, in the translation transformation, if and how many units of translation will be done should be as the translation of all points of the given shape as a given unit. Besides, another reason why the participants found the wrong points of the new shape when a closed shape was translated might be because of the fact that they could not understand the necessity to direct the translation based on the vector. In a study which Yanik and Flores (2009) made with a teacher, they wanted the teacher candidate to make a translation of a closed shape. They stated that the candidate firstly thought the translation as a movement and changed its position. With the given educational coursed, they provided acquisitions to teach that translation transformation is a mapping based on a vector. Using vector parameters while finding the image of the point of a given shape under translation could provide a possibility in which the student could match the points.

The results of the analysis of the t-test on the performance of students taught using GeoGebra and when taught using the conventional method of instruction (talk-and-chalk) indicated a significant difference in achievement in favour of the students result when taught with GeoGebra. The students when exposed to GeoGebra achieved a higher average score compared to their scores during the pre-test. This is in line with those of Engel and Green, (2011), MacBride and Luehmann, (2008) and Shirley et al., (2011) that when teachers integrate technology appropriately into the learning process, student motivation and student achievement levels increased. The possible reasons for this finding could be that GeoGebra enabled students during the post-test to check the correctness of their methods and the accuracy of their work. Being able to check one's own work goes a long way in determining achievement levels. Because GeoGebra is dynamic, students during the post-test had opportunities of re-examining their work, which they could not do during the pre-test. GeoGebra enables remediation and re-teaching immediately to get students back on track in the lesson (Shirley et al., 2011). With the traditional method, teaching was limited to a few examples, because drawing many diagrams on the chalkboard consumed both time and space.

In addition, the production of good-quality sketches requires competence in technical drawing skills, which not all teachers possess. GeoGebra-generated sketches are neat and accurate. GeoGebra allowed students real-time exploration opportunities. Consequently, this improved the learning process in terms of speed and quality (Ljajko and Ibro, 2013). When students learn using GeoGebra they spend less time drawing diagrams (sketches) and making calculations; this allows them more time to explore the characteristics of different geometric figures. All these factors could have contributed to the superior achievement of the participants in the post-test.

It is virtually impossible to have passive students when computer technology, such as GeoGebra, is used in the teaching and learning process. GeoGebra changes passive students to independent explorers and the role of the teacher is to direct and monitor students' work. Mathematical concepts and procedures learnt using GeoGebra are long-lasting and better incorporated into students' cognitive structure, which makes them easier to apply (Ljajko and Ibro, 2013).

This study has revealed that using GeoGebra in teaching and learning not only increases students' achievement in general, but also motivates them. All six participants in the interview affirmed that GeoGebra enhanced their motivation to learn rigid motion. Research provides extensive evidence of GeoGebra having positive motivational effects on geometry students (BECTA, 2013) in the form of increased participation in class activities, improved concentration in class, enjoyment during learning times, self-confidence, content mastery and ultimately recommendation of this teaching and learning method.

GeoGebra can also provide some opportunities for students' cognitive development. These are facilitating and promoting learning, understanding, thinking, visualization in the mind, seeing details, internalization and recall. Given that visualization can play an important role in today's mathematics education (Majerek, 2014), these findings seem to be remarkable. In this connection, Dikovic (2009) stressed that GeoGebra can provide many opportunities for students to visualize the mathematical process and acquire an intuitional viewpoint. Furthermore, these views concur with the statements of high school students found in the study conducted by Zengin et al (2010) using activities and applications developed through GeoGebra. The high school students stated that they use GeoGebra willingly and enthusiastically, the information they learned previously by memorizing can be retained more easily when visualized by using GeoGebra, the program enhances visualization and provides a discovery-based learning environment enabling them to recognize the relationships between mathematical concepts.

The findings of this study agree with those of Okoro and Etukudo (2001), Paul and Babaworo (2006), Egunjobi (2002) and Karper, Robinson and Casado-Kehoe (2013) that students taught with CAI packages in chemistry, mathematics and education in general, perform better than those taught with normal classroom instruction.

CHAPTER FIVE

SUMMARY OF FINDING, CONCLUSIONS AND RECOMMENDATIONS

5.0 Overview

In this chapter, a summary of findings of a study that aimed at investigating the impact of GeoGebra software on senior high school students' ability to use rigid motion in doing transformation geometry will be presented in Section 5.1. This will be followed by a concluding remark in Section 5.2, recommendations will be made in section 5.3 and suggestion for further studies is made in Section 5.4. The interview and the written test that was conducted with students were very useful in providing data used in the description of students' ability to use GeoGebra in doing rigid motion of transformation geometry

5.1 Summary of Findings of the study

The research question one was answered using students' performance and for that matter their mistakes committed in answering the pre-test questions. The results indicated that about 95% of the students' experienced difficulties in rigid motion involving rotation. Out of 45 students only 11 of them attempted question 3(iii). Only 5% students out of the eleven had pre-test question 2(iii) correct. Students seem to have difficulties in finding mostly the centre of rotation when a figure is rotated about a point outside the origin.

Furthermore, it was found that most of the students tried to memorize the rule of rotation in order to make rotation. For instance, to rotate the point (3,2) around the origin 90^0 clockwise they just change the sign of the *x*- intercept and interchange the numbers, and as a result obtain (-2,-3).They experienced difficulties relating to performing a simple rotation when given size and direction. They had difficulties also in rotating a figure through a given degree about an origin and predicting the exact position of a figure when it is rotated through a certain angles in degree.

After this rigorous process that took around one months the students were once again subjected to a post-test examination attached as Appendix C. The results of the two tests were recorded and analyzed to establish if there was a statistically significant difference in scores of students when taught with the Geogebra software and when taught without the Geogebra software. The data obtained was analyzed using t-test and the results were as shown on Table 4.

In comparing the performance of students in the tests, the gained score for students when used GeoGebra in learning was seen to be statistically significantly higher than that of the traditional method, $t(44)= -13.1$, $p=0.000$. The mean of a total of 45 students when used GeoGebra was 25.0 compared to a mean of 13.6 for the same group of students when used the conventional method of studying mathematics as seen on Table 3.

The study was motivated by the feedback the researcher had in the students' pre-test scores. Rigid motion was seen as one of the most challenging areas in the secondary school mathematics. It was noted that more than half the students face difficulties in learning rigid motion. This explains the fact that questions involving Geometry and for that matter rigid motion are the most poorly performed at the Senior High School level.

Sampled students were trained in a dynamic Geometry Software involving use of GeoGebra, six of them who performed better in the post-test were interviewed about their views towards use of GeoGebra as a tool for learning rigid motion. It was found that the students who went through training felt that GeoGebra enhanced their understanding of rigid motion concepts. Students felt that GeoGebra was able to build a connection between mathematics concepts and the physical representations within their minds.

Although the students perceived GeoGebra to be useful and applicable in their mathematics lessons during the interview, they said they have never been introduced to any software in learning mathematics. From the Rogers Model, Adoption of GeoGebra in Ghana is at the early adopters' stage due to the slow pace of adoption. The Rogers TAM indicates the first stage of adoption as including Communication behavior and socioeconomic characteristics as being important for adoption. The study reveals that the uptake of technology and in this case GeoGebra is slow among the senior High Schools in Ghana even though the students claimed to be comfortable using the new innovation. This is in spite of inhibitive factors such as the learning environment which includes availability of computers.

5.2 Conclusions

The use of GeoGebra software is a new area of study in Ghana and not much has been documented about it in Ghana. The following conclusions have been made based on findings of this study.

On the uptake of technology, the study concludes that the students were not introduced to modern technologies in their classes. Several reasons were given including lack of resources indicating that they have not been introduced to any software in studying mathematics. The availability of resources at the schools played a role in the use or non-use of the innovation. This is in agreement with the Diffusion of Innovation Model.

An adoption model for technology in Ghanaian senior high schools would have to combine various factors in the Ghana set up, including, readiness to use the technology, perceived ease of use, perceived benefits and also usefulness in our secondary schools environment.

The evidence in this paper shows that technology has a positive effect on student learning expectations and outcomes. To reiterate, technology integration has the following benefits: 1) increased student motivation; 2) increased student engagement; 3) increased student collaboration; 4), increased hands-on learning opportunities; 5) increased confidence in students, and 6) increased technology skills.

The study concludes that GeoGebra is one sure tool which can aid the improvement of the poor performance in questions involving Geometry and for that matter rigid motion as it enhances understanding which is key to good mathematics learning and hence improved performance in the area of rigid motion at secondary school level.

The study concludes that if GeoGebra is introduced to the teaching and learning of rigid motion concepts in Senior High Schools in Ghana and teachers trained using Gerrit Stols training manual, contextualized by the Ghanaian curriculum using and the training guide provided in this study, there is expected to be improvement in performance in Mathematics.

5.3 Recommendations for Policy and Practice

From the study there was a strong indication that the learning of Geometry and for that matter rigid motion in the senior high school is poor and requires immediate intervention. This study revealed issues that led to the following recommendations.

1. There should be regular in-service training for mathematics teachers to ensure that they are in touch with modern teaching methods in line with the changing times.
2. Studies should focus more on specific areas or topics of mathematics that are poorly performed rather than looking at mathematics from a general point of view, this could help resolve the problem of poor performance in mathematics.
3. Uptake of technology is very slow in the senior high schools in Ghana. The government having introduced calculators use at senior high school level must opened the avenue for use of other technologies in our mathematics classrooms. It is recommended that the government further directs and supports the use of computers for learning mathematics to complement the traditional methods of teaching mathematics. This will make mathematics more exciting and interesting for the learners.

5.4 Suggestions for Further Research

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

1. This study restricted itself to use of GeoGebra in the teaching and leaning of rigid motion. There is the need for a study on other computers applications that can be used to enhance the teaching and learning of rigid motion. It would be useful to find out if a combination of various computer applications would lead to better teaching and learning of rigid motion.
2. The study majored on the use of GeoGebra software in learning of rigid motion. A further study may be done to check if GeoGebra will be useful in other areas of mathematics such as algebra, statistics and calculus in the senior

high school curriculum in Ghana. It would be useful to investigate the level of students' performance in these areas when taught using GeoGebra.

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APPENDICES

APPENDIX A

Pre-test Examination for Form 2 Students

PRE-TEST QUEATIONS

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENNT OF MATHEMATICS EDUCATION

Subject: Core Mathematics

Code:

This test is part of a research on your ability to solve 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

OBJECTIVES

1. The point P(2,4) is rotated about the origin the co-ordinate plane through a clockwise angle 270°. Find the image P'.

   A. (4 – 2) B. (– 2, - 4) C. (- 4, 2) D. (- 4, - 2)

2. The point P (-3, 4) is reflected in the line x + 2 = 0. Find the co-ordinates of the image of P.

   A. (7, 2) B. (– 2, 4) C. (- 3, -2) D. (- 1, 4)

3. The Point P (x, y) is mapped onto P' (6, 8) under a translation by the vector $\begin{pmatrix} 3 \\ 7 \end{pmatrix}$, find the coordinates of P.

   A. (9, 15) B. (3, 1) C. (- 3, -1) D. (- 9, -15)

4. Find the co-ordinates 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 $\begin{pmatrix} -5 \\ -7 \end{pmatrix}$. What is the coordinate of G?

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

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

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

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

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

A. (–7, 6) B. (–1, 6) C. (–1, – 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 $\begin{pmatrix} x \\ y \end{pmatrix} \longrightarrow \begin{pmatrix} -y \\ x \end{pmatrix}$?

A. Reflection in the y-axis B. Reflection in the x-axis

C. 90^0 clockwise rotation about the origin D. 90^0anticlockwise rotation about the origin

10. The point *P*(–5, 1) is rotated about the origin through 180^0. Find the coordinates of its image.

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

THEORY: SECTION B

1a. Using a scale of 2 cm to 2 units on both axes, draw on a sheet of sheet of graph paper two perpendicular axes OX and OY, for the intervals $-8 \leq x \leq 12$ and $-8 \leq y \leq 8$.

b. Draw on the same graph sheet indicating clearly the coordinates of all vertices,

i) The square PQRS with coordinates P(2,2), Q(6,2), R(6, 6) and S (2,6)

ii) The image $P_1Q_1R_1S_1$ of the square PQRS under a reflection in the y-axis where $P \rightarrow P_1$, $Q \rightarrow Q_1$, $R \rightarrow R_1$ and $S \rightarrow S_1$

iii) The image $P_2Q_2R_2S_2$ of the square PQRS under a translation by the vector $\begin{pmatrix} 4 \\ -8 \end{pmatrix}$

where $P \rightarrow P2$, $Q \rightarrow Q_2$, $R \rightarrow R_2$ and $S \rightarrow S_2$

iv) The image $P_3Q_3R_3S_3$ of the square PQRS under a rotation through 180^0 about the origin, where $P \rightarrow P_3$, $Q \rightarrow Q_3$, $R \rightarrow R_3$ and $S \rightarrow S_3$

2a) Using a scale of 2 cm to 2 units on each axis, draw on a sheet of graph paper, two perpendicular axes O_x and O_y, for the intervals $-10 \leq x \leq 10$ and $-10 \leq y \leq 10$.

b). Draw, labeling all the vertices clearly together with their coordinate:

i) ΔABC with vertices $A(2,6)$, $B(2,2)$ and C(6, 2).

ii) The image $\Delta A_1B_1C_1$ of under a reflection in the line
y= -1,where $A \rightarrow A_1$, $B \rightarrow B_1$, $C \rightarrow C_1$.

iii) The image $\Delta A_2B_2C_2 \Delta ABC$ under an anticlockwise rotation of 90^0 about the point (– 2, 2) where A A_2, $\cancel{B} \rightarrow$ B_2, $\cancel{C} \rightarrow$ C_2; $\rightarrow$

iv) The image$\Delta A_3B_3C_3$ ΔABC under a translation by the vector $\begin{pmatrix} 2 \\ -6 \end{pmatrix}$
where $A \rightarrow A_3$, $B \rightarrow B_3$, $C \rightarrow C_3$.

APPENDIX B

PRE-TEST FINAL MARKING SCHEME

	OBJECTIVE	
Question Number.	**Answer**	**Marks**
1. 2. 3. 4. 5. 6. 7. 8. 9. 10.	C D B A C A D A D B	10=(10MARKS)
	THEORY	
QUESTION No	**DETAIL**	**MARKS**
1(a) (b) (i) (ii) (iii) (iv)	B2(-1ee) for axes B2(-1/2ee) for drawing △ ABCD with A(2,2),B(6,2), C(8,8) and D(4,8) B2(-1/2ee) for drawing △ A_1,B_1,C_1,D_1 with A_1(-2,2), B_1(-6,2),C_1(-8,8), and D_1(-4,8) B2(-1/2ee) for drawing △ A_2,B_2,C_2,D_2 with A_2(-2,-2),B_2(-6,-2),C_2(-8,-8), and D_2 (-4,-8) B2(-1/2ee) for drawing △ A_3,B_3,C_3,D_3 with A_3(2,2),B_2(6,2),C_2(8,-4), and D_2 (4,-4)	2 2 2 2 2 [10]
2(a) (b)(i) (ii)	B2(-1ee) for axes B2(-1/2ee) for drawing △ PQRS with P(2,2),Q(6,2), R(6,6) and S(2,6)	2 2

   (iii) (iv)	B2(-1/2ee) for drawing ≙ $P_1Q_1R_1S_1$ with $P_1(-2,2)$,$Q_1(-6,2)$, $R_1(-6,6)$ and $S_1(-2,6)$ B2(-1/2ee) for drawing ≙ $P_2Q_2R_2S_2$ with $P_2(6,-6)$,$Q_2(10,-6)$, $R_2(10,-2)$ and $S_2(6,-2)$ B2(-1/2ee) for drawing ≙ $P_3Q_3R_3S_3$ with $P_3(-2,-2)$,$Q_3(-6,-2)$, $R_3(-6,-6)$ and $S_3(-2,-6)$	 2 2 [10]
3(a) (b) (i) (ii) (iii) (iv)	B2(-1ee) for axes B2(-1/2ee) for drawing ≙ ABCD with A(2,6),B(2,2) and C(6,2) B2(-1/2ee) for drawing ≙ A_1,B_1,C_1 with $A_1(-2,-6)$, $B_1(-2,-2)$and $C_1(-6,-2)$ B2(-1/2ee) for drawing ≙ A_2,B_2,C_2,D_2 with $A_2(-6,6)$,$B_2(-2,6)$ and $C_2(-2,10)$ B2(-1/2ee) for drawing ≙ A_3,B_3,C_3,D_3 with $A_3(4,0)$,$B_2(4,-4)$,$C_2(8,-4)$	2 2 2 2 2 [10]
TOTAL		**50×2 = 100marks**

APPENDIX C

POST-TEST EXAMINATION FOR FORM 2 STUDENTS

POST-TEST QUESTIONS

UNIVERSITY OF EDUCATION, WINNEBA

DEPARTMENNT OF MATHEMATICS EDUCATION

Subject: Core Mathematics

Code:

This test is part of a research on your ability to solve 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

OBJECTIVES

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

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

2. G' (–4, 6) is the image of G under a translation by the vector $\begin{pmatrix} -5 \\ -7 \end{pmatrix}$ What is the coordinate of G?

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

3. The point P(2, 1) reflected in the line x = 3. Find the coordinates of its image

   A. (–2, 1) B. (2, –1) C. (2, 4) D. (4, 1)

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

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

5. 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)

6. The image of the point (2, 4) under a translation by the vector **p** is (5, 3), find the vector **p.**

   A. $\begin{pmatrix} 1 \\ 1 \end{pmatrix}$ B. $\begin{pmatrix} 7 \\ 7 \end{pmatrix}$ C. $\begin{pmatrix} -3 \\ 1 \end{pmatrix}$ D. $\begin{pmatrix} 3 \\ -1 \end{pmatrix}$

7. Find the coordinates of the image of the point (m, – 7) under an anticlockwise rotation through 90^0 about the origin.

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

8. The point *P*(–5, 1) is rotated about the origin through 180^0. Find the coordinates of its image.

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

9. Find the image of the point $P(-12, 4)$ under the reflection in the line $y = -3$

A. (–12, 4) B. (–12, 2) C. (–12, 10) D. (–12, –10)

10. What transformation does $\begin{pmatrix} x \\ y \end{pmatrix} \longrightarrow \begin{pmatrix} x-3 \\ y \end{pmatrix}$ represent?

A Translation by the vector $\begin{pmatrix} -3 \\ 0 \end{pmatrix}$ B. Rotation about the point $(-3, 0)$ through 180^0

C. Reflection in line $y = -3$ D. Translation by the vector $\begin{pmatrix} 0 \\ -3 \end{pmatrix}$

THEORY: SECTION B

1a. Using a scale of 2 cm to 2 unit on both axes, draw on a graph sheet, two perpendicular axes OX and OY for $-10 \leq x \leq 10$, $-10 \leq y \leq 10$.

b. Draw ΔPQR with vertices P(1,1), Q(1,5) and R(5,4)

c. Draw the image $\Delta P_1Q_1R_1$ of ΔPQR through a rotation of 180^0 about the origin where $P \rightarrow P_1$, $Q \rightarrow Q_1$ and $R \rightarrow R_1$

d. Draw the image $\Delta P_2Q_2R_2$ of $\Delta P_1Q_1R_1$, under a translation by the vector $\begin{pmatrix} 4 \\ -3 \end{pmatrix}$ where $P \rightarrow P_2$, $Q \rightarrow Q_2$ and $R_1 \rightarrow R_2$.

e. Draw the image $\Delta P_3Q_3R_3$ of ΔPQR, under a reflection in the line x = 0 where $P \longrightarrow P3$, $Q \longrightarrow Q_3$ and $R \longrightarrow R_3$.

2a) Using a scale of 2 cm to 2 units on each axis, draw on a sheet of graph paper, two perpendicular axes Ox and Oy for the intervals $-10 \leq x \leq$ and $-10 \leq y \leq 10$.

b). Draw, labeling all the vertices clearly together with their coordinate:

i) ΔABC with vertices $A(2,6)$, $B(2,2)$ and C(6, 2).

ii) The image $\Delta A_1B_1C_1$ of ΔABC under a reflection in the line x= -2, where

$A \rightarrow A_1$, $B \rightarrow B_1$ and $C \rightarrow C_1$

iii) The image $\Delta A_2B_2C_2 \Delta ABC$ under an anticlockwise rotation of 90^0 about the point (2,-2) where $A \rightarrow A_2$, $B \rightarrow B_2$, $C \rightarrow C_2$;

iv) The image $\Delta A_3B_3C_3$ ΔABC under a translation by the vector $\begin{pmatrix} 2 \\ -6 \end{pmatrix}$ where $A \rightarrow A_3$ $B \rightarrow B_3$, $C \rightarrow C_3$.

APPENDIX D

POST-TEST FINAL MARKING SCHEME

	OBJECTIVE	
Question NUMBER.	**Answer**	**Marks**
1.	A	1×10=(10MARKS)
2.	C	
3.	D	
4.	B	
5.	A	
6.	D	
7.	D	
8.	B	
9.	D	
10.	A	
	THEORY	
QUESTION No	DETAIL	MARKS
1(a)	B2(-1ee) for axes	2
(b) (i)	B2(-1/2ee) for drawing $\triangle$ PQR with P(1,1),Q(1,5) and R(5,4)	2
(ii)	B2(-1/2ee) for drawing $\triangle$ $P_1Q_1R_1$ with P_1(-1,-1),Q_1(-1,-5)and R_1(-5,-4)	2
(iii)	B2(-1/2ee) for drawing $\triangle$ $P_2Q_2R_2$ with P_2(3,-4),Q_2(3,-8) and R_2(-1,-7)	2
(iv)	B2(-1/2ee) for drawing $\triangle$ $P_3Q_3R_3$ with P_3(-1,1),Q_3(-1,5) and R_3(-5,4)	2
		[10]
2 (a)	B2(-1ee) for axes	2
(b) (i)	B2(-1/2ee) for drawing $\triangle$ ABCD with A(2,6),B(2,2) and C(6,2)	2
(ii)	B2(-1/2ee) for drawing $\triangle$ A_1,B_1,C_1 with A_1(-6,6), B_1(-6,2)and C_1(-10,2)	2
(iii)	B2(-1/2ee) for drawing $\triangle$ A_2,B_2,C_2,D_2 with A_2(-6,-2),B_2(-2,-2) and C_2(-2,2)	2
(iv)	B2(-1/2ee) for drawing $\triangle$ A_3,B_3,C_3,D_3 with A_3(4,0),B_3(4,-4),C_3(8,-4)	2
		[10]
TOTAL		**30marks**

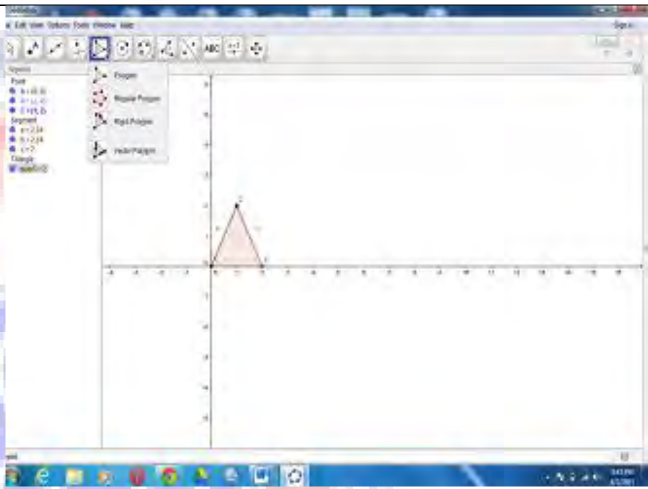
APPENDIX E

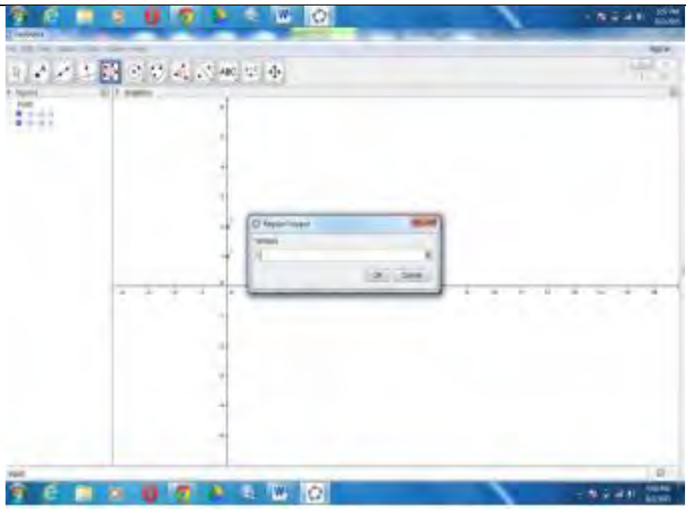
STUDY CONTRIBUTION: TRAINING GUIDE ON GEOGEBRA

Students were taken through 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.

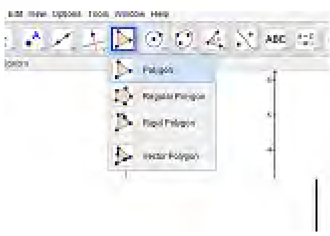
TRAINING GUIDE ON USE OF GEOGEBRA IN FORM TWO MATHEMATICS GEOMETRY TOPICS IN THE GHANAIAN CURRICULUM

Step1. Drawing basic shapes

Figure	Instruction	Illustration/ Images
1. Triangle	Click on Polygon on the screen select a point of your choice e.g (0,0). Then select other 2 points joining to the first point to form a Triangle.	
2.Regular polygon	On the dropdown menu click on Regular Polygon Select 2 points of your choice, A dialogue box will appear so that you	

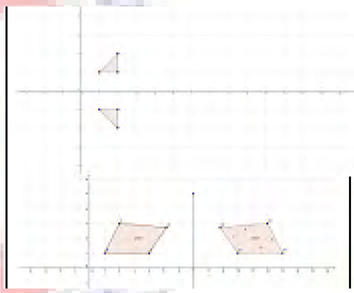
	indicate how many sides your figure should have e.g, for a pentagon enter 5, triangle=3, square =4	

Step2. Translation of Objects

Step	Instruction	Description	IMAGE
1	**Draw a vector AB** ● Click on Line Tool ● Select Vector ● Click on the Graphics window twice	A vector from Point A to Point B	
2	**Draw a triangle XYZ** Choose on the Polygon Tool Create 3 Free Points X, Y and Z	A triangle whose vertices are X, Y and Z	

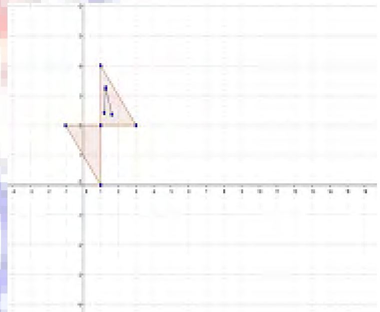
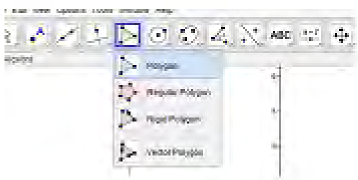
	Click on X, Y, Z then X		
3	**Translate Triangle XYZ by Vector** AB ●Click on Triangle XYZ ●Click on Vector		

Step 3. Reflection of objects

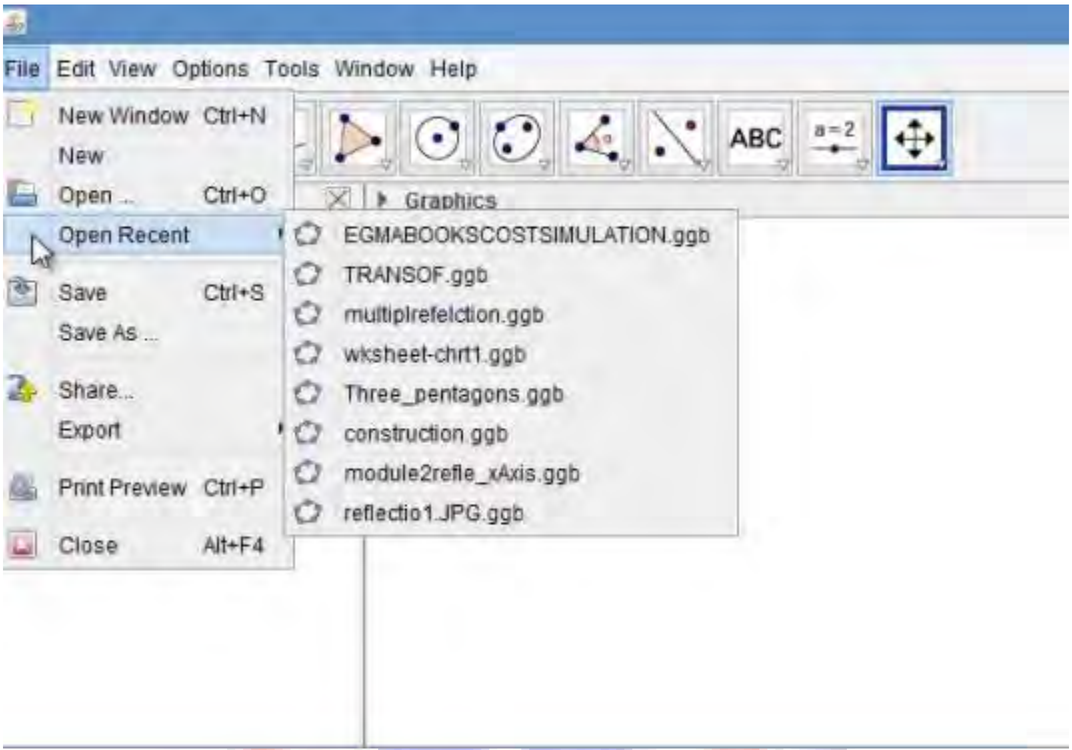
Step	Instruction	Description	IMAGE
1	**Reflect Object about Line** ● Select the object you want to reflect. Then, click on a line to specify the mirror/line ofreflection (also see command Reflect).	click on the triangle, then reflection icon, then click on the mirror line	
2	Reflect Object about Point Select the object you want to reflect. Then, click on a point to specify the mirror line/point of	A triangle whose vertices are C, D and E	

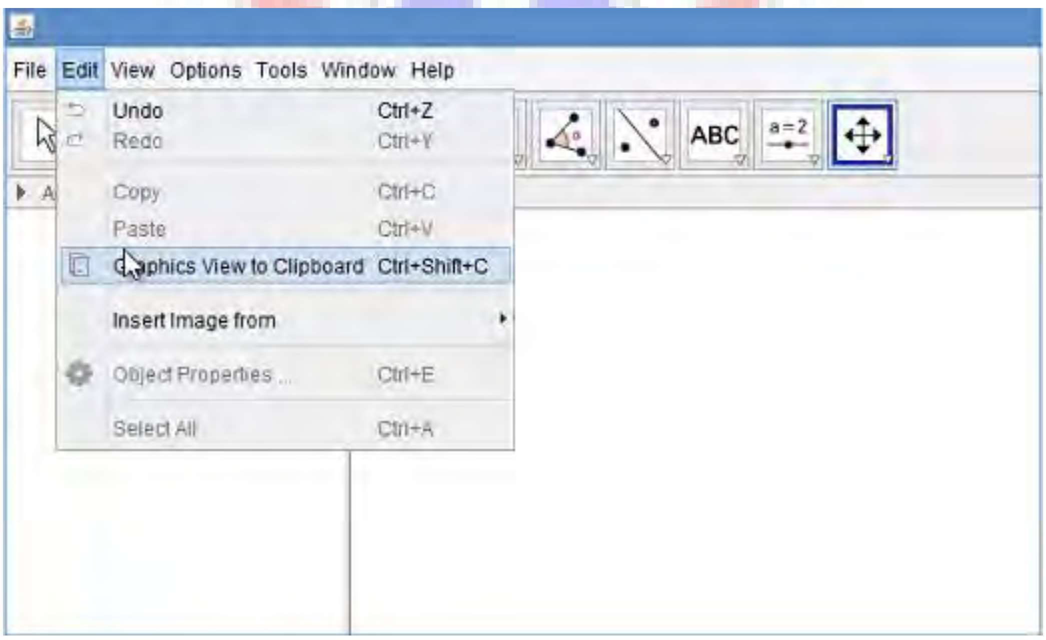
	reflection (also see command Reflect).		

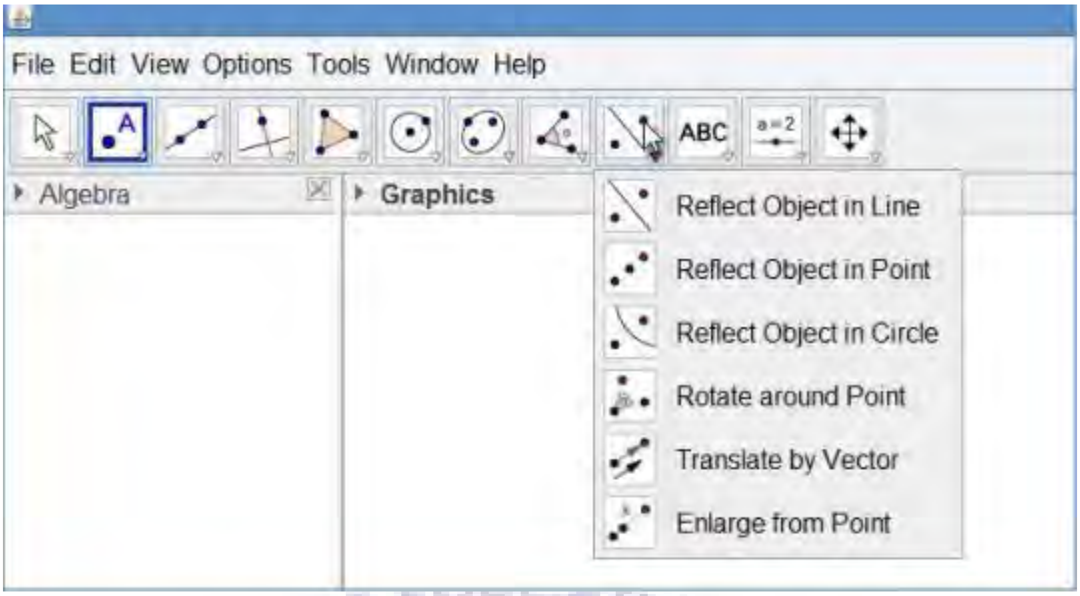
Step 4. Rotation of Geometrical shapes

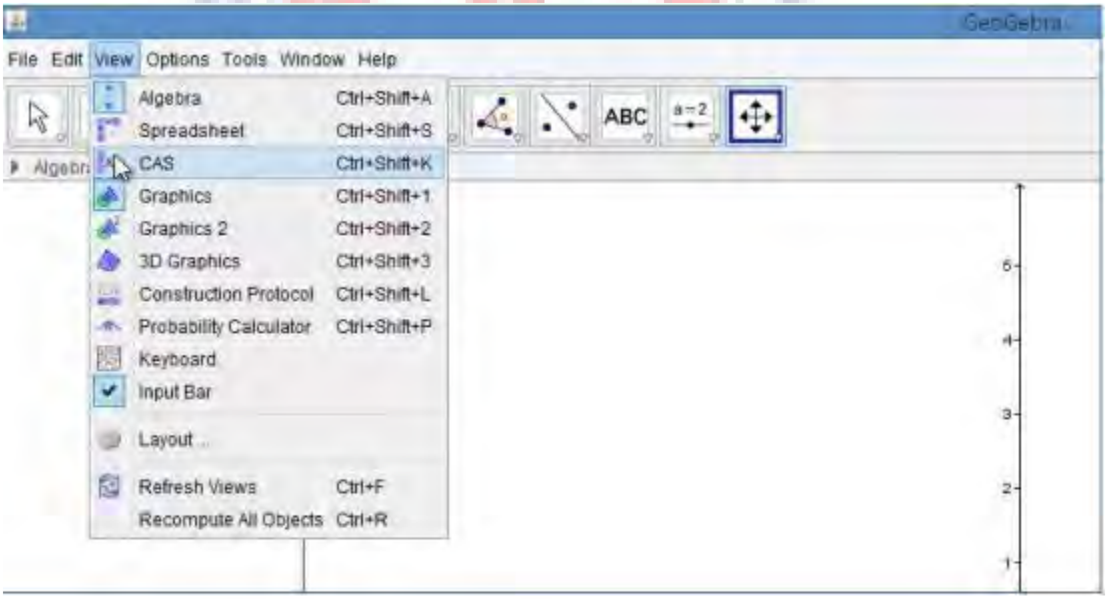
Step	Instruction	Description	IMAGES
1	**Rotate Object around Point by Angle** ● Select the object you want to rotate. Then, click on a point to specify the centre of rotation and enter the rotation angle into the text field of the appearing dialog window (also see command Rotate).	Centre of rotation eg Point A free object	
2	Draw a triangle XYZ and rotate it Choose triangle icon on the Polygon Tool Create 3 Free Points X,Y and Z	centre of rotation eg Point A(1,2) 0n The cartesian plane	

Some useful features in GeoGebra which give a drop down menu of its functions

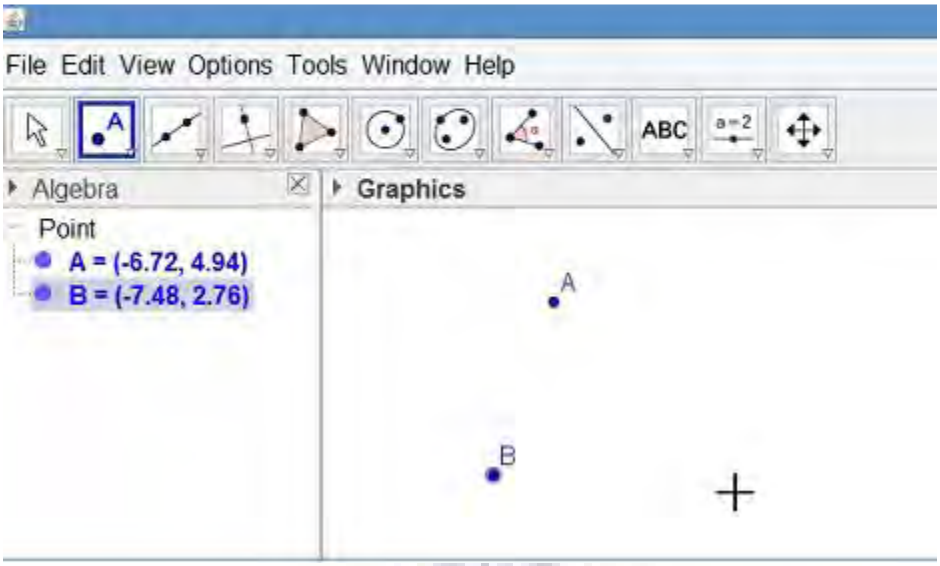


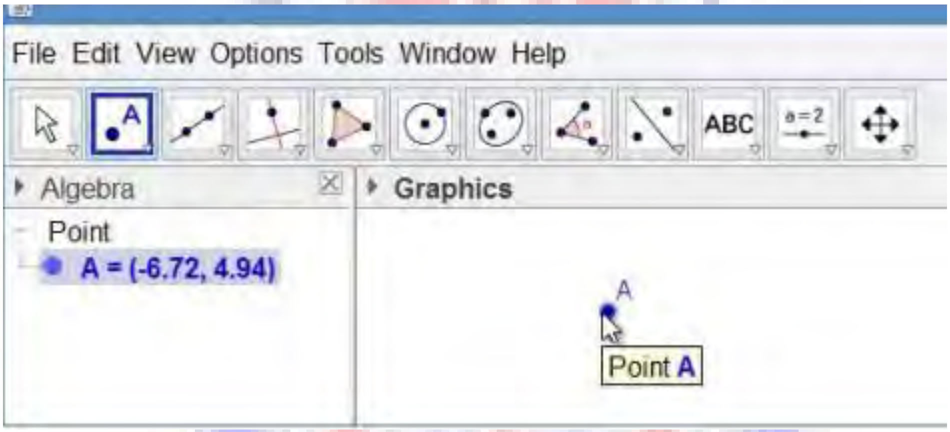


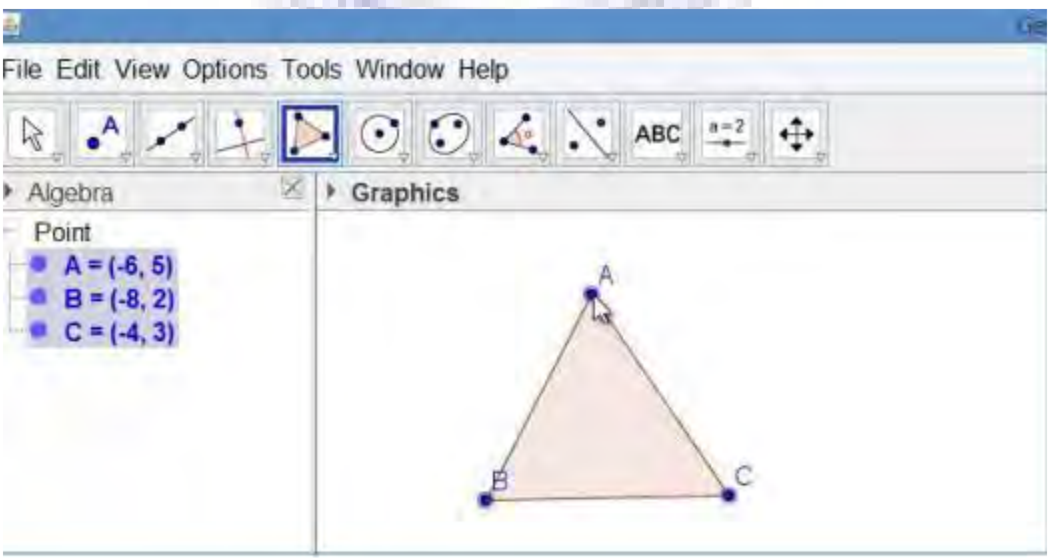


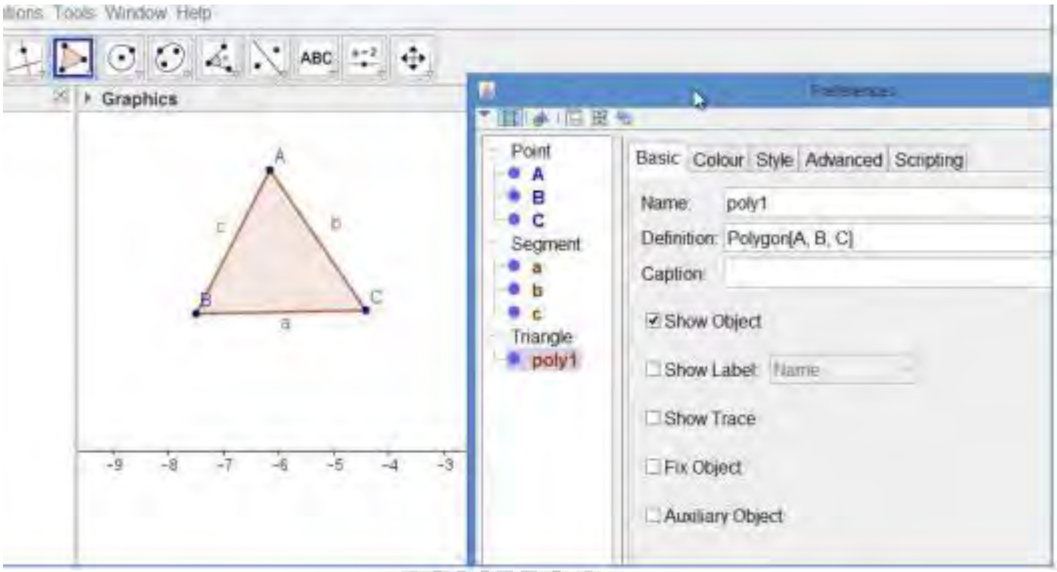


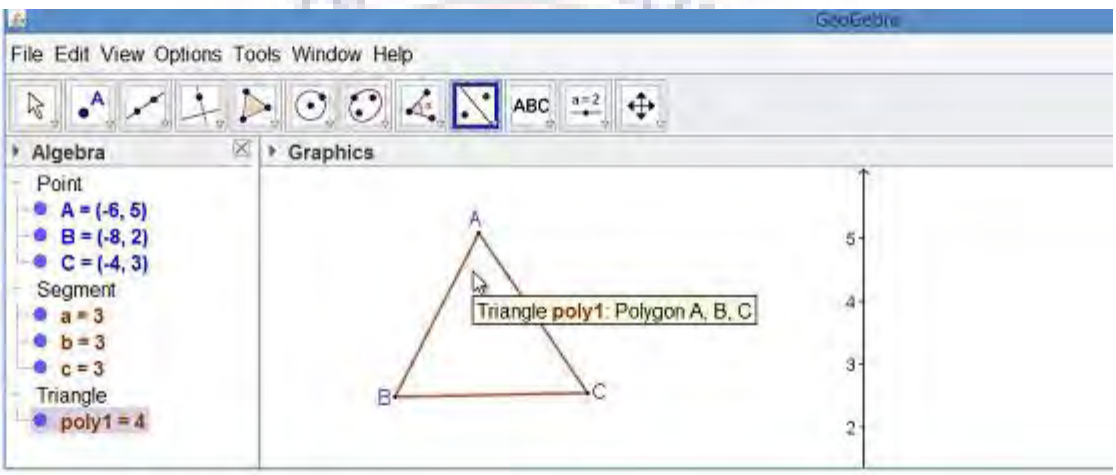
Drawing of regular polygon using GeoGebra

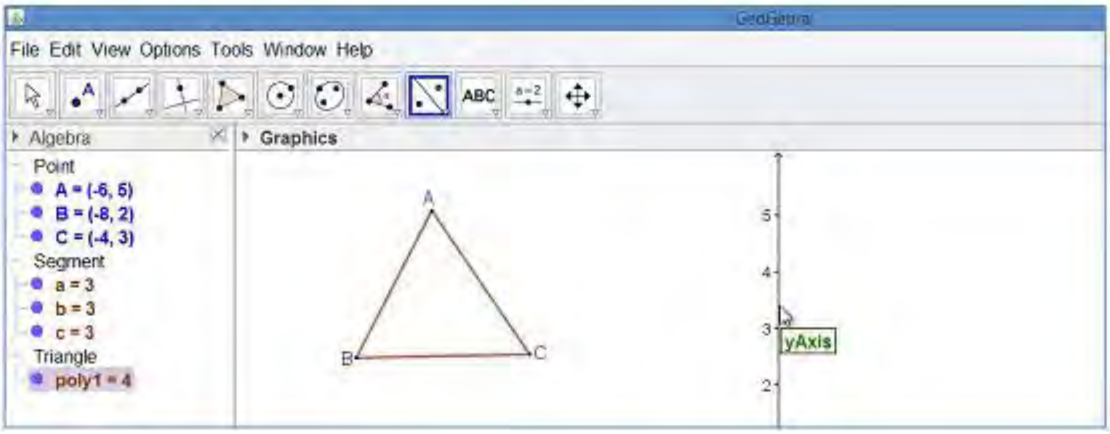

File Edit View Options Tools Window Help
ABC
a=2
Algebra
Graphics
Point
A = (-6.72, 4.94)
B = (-7.48, 2.76)
A
B

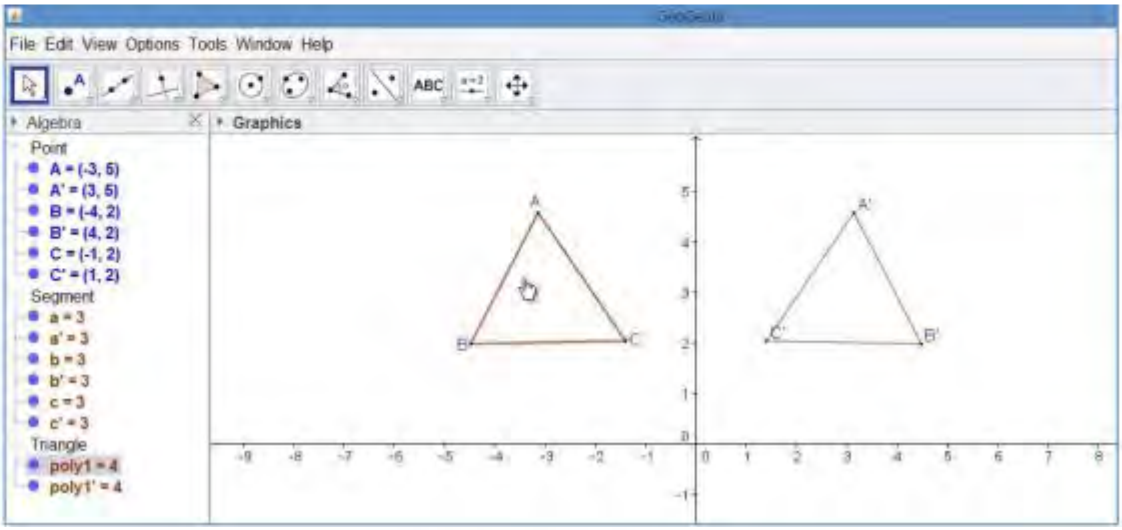

File Edit View Options Tools Window Help
ABC
a=2
Algebra
Graphics
Point
A = (-6.72, 4.94)
A
Point A


File Edit View Options Tools Window Help
ABC
a=2
Algebra
Graphics
Point
A = (-6, 5)
B = (-8, 2)
C = (-4, 3)
A
B
C


Tools Window Help
Graphics
Preferences
Point
A
B
C
Segment
a
b
c
Triangle
poly1
Basic
Colour
Style
Advanced
Scripting
Name: poly1
Definition: Polygon[A, B, C]
Caption:
Show Object
Show Label Name
Show Trace
Fix Object
Auxiliary Object

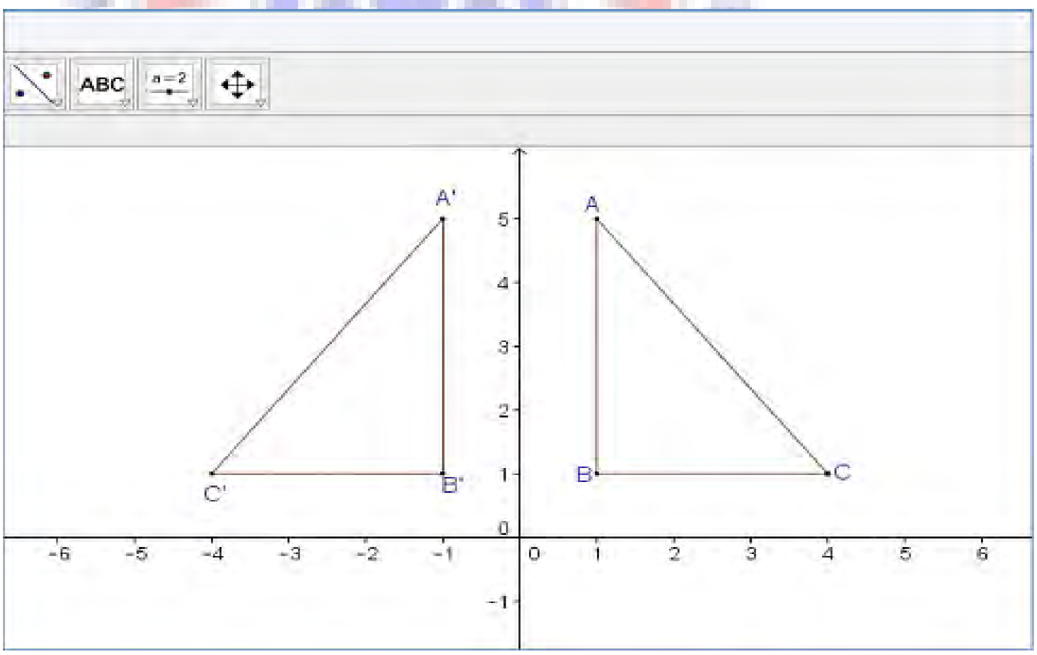

GeoGebra
File Edit View Options Tools Window Help
Algebra
Graphics
Point
A = (-6, 5)
B = (-8, 2)
C = (-4, 3)
Segment
a = 3
b = 3
c = 3
Triangle
poly1 = 4
Triangle poly1: Polygon A, B, C


GeoGebra
File Edit View Options Tools Window Help
Algebra
Graphics
Point
A = (-6, 5)
B = (-8, 2)
C = (-4, 3)
Segment
a = 3
b = 3
c = 3
Triangle
poly1 = 4
yAxis

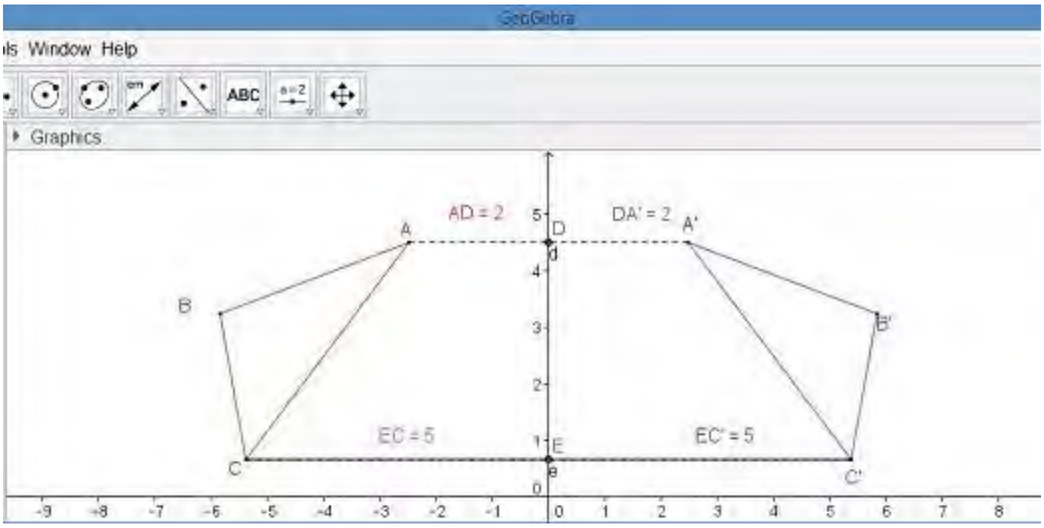


In reflection/rotation

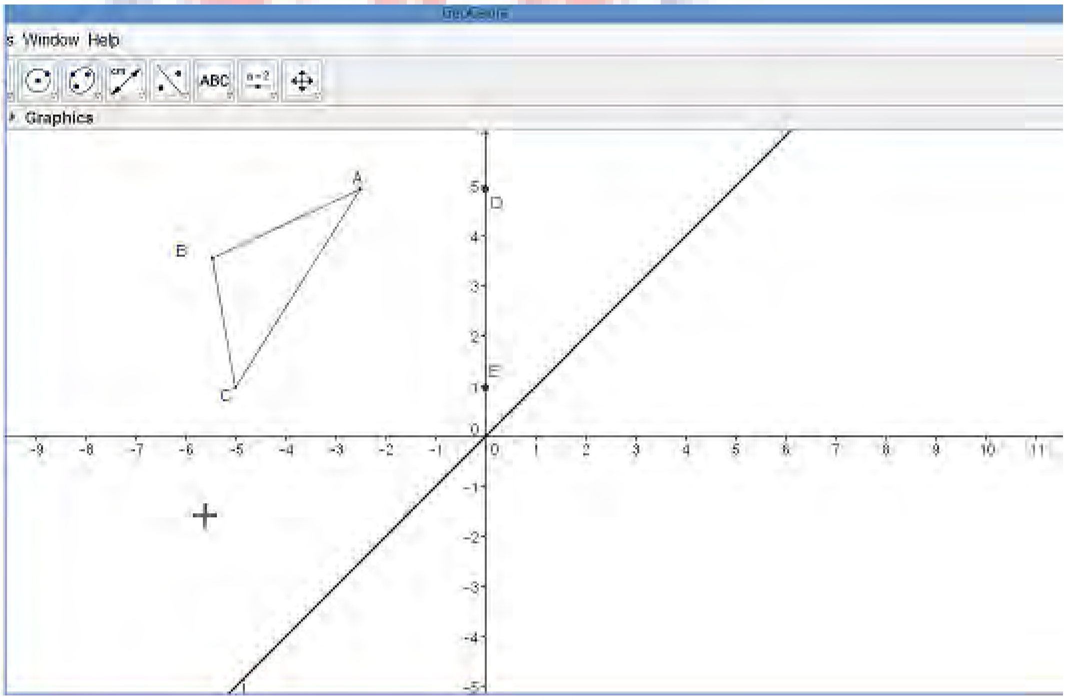
- ❖ select the reflection/rotation icon
- ❖ select the figure you want to reflect/rotate
- ❖ select the line of reflection/angle of rotation
- ❖ the image will show



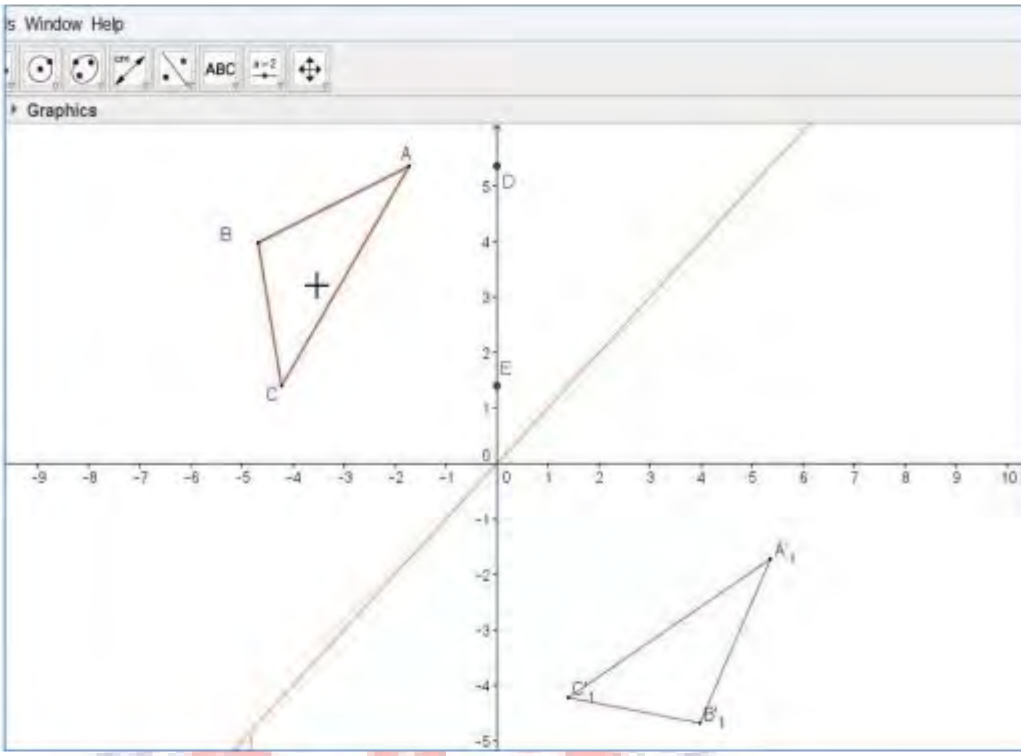
A reflection of triangle ABC along the Y-axis (X=0)



A reflection of triangle ABC along the Y-axis (x=0), showing the distances from the mirror line



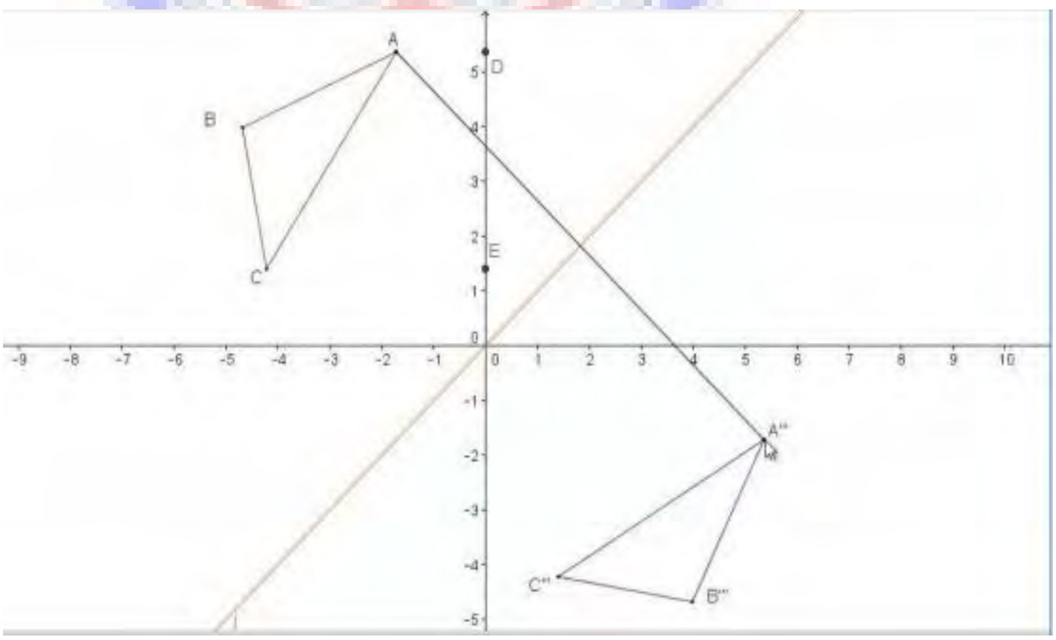
Given an object of triangle ABC to reflect along the line X=Y

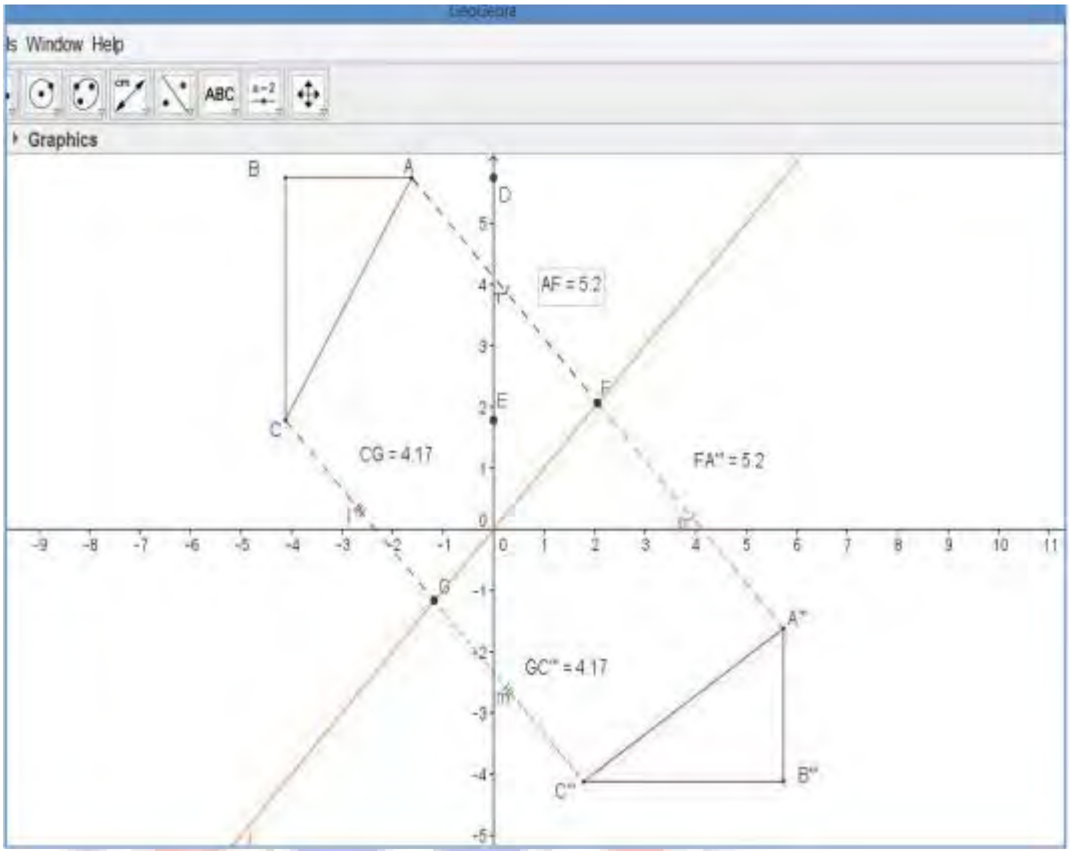


A reflection of an object of triangle ABC reflected along the line X=Y.

Clicking on the object, then the reflection icon followed by the mirror line, image

A_1,B_1,C_1 is obtained





A reflection of an object of triangle ABC reflected along the line X=Y. On a student's

book, using pen and paper

APPENDIX F

INTERVIEW GUIDE AND QUESTIONS

Interview Introduction
I want to thank you for taking the time to meet with me today. I would like to talk to you about your experiences in participating in the programme (Using GeoGebra to solve rigid motion questions). Specifically, as the major components of our overall program evaluation, we are assessing program effectiveness. The interview should take less than an hour. I will be taking note of the session because I don't want to miss any of your comments. Although I will be taking some notes during the session, I can't possibly write fast enough to get it all down. Please be sure to speak up so that I don't miss your comments. All responses will be kept confidential. This means that your interview responses will only be shared with research team members and I will ensure that any information I include in my report does not identify you as the respondent. Remember, you don't have to talk about anything you don't want to and you may end the interview at any time. Are there any questions about what I have just explained? Are you willing to participate in this interview? ____________________ ____________ Interviewee Date

Interview Questions
1. Have you ever used any software in studying mathematics? If yes, which software have you ever used? 2 To what extent did participation in using GeoGebra in solving rigid motion question aided or hinder your mathematics learning? Please explain. 3. Will you recommend the use of Geogebra software in learning mathematics? If yes Why (what are the benefits of the Geogebra software) Please elaborate. Is there anything more you would like to add? Thank you for your time.

APPENDIX G

PERMISSION TO CONDUCT PILOT STUDY

THE HEADMASTER

KOFORIDUA SECONDARY TECHNICAL SCHOOL

P.O. BOX KF 48

KOFORODUA

Dear Sir

REQUEST FOR PERMISSION TO CONDUCT PI LOT STUDY AT YOUR SCHOOL

I am currently a student at the University of Education, Winneba pursuing M.Phil in mathematics Education.

As part of the condition for my studies, I am conducting a research titled "Impact of Geogebra on Senior High School Students' Ability to Use Rigid Motion in Doing Transformation Geometry".

As part of the research I need to conduct an interview and 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 investigation will be treated confidentially and will only be used for academic purposes only.

Thanks for your co-operation

Yours faithfully,

……………….

Asare, James Tetteh

APPENDIX H

PERMISSION TO CONDUCT RESEARCH STUDY

THE HEADMASTER

NEW JUABEN SENIOR HIGH SCHOOL

P.O. BOX KF 48

KOFORODUA

Dear Sir

REQUEST FOR PERMISSION TO CONDUCT RESEARCH STUDY AT YOUR SCHOOL

I am currently a student at the University of Education, Winneba pursuing MPhil in mathematics Education.

As part of the condition for my studies, I am conducting a research titled “Impact of using GeoGebra software in teaching and learning Rigid Motion on Senior High School Students in Ghana”.

As part of the research I need to conduct an interview and 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 investigation will be treated confidentially and will only be used for academic purposes.

Thanks for your co-operation

Yours faithfully,

……………….

Asare, James Tetteh

APPENDIX I

PERMISSION TO CONDUCT RESEARCH AT YOUR SCHOOL

THE EASTERN REGIONAL DIRECTOR
GHANA EDUCATION SERVICE
P.O.BOX
KOFORIDUA
Sir/Madam
REQUEST FOR PERMISSION TO CONDUCT RESEARCH IN SCHOOLS

I am a student at the University of Education, Winneba pursuing MPhil in mathematics Education.

The title of my proposed thesis is "Impact of using GeoGebra software in teaching and learning Rigid Motion on Senior High School Students in Ghana".

To complete the requirement for this degree I need to conduct a research on the above mention topic. I hereby ask for permission from the Director's office to conduct my research at New Juaben Senior High School and a pilot study at Koforidua Secondary Technical School.

I assure you that all information obtained during the investigation will be treated confidentially and will only be used for academic purposes only.

Thanks for your co-operation

Yours faithfully,

………………………

Asare James Tetteh