FEASIBILITY OF USING GEOGEBRA IN THE TEACHING AND LEARNING OF GEOMETRY CONCEPTS IN SECONDARY SCHOOLS IN KAJIADO COUNTY, KENYA

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E83/21795/2012

A THESIS SUBMITTED IN FULFILMENT FOR THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (MATHEMATICS EDUCATION) IN THE SCHOOL OF EDUCATION OF KENYATTA UNIVERSITY

June, 2016
DECLARATION

I declare that this thesis is my original work and has not been presented in any other university/institution for consideration of any certification. This thesis has been complemented by referenced sources duly acknowledged. Where text, data (including spoken words), graphics, pictures or tables have been borrowed from other sources, including the internet, these are specifically accredited and references cited using current APA system and in accordance with anti-plagiarism regulations.

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DEDICATION

This work is dedicated to my daughter Immaculate, son Justin and parents Mr. and Mrs. Joseph Mwingirwa Kibaki who have eagerly waited for this achievement.
ACKNOWLEDGEMENT

I would like to acknowledge the support given by various individuals who made it possible for me to complete this work successfully.

To begin with, special thanks to my Supervisors for their invaluable input. I thank Dr. Miheeso Marguerite O’Connor, my mentor, for her commitment, thoroughness and prompt responses as we worked together towards writing this Thesis. I thank Dr. David Khatete for his support, commitment and on many occasions going out of his way to meet me.

Moreover, I acknowledge the support of Mr. Ogwel Ateng’ who showed special interest in GeoGebra and so worked with me by helping in training the teachers, developing training materials and providing venue for meeting with the teachers.

I thank NACOSTI and the Director of education, Kajiado County, for providing the necessary permits to allow me to conduct the research. I also thank the secondary school principals and mathematics teachers who not only collaborated with me but also helped in the class facilitation process.

In addition, I appreciate my parents for their daily prayers, encouragement and support throughout the study period.

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

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tbody>
<tr>
<td>CAL</td>
<td>Computer Assisted Learning</td>
</tr>
<tr>
<td>CAI</td>
<td>Computer Assisted Instruction</td>
</tr>
<tr>
<td>CFSK</td>
<td>Computer for Schools Kenya</td>
</tr>
<tr>
<td>DGEs</td>
<td>Dynamic Geometry Environments</td>
</tr>
<tr>
<td>DGS</td>
<td>Dynamic Geometry Software</td>
</tr>
<tr>
<td>DIM</td>
<td>Diffusion innovation model</td>
</tr>
<tr>
<td>ICT</td>
<td>Information Communication Technology</td>
</tr>
<tr>
<td>KCSE</td>
<td>Kenya Certificate of Secondary Education</td>
</tr>
<tr>
<td>KESSP</td>
<td>Kenya Education Sector Support Program</td>
</tr>
<tr>
<td>KNEC</td>
<td>Kenya National Examinations Council</td>
</tr>
<tr>
<td>NEPAD</td>
<td>New partnership for Africa’s Development</td>
</tr>
<tr>
<td>PCAST</td>
<td>President's Committee of Advisors on Science and Technology</td>
</tr>
<tr>
<td>PST</td>
<td>Pre-service secondary mathematics teachers</td>
</tr>
<tr>
<td>SMASSE</td>
<td>Strengthening of Mathematics and Sciences in Secondary Education</td>
</tr>
<tr>
<td>UNESCO</td>
<td>United Nations Educational, Social and Cultural Organization</td>
</tr>
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</table>
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 and how this resource can be used to enhance the teaching of Geometry in secondary schools in Kajiado County in Kenya. The objectives of this study were to assess the applicability of GeoGebra in the teaching of mathematics in secondary schools in Kenya. The relationship in performance of students taught with the help of this innovation and those students not using it was established. The study also compared the change in girls’ performance with that of boys after being introduced to Geometry using GeoGebra. The study further assessed how teachers responded to training on use of GeoGebra in teaching. The design adopted for this study was a mixed methods design of qualitative and quantitative approaches. The quantitative approach entailed the use of a quasi-experimental method whereby 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 Geometry. The target population was the secondary school mathematics teachers and students. The study sampled two boys’ secondary schools, two girls’ secondary schools and two mixed secondary schools in Kajiado County. Another mixed school was used for piloting of the instruments. Cronbach alpha of 0.79 was obtained for the teachers’ questionnaires while the reliability of the mathematics test was calculated using split half reliability index of 0.84. The data obtained was analyzed with the help of split plot ANOVA and descriptive 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 gender differences were not seen to affect performance of students in mathematics after learning in a GeoGebra environment. Although mathematics teachers in the county were mostly male, the female students were able to compete fairly well with the male students. The study concludes that GeoGebra is useful in improving performance of secondary school students in Geometry if teachers are well trained using the guides indicated in this study. It also concludes that GeoGebra benefits both girls and boys and therefore it is useful in bridging the gap between the genders in the learning of mathematics. It also developed a prototype GeoGebra manual for Kenyan mathematics teachers using GeoGebra. The study recommends that GeoGebra be used in teaching geometry in Kenyan secondary schools. The findings of this study will be useful to scholars of Mathematics Education, Quality Assurance and Standard Officers, Mathematics teachers, students and the schools administration. The study will add to the current knowledge in the teaching of mathematics in the Kenyan curriculum and hence improve performance.
CHAPTER ONE

INTRODUCTION AND BACKGROUND TO THE STUDY

1.1. Preamble

This section gives a background of the study, problem statement, study objectives research questions and the research hypothesis. The chapter further reviews the supporting theory and illustrates the study variables in the conceptual framework.

1.2. Background of the study

Developments in Information Communication Technologies (ICT) have influenced economic and social development with education taking a new dimension with the ICT’s influence. This is mostly so with post-secondary education due to the increased use of internet as a source of information. The internet and other ICT tools used in education in today’s paradigm offer a new space in education, making it necessary to introduce new instructional methods (Rosenberg, 2001). Lately, the universities have started open and distance learning programs through which students are able to learn without necessarily sitting in a classroom. In Kenyan secondary schools, for instance a policy on use of calculators was put in place since the year 2002, a sign that education has been taking a new dimension in relation to technology. This calls for research and clear analysis of various ICTs being used in the process of teaching and learning.

Pelgrum and Plomp (2001) note that investment in information and communication technology (ICT) has increased in the recent years, with the perception that increased
student use of computers and other electronic forms of media may have a positive impact on students’ achievement. The entire world is moving towards ICT in all sectors ranging from the banking industries, communication sectors and also education. However, mathematics educators in Kenya have noticed no improvement in Mathematics performance at the national examination levels. The availability of computers and various ICT resources does not seem to have had a positive effect on the performance of students in Mathematics. Ogwel (2008) notes that educators in Kenya as in some other countries have been concerned with students’ performance, low motivation and negative attitudes towards mathematics. Not much research has been done to show effects of ICT on education in Kenya.

Performance in mathematics in Kenya Certificate of Secondary Education (KCSE) over the years has remained poor despite introduction of calculators in 2002, the mean mark in mathematics as a subject has remained lower than other subjects. Candidates’ overall performance in the mathematics national examinations ranges from averages of 15% to 22% in the both papers 1 and 2. Table 1.1 shows the KCSE National Mathematics Mean scores for paper 1 and 2 between 2005 and 2008.
Table 1.1 KCSE National Mean Scores for mathematics papers 1 and 2

<table>
<thead>
<tr>
<th>YEAR</th>
<th>PAPER</th>
<th>Mean-score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>out of 100</td>
</tr>
<tr>
<td>2008</td>
<td>1</td>
<td>22.76</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>19.82</td>
</tr>
<tr>
<td>2009</td>
<td>1</td>
<td>22.37</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>19.89</td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td>26.21</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>19.92</td>
</tr>
<tr>
<td>2011</td>
<td>1</td>
<td>21.36</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>28.22</td>
</tr>
</tbody>
</table>


Over the years, the consistent poor performance in Mathematics is yet to be resolved. Out of the possible score of 100%, means scores of the national mathematics went as low as 19% several times. It is noted from the table 1.1 that the highest mean was achieved in the year 2011 paper 2, where the mean score improved to 28.22.

Some of the main areas of study in secondary school mathematics include Algebra, Geometry, Calculus, Trigonometry, Probability, and Statistics. Technology has been used in various areas in mathematics including Algebra (Wilson, 2000), in statistics (Abrahamson and Wilensk, 2007) and in Geometry (Cobo et al, 2007). Some of the computer software available for teaching and solving mathematical problems include
Spreadsheets, Dr Geo, Dynamic geometry software, Matlab, and GeoGebra among others. Since it was not possible to study all these available computer applications at the same time, the study gravitates towards GeoGebra and how it can be useful in the Kenyan Mathematics curriculum, specifically in the area of Geometry.

Geometry has been defined by various scholars; as “a complex interconnected network of concepts, ways of reasoning, and representation systems that is used to conceptualize and analyze physical and imagined spatial environments” (Battista, 2001a). Geometry is also defined as a branch of Mathematics that is concerned with shapes, sizes, relative position of figures and the properties of space. Geometry is concerned with lengths, areas and volumes (En.wikipedia.org/wiki/geometry). Geometrical definitions have to do with space and shape. Hence when defining a geometrical shape, properties such as angles and measurements are used. According to Clements and Battista, (1990) “underlying most geometric thought is spatial reasoning which is the ability to see, inspect and reflect on spatial objects, images, relationships and transformations”. In the process of teaching topics and concepts involving Geometry, the teacher expects his/her students to be able to visualize figures, shapes and planes that many not be very obvious to the student. This concept is what makes geometry unique and difficult to teach and learn. This is because spatial ability is not easy for all students. Complications in teaching and learning of Geometry as cited in the second handbook of research on mathematics teaching and learning, Battista (2007), include:

i) Conception affects perception since what one sees is affected by what one knows and conceives.
ii) Diagrams as data or representations. It is through analyzing the geometrical diagrams that concepts are derived. According to Chazan & Yerushlmy, (1998) “diagrams are aids for intuition and are not necessarily the objects of study themselves” P70. The diagrams used in mathematics are representations of the actual object.

In teaching the concepts of geometry therefore, the teacher is faced with the task of helping learners ‘see’ the objects represented in the image and further derive some meaning from it. Looking at the Kenyan Secondary school mathematics, some of the topics that fall under this broad branch of mathematics include area, volume, geometrical constructions, trigonometry, longitudes, and latitudes as listed in Appendix C.

The Kenya National Examinations Council (KNEC) reports, 2008, 2009 and 2010 shows a consistent poor performance in Geometry. Questions recorded as being difficult according to candidates’ responses in sampled KCSE exam papers are tabulated on Table 1.2

<table>
<thead>
<tr>
<th>Year of Exam</th>
<th>Paper</th>
<th>Number of Questions Listed as Difficult</th>
<th>No. of difficult Questions in Geometry</th>
<th>Percentage of the Difficult Questions in Geometry</th>
</tr>
</thead>
<tbody>
<tr>
<td>2008</td>
<td>1</td>
<td>6</td>
<td>4</td>
<td>67</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>7</td>
<td>4</td>
<td>57</td>
</tr>
<tr>
<td>2009</td>
<td>1</td>
<td>10</td>
<td>5</td>
<td>50</td>
</tr>
<tr>
<td>2010</td>
<td>1</td>
<td>7</td>
<td>4</td>
<td>57</td>
</tr>
</tbody>
</table>

It is observed that more than other areas in secondary school mathematics, questions in Geometry are poorly performed.

National Council of Teachers of Mathematics NCTM (1995) findings show that more than other areas of school mathematics, the study of Algebra and Geometry is bound to change dramatically with the infusion of currently available and emerging technology. Lately, technology has been brought forth as a solution to improve the teaching and learning of the subject.

“Technology allows students to study algebra and geometry as the meaningful and related representations of functions, variables and relations rather than as an acquisition of skills in manipulating symbolic representations stripped of other meanings.” (NCTM 1995:1)

This learning style where students make relations between variables ensures proper understanding of concepts as opposed to rote learning.

Hiebert (2000) defines understanding as a situation when a mathematical idea or procedure or fact becomes part of an internal network of representations. He further clarifies that “the degree of understanding is determined by the number and the strength of the connections” p.65. Since technology has been found to allow students to study Algebra and Geometry by making meaningful related representations, then it is likely to improve understanding of concepts in these areas. The introduction of SMASSE in 1998 was mainly aimed at developing hands-on activities for students as this had been proposed as a way to improve understanding of concepts in mathematics. It is therefore the purpose of this study to establish the extent to which technology can improve students’ understanding and hence learning of Algebra and Geometry.

GeoGebra is a cross platform mathematics software that integrates Geometry and Algebra hence the name GeoGebra. These are major areas of study in secondary schools
mathematics, improving their teaching and learning is therefore paramount to an improvement in the performance of the subject. In his report Eshiwani (2001), shows the importance of Algebra in school mathematics, he says Algebra is the main transition from numeracy to mathematics. It is the core language of mathematics. Because of this, many other topics need knowledge of algebra, for example probability, geometry. Algebra is a basic component of mathematical literacy. GeoGebra combines Algebra and Geometry since it is impossible to do Geometry without Algebraic representations. Eshiwani (2001) defines Algebra as; Number systems (rational numbers, irrationals, complex), use of symbols, symbolic manipulation of expressions (expansion, factorization up to binomials), Binary relations (=, <, >, . . .) binary equations, unitary operations ( x -> |x|, 1/x, x^n, . . .) and sequential operations.

GeoGebra was first created in 2001 by Markus Hohenwarter as part of his Masters thesis in Mathematics Education and Computer Science at the University of Salsburg in Austria. GeoGebra is a dynamic software that has four components including Algebra view, Graphics view, Spreadsheet view, and the Input bar. Since 2006, GeoGebra, has been supported by the Austrian Ministry of Education and it has been used for teaching mathematics at high schools and universities. GeoGebra has also been used in USA at the Florida University and at other levels. Students using it have expressed satisfaction at how well they are able to solve related problems using the software. Could this be the missing link in the Kenyan mathematics teaching styles? This study tried to establish if this recent development in terms of technology can be useful in enhancing teaching and learning of mathematics in secondary schools in Kenya, looking specifically at topics in Geometry and how they can be improved using this software.
The study also assessed the uptake of technology (in this case GeoGebra) among teachers and learners. Mathematics is challenging to both teachers and learners. For ICT to help, the experience teachers have in using technology must be in context of mathematics concepts. This study assessed the uptake of technology in Kenya in relation to gender. It was keen to find out if these AAUW findings remain consistent in the Kenyan set up.

Technology in the teaching and learning of mathematics has been studied in several developmental research projects globally. Studies of computer use in school mathematics have largely examined innovations linked to developmental research projects. Many of these studies have investigated teacher participation and computer use in these developmental projects against the background of computer-based resources: for example, use of diverse interactive video materials to support a range of mathematical tasks at secondary level in England (Phillips & Pead, 1995); using GeoGebra to teach upper secondary level mathematics (Lu, 2008); the influence of dynamic geometry software on plane geometry problem solving strategies (Aymemi, 2009). Jaworski, (2010) has studied the challenges of using GeoGebra as a tool directed at generating conceptual understanding through exploration and inquiry for undergraduate mathematics students; Niess (2005) has investigated the development of prospective mathematics teachers’ technological pedagogical content knowledge in a subject specific, technology integrated teacher preparation program. Collaboration and partnerships on projects and studies on technology in mathematics in secondary education in Kenya have recently been on the rise, with developing the use of technology to support teaching and learning being identified as a priority in most of these projects.
1.3. Statement of the Problem and justification

Although the technology community has advanced the benefits of integrating technology in education, there are discerning voices that have cautioned on learning in technology-based environments. For example, research has shown that technology tools can engage students in authentic learning opportunities that enhance the development of basic and higher-order skills but United Nations Educational, Scientific, and Cultural Organization (UNESCO, 2008) warns that the success to integrate lies in the ability of the teacher to effectively integrate technology into classroom lessons. Drijvers and Trouche (2008) have acknowledged the double jeopardy of teaching and learning mathematics in a technology-based environment, given the complexities of teaching and learning and the complexities of use of the technology tool. Mathematics teachers should be knowledgeable about mathematics content, pedagogy and learners in relation to technology integration in learning. Drijvers and Trouche (2008:364) elucidate on the double reference phenomenon which is the double interpretation of tasks by teachers and learners giving an example where “tasks that address mathematical concepts may be perceived to address how the computer environment would deal with such a task”.

While technology tools can be used to foster mathematical thinking processes such as conjecturing, justification, and generalization, it is imperative that attention should be paid on how the use of technology enhances learning of specific topics in contexts of research area. Implementation of technology based instruction may boost mathematical thinking through visualisation and abstraction. Understanding of how GeoGebra is best suited for addressing learning high school geometry in Kenya requires an understanding of the constraints and affordances of GeoGebra.
The study focused on learning school geometry in the GeoGebra based environment by examining its feasibility in the Kenyan context. The study was motivated by the Kenya National Examinations Council (KNEC) reports of 2008, 2009 and 2010 which show that problems involving geometry have been poorly performed.

1.4. Purpose of the study

The purpose of this study was to investigate the influence of using GeoGebra on secondary school students’ achievement in Geometry in Kajiado County in Kenya. This entailed observation and analysis of efforts by teachers to engage students in the use of the application in classroom lessons.

1.5. Objectives

The study was guided by the following specific objectives:

a) To assess Mathematics teachers’ competences in technology
b) To assess the extent to which GeoGebra is used in teaching geometry concepts in Secondary schools in Kenya
c) To establish the relationship between use of GeoGebra in teaching and learning and students’ achievement in Geometry.
d) To establish gender differences in terms students’ achievement in Geometry after learning using computer applications such as GeoGebra.
e) To develop a prototype GeoGebra manual for Kenyan mathematics teachers.

1.6. Research questions

The study attempted to answer the following research questions:

a) What are the Mathematics teachers’ competences in the use of technology?
b) To what extent is GeoGebra used in teaching geometry concepts in Secondary schools in Kenya?

c) Is there a relationship between students’ achievement in Geometry and the use of GeoGebra in teaching and learning?

d) Are there gender differences in terms students’ achievement in Geometry after learning using computer apps such as GeoGebra?

1.7. Hypotheses

The following null hypotheses were applied for the study;

H0: There is no statistically significant difference in performance between students learning mathematics using GeoGebra and those not using GeoGebra.

H0: There is no statistically significant difference between the change in the mean scores of girls and that of boys in tests involving geometry after learning with the help of GeoGebra.

1.8. Significance of the Study

The findings of this study would be useful to scholars in the area of Mathematics Education as it will add to the field of knowledge. It would benefit secondary school mathematics teachers by giving them insight on how GeoGebra can be used to improve their teaching. The study findings would be useful to quality assurance and standards officers by enabling them to achieve better teaching and hence better results. School principals would know the importance of technology in mathematics as a subject and
hence be able to make informed decisions on which ICTs to provide in their schools. Students would be the main beneficiaries from this study since they would be able learn about GeoGebra and use it to achieve better understanding of mathematical concepts.

1.9. Scope and Limitations of the study

1.9.1. Scope
This study focused on the secondary school mathematics in Kenya. Therefore, the generalizations made in the conclusions are limited to the subject and at secondary school level only. Secondly, although there are many computer applications, the study focused on GeoGebra only and how it is used to unpack only two areas of secondary school mathematics; these two areas will be Algebra and Geometry. The researcher therefore did not attempt to find out how the learning in unrelated topics take place or attempt to intervene in other topics. The researcher did not look at general computer assisted learning (CAL).

1.9.2. Limitations
The study was mainly concerned with Geometry (although Algebra was implicitly dealt with) in secondary school mathematics in Kenya. The generalizations are therefore specific to selected topics of Geometry in secondary schools in Kenya. Although the researcher was interested in specific topics in Geometry in secondary school mathematics, the study will form a basis for study in other topics in Mathematics. Another limitation faced was that of scarcity of time and resources. The researcher however tried to optimize the available resources and plan for the available time to ensure
that the study was done successfully. The levels of ICT skills among teachers were also a
limiting factor, to overcome this, training was done for the selected mathematics teachers.
Since not all students were computer literate at the time, the study focused on schools
which had computers to ensure only students who were conversant with the computers
took part in the study in the experimental group.

1.10. Assumptions of the study

The study assumed that the selected students had some basic computer knowledge and
were comfortable with the use of computer so as to be able to manipulate the resource.
The study further assumed that secondary school mathematics teachers would be willing
to truthfully disclose areas and topics they experienced difficulties while teaching. It also
assumed that technology if well used was likely to make a difference in learning.

1.11. Theoretical framework

The study was guided by Diffusion Innovation Model adapted 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 channels, time, and social systems. 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:
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 lab, having a technician in the school and the teachers being qualified in computer use.

Persuasion and decision

Persuasion is important as it gives rise to the willingness to attend to the innovation. The teachers and student 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.

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. Trial ability- this refers to how easily an innovation may be experimented. If an individual is able to test a new innovation, he is more likely to adopt it.

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.

GeoGebra, which is a recent innovation, was investigated by this study. The study assessed the applicability of Diffusion Model in the Kenyan secondary school education mathematics curriculum. The study tried to establish if this application was in line with the Rogers model of implementing technology. Whether teachers would find GeoGebra useful in their teaching and find it easy to adapt? The study compared the performance of students using the computer app with that of their cohorts who were taught using conventional methods.
1.12. **Conceptual Framework**

This study on the use of GeoGebra in the teaching and learning of Mathematics looked at the topics involving Geometry in secondary school mathematics and how applicable the software would be in improving their learning and understanding. The dependent variable was the understanding of concepts in the area of Geometry which was measured using the performance of students in geometrical concepts in secondary schools in Kenya. The independent variables include the use of GeoGebra in teaching and learning of mathematics in the Kenyan secondary schools. The use of new computer application is influenced by some intervening factors such as compatibility, complexity, trial ability, 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. Other factors include knowledge, which refers to teacher training and ICT qualifications and social factors such as gender. The interaction of these factors will influence the decision of whether to use or not use the resource.

The contention of this study in using ICT to enhance the teaching and learning of mathematics was that these technologies might impact on learning leading to improved understanding. Kanja (2001) found out that students had difficulties understanding mathematical concepts. This study tried to intervene by introducing GeoGebra to enhance relational understanding in specific areas in Geometry which are core areas in secondary school curriculum. Assessment was used to find out the level of learning and hence give feedback to the teacher. Figure 1.1 conceptualized framework of the study.
Figure 1.1: Conceptualized Framework of the Study
(Source: Researcher’s consolidated ideas from DIM, and variables of the study)
1.13. Operational Definition of Terms

**Algebra**- the branch of mathematics in which symbols, usually letters of the alphabet, represent unknown numbers.

**Calculators**- electronic hand held device used to compute arithmetic. In this study, the word calculator was used in reference to scientific calculators which are recommended for secondary school students.

**Conventional methods of teaching**- This term will be used in this study to refer to the teaching using chalk and board for teachers; pen and paper for students. Rather the teacher uses other methods such as demonstration using examples, lecture methods, question answer methods among others.

**GeoGebra**- A computer software that has four views. The algebra view, geometry view, spreadsheet view, and the input bar.

**Geometry**- this is the branch of mathematics that is concerned with the properties and relationships of points, lines, angles, curves, surfaces, and solids.

**Information and Communications Technology** - the use of any equipment or software for processing or transmitting digital information that performs diverse general functions whose options can be specified or programmed by its user.
CHAPTER TWO

REVIEW OF RELATED LITERATURE

2.1 Introduction
This section gives literature review of the study. Literature was reviewed briefly under various headings including: use of technology in education, Africa and ICT, uptake of technology, reviewing various technology adoption models and GeoGebra use in mathematics, gender differences in technology and mathematics.

2.2. Use of Technology in Education
Educational change is indeed difficult to accomplish, and efforts that involve technology may be particularly difficult to achieve. According to Coffland, (2000), technology has the potential to transform the relationship between teachers and students and even to change what schools look like. However, the history of education reform provides scanty evidence that such transformation will occur simply because the technology exists.
Today, most countries include ICT integration, either in the national policies or in the laws pertaining to the education sector. In Australia, for example, the commonwealth Government has set goals for schools in relation to ICT development. The Government wants students to leave schools as confident, creative and productive users of new technologies in the society. Schools are expected to integrate ICT into their operations. In the Philippines Department of Education has also formulated policies for ICT use. The same trend is seen in Indonesia, Malaysia, Uzbekistan, Vietnam and other countries where the national government sets goals for ICTs in education. In Asia and the Pacific, including emerging countries, teachers in primary, secondary and tertiary levels are being
trained in the use of ICTs in education with varying degree of scope. Most of the training programs carry general objectives aimed at developing awareness, knowledge and skills in either the use of computers or the integration of computers into teaching and learning (IPS, 2003). In a study done in Canada almost all principals reported that their schools used desktop computers or laptops for educational purposes such as activities directed towards lesson preparation, execution or evaluation during the 2003/04 school year. Less than 1% of the elementary and secondary schools in Canada were without computers (Plante, 2004).

ICT started to be regarded gradually not only as a skill worthy to acquire, but also as a valuable tool for development of other skills. In the present world ICT has become an important component of a school curriculum, a support tool for providing teachers and students with enhanced teaching opportunities in the whole range of school subjects (Khatoon & Mahmood, 2011). The content of the national curriculum statements of countries like UK, the USA and Australia provide clear evidence of this shift from the teaching of ICT alone to the infusion of ICT as a significant tool in the school curricula (McDonald & Davis, 1995). In response to the modern advancement in technology, the revised curriculum in Kenya incorporated ICT as a teaching tool (Kenya Institute of Education, 2002).

Shunguyia (1995) conducted a case study of instruction technology in the curriculum of the education program of Kenyatta University. The study found out that the instructional media are meager and limited such that most student teachers end up finishing their training program without a single opportunity for involvement in necessary practical
professional experiences. The study further found out that communication technology department had constraints and shortages of various types (in relation to media), including equipment, technicians, practice rooms and ever present debilitating influence of the large student numbers (Shunguyia, 1995). The study recognizes that with such a background the teachers may have challenges incorporating technology in teaching. At the same time when the teachers have schools with good ICT facilities they may motivate the teachers to take advantage of the facilities and use them in teaching. This study assessed factors that may affect use of technology, in specific GeoGebra, since this has not yet been established.

2.2.1. Use of Technology in Teaching and Learning in Africa

In Africa, pre-service teacher training institutions in even the poorest African countries are slowly being equipped with computers and consequently, teachers are being exposed to this technology through various school networking initiatives as well as the presence of telecenters, multipurpose community centers and internet cafes (James et al., 2003). A viable example is NEPAD e-school program, one of the most ambitious African initiatives. The program is on a multi-collaborative partnership strategy between the NEPAD, major ICT companies and ministries/departments of education in different participating African countries. Due to high costs and shrinking educational resources in Africa and the increasing demand for secondary education in the regions, technology intervention is seen to be one of the most feasible choices for education transformation (Chisenga, 2006). Without disregarding the basic needs of secondary education in Africa, such as building more classrooms, there is growing evidence that ICTs may be the only feasible and economically sound means of expanding access to and improving the quality
of secondary education in Africa (Isaacs et al, 2002). The NEPAD e-school initiative is
designed to accomplish this goal through public-private partnership approach. As with so
many other educational ICT initiatives in Africa, its focus remains primarily on the
importance of giving pupils and teachers ICT skills, rather than on using ICT to enhance
their wider learning experience. A review of experience with ICTs in education project
by IEC (2001) elucidate that in Africa, projects tend to follow a pattern of high levels of
take-up.

Studies point to the fact that use of ICTs results in improvement in academic
performance. Two studies in the USA written by the National Center for Educational
Statistics (2001a & 2001b) found a positive relationship between availability of
computers in schools and test scores. In a study done in USA the level of computer use in
mathematics classes and scores on mathematics tests were compared and a positive
relationship was established between the use of computers and learning in both 4th and
8th grades (Wenglinsky, 1998). Similar positive relationships have been found in OECD
countries between computer uses and test scores for mathematics (Cox et al, 2003).

However, using ICTs is not a cheap solution for education, but can be a means of
facilitating the creation of new types of learning environment, by supporting distance
based models of teacher training, and by opening up a wealth of new educational
resources and thus playing a significant role in education. In its 2005 ICT in education
Options Paper, Kenya recognizes the many ways in which information and
communication technologies (ICTs) can be leveraged to support and improve the delivery
of quality education for Kenyans. These options are as per the educational priorities
outlined in Sectional Paper No. 1 of 2005 (G.O.K, 2005b) and Kenya Educational Sector Support Program (KESSP) document (G.O.K., 2005c) which include Quality Training and Learning through ICTs.

Waema, (2002) argues that, most curricula are oriented towards teaching the technical aspects of the technology and ignore the social and organizational aspects of ICT. Graduates lack organizational and managerial skills and are therefore inadequately prepared to deal with the complexity of analysis, design and implementation of ICT in educational organization. Waema, (2005) further argues that most programs for training ICT professionals are copied from economically developed countries with little modification to reflect the realities of industrial and development goals in individual countries. These training programs need to be adapted to the local environment to reflect among other things, the application environment, and availability of resources and capabilities of existing training institutions. Waema, (2002) says that, most curricula are rarely modified. In some situations, they are still geared towards producing people with specific skills that do not match the demand of the industry or reflect changes in technology. Early ICT initiatives in schools were essentially technology driven, aiming at developing students’ computer literacy. It is necessary to find out through this study if besides acquiring computer literacy, students can benefit by using computers for learning purposes to enhance understanding in the learnt concepts.
2.2.2. Uptake of Technology for Teaching

Technology is illuminated as the missing link in mathematics education by many authors, Hooper, & Rieber, (1995), Groman (1996), Darrel L. B & Sellbom (2002). The process of using technology in teaching is gradual and takes time to be actualized.

Many models have been used to explain how people use technology, what they use it for and why people choose to use technology. The model on adoption of innovation by Hooper & Rieber (1995) indicates that people grow from the familiarisation level to a point of utilisation and eventually they integrate the technology (shown on figure 2.2). This would mean a gradual growth in numbers of teachers using the technology in their classrooms. The model indicates that in use of technology, the traditional perspective of educational technology only goes up to integration model while involving students in active participation goes on up to a level of evolution. A total change of the learning process occurs if the teachers allow learners’ active construction to be pivotal in the mathematics lessons.

According to Hooper & Rieber, (1995);

Educational technology involves applying ideas from various sources to create the best learning environments possible for students. Educational technologists also ask questions such as how a classroom might change or adapt when a computer is integrated into the curriculum. This integration means that the curriculum and setting may also need to change to meet the opportunities that the technology may offer. P154

Educationists should avoid paying attention to the number of computers and hardware in a class only but should also be keen to explore how these can be used to change the classroom environment in order to aid the teaching and learning process. Hence, more attention is given to integration of technology in teaching and learning. A look at the
adoption model, users of new technologies begin with a basic step of familiarization, proceeds to utilization and then integration. According to Hooper, The distinction between educators who enter and stall at the Integration phase versus those who are "transformed" and enter the Reorientation phase is best characterized as a magical line on an "instruction/construction" continuum shown on Figure 2.1

![Figure 2.1 Transformation of the learning process from behavioral to construction](image)


According to Hooper, all learning philosophies are based somewhere on this continuum. Groman, (1996) discovered that through the use of Geometry Sketch Pads, students could construct medians of triangles and create conjectures that would eventually lead to the students writing proofs and thinking on higher levels. Groman contended that dynamic Geometry environments, allow students to learn through the vehicle of the constructivist theory. Technologies have the power to transform learning past the behavioral level.
According to Myers, (2009:20) “Constructivist teaching and learning removes the direct burden of the teacher being the sole disseminator of information and changes the role of the teacher into being the facilitator and not the primary source of all learning”. This makes the classroom learning more learner-centered. This is shown on Figure 2.2 on adoption of both idea and product technologies in education.

![Diagram of technology adoption phases]

**Figure 2.2:** A model of adoption of both "idea" and "product" technologies in education.


The Diffusion of Innovation model is the main model that explains how adoption of technology takes place since it is mostly used by marketers for new innovations. Innovators of technology are normally the least in number, making up only 2.5% of a population while the early adaptors are few and make up 13.5% of a population. Early majority take up the software to use it only if they are sure that it will work and that it is useful to them. These require that the dots are joined and their questions are answered.
This group requires encouragement to use an innovation. On the other hand the late majority group wants to see the innovation working then they can use it. In every population, according to the diffusion model, there is a group of 16% of the population that fear change and will not accept change. These require extra training and evidence of what has been achieved using the innovation. Figure 2.3 illustrates the categories of innovation as per the Rogers Diffusion of Innovation.

**Figure 2.3: Categories of Innovativeness**


According to Darrel & Sellbom (2002) a study on barriers in adopting technology in teaching and learning, identified barriers in use of technology as economic, social organizational and psychological. The study however noted the importance of faculty proficiency with technology. These barriers explain why adoption of technology is a
gradual process since some teachers require reason and justification before they can accept technology.

Another model trying to explain adoption of technology is the Gartner’s 1995 Hype Cycle. This is a branded graphical representation that was developed and is currently used by IT researchers in showing maturity, adoption and social application of technologies. It is used to characterise a typical progression of an emerging technology to its eventual position in a market or a domain. It shows five levels of uptake of technology as technology trigger, which just as the Rogers model has a small percentage of users. The peak is reached due to success stories from other users characterised by many users and experimentation in using the technology. Most users begin to get frustrated as they look for quick solutions and hence the numbers of users reduce. The stabilisation stage is reached later when technologies have been integrated beyond the frustration of users hence getting to enlightenment and further the productive stage. The Hype Cycle therefore is similar to the Diffusion of Innovation model as it also takes the shape of a normal curve with a peak arrived at in the middle of the cycle. It would be well informed to conclude that uptake of technology takes a normal curve with fewer users getting to the maturity, productive or evolution stage as shown by different authors. The Gartner’ Hype Cycle model just like the Diffusion of Innovation model by Rogers shows that at the beginning there is a positive steep slope upwards meaning that teachers or any other technology users are curious hence actively using the technology. The Hype Cycle is shown of figure 2.4.
The Gartner’s Hype Cycle indicates that the position of technologies move along a predictable pattern of enthusiasm, disillusionment and eventually gets to a point of realism. It highlights technologies that are the focus of attention because of particularly high levels of hype, or those that may not be broadly acknowledged. According to Gartner, (1995) a technology is introduced to users and gradually gets accepted by the market. Table 2.1 shows the phases of the Hype Cycle. When users understand the usefulness of a technology, it hits the peak through word of mouth and the hype that comes as a result of expected outcome from the technology.
Table 2.1: The Hype Cycle phases of technology adoption

<table>
<thead>
<tr>
<th>No.</th>
<th>Phase</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Technology Trigger</td>
<td>A potential technology breakthrough kicks things off. Early proof-of-concept stories and media interest trigger significant publicity. Often no usable products exist and commercial viability is unproven.</td>
</tr>
<tr>
<td>2</td>
<td>Peak of Inflated Expectations</td>
<td>Early publicity produces a number of success stories—often accompanied by scores of failures. Some companies take action; many do not.</td>
</tr>
<tr>
<td>3</td>
<td>Trough of Disillusionment</td>
<td>Interest wanes as experiments and implementations fail to deliver. Producers of the technology shake out or fail. Investments continue only if the surviving providers improve their products to the satisfaction of early adopters.</td>
</tr>
<tr>
<td>4</td>
<td>Slope of Enlightenment</td>
<td>More instances of how the technology can benefit the enterprise start to crystallize and become more widely understood. Second- and third-generation products appear from technology providers. More enterprises fund pilots; conservative companies remain cautious.</td>
</tr>
<tr>
<td>5</td>
<td>Plateau of Productivity</td>
<td>Mainstream adoption starts to take off. Criteria for assessing provider viability are more clearly defined. The technology’s broad market applicability and relevance are clearly paying off.</td>
</tr>
</tbody>
</table>

Source: Gartner in 1995. [www.gartner.com](http://www.gartner.com)

The adoption of innovation models reviewed in this section seem to agree that for most technologies, both hardware, software applications and also the communication involved in forming the broad body of information communication technologies (ICT) begin slowly, gradually as a low kind of unsure uptake by users at a familiarization level then
there is a rapid rush characterized with enthusiasm, followed by disillusionment in the face of real-world challenges such as content to be covered in classroom set up. After overcoming these challenges, users may develop a deeper understanding, overcome and adopt or give up on the technology and hence reject the particular technology. This study sought to investigate the uptake of GeoGebra as a technology for teaching mathematics in Kenyan secondary schools. It sought to find out the level at which the mathematics teachers were, and what their perception(s) towards the use of the technology.

### 2.3. Technology in the teaching and learning of mathematics

The formidable problem currently facing mathematics education in Kenya is the need to improve the students’ performance in mathematics. Mathematics is acknowledged by most people as essential and useful (Cockcroft 1982, Orton & Frobisher 1996, Khatoon & Mahmood, 2011). Its usefulness ranges from social, aesthetic, utility, and communication. Mathematics plays a pivotal role 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. Mathematics has been pointed as a subject area that requires practice, if the objectives of teaching the
subject are to be achieved. Another important aspect of mathematics is time management. Mathematics is a subject which not only examines what a student knows but also how fast and accurately he or she can express it without making errors, a reason why mathematics examinations are strictly timed.

Classroom teaching is a demanding job but most people outside education probably think teachers spend most of their time teaching. They do not understand that teachers are responsible for many tasks that have little to do with classroom instruction. Beyond planning and implementing instruction, teachers are also expected to be managers, psychologists, counselors, custodians, and community ambassadors, not to mention entertainers. Gunga, (2006) argues that teaching sounds like an unreasonable and almost impossible job. According to Hooper & Rieber, (1995) “it is easy to understand how a teacher might become frustrated and disillusioned” in the process of trying to spark joy and excitement in the learning environment. Unfortunately, the other demands of the classroom are very distracting and consuming. Research appears to support the belief that product technologies improve learning (Kulik, Bangert, & Williams, 1983). Yet, product technologies alone do not ensure good learning (Clark, 1983). Technology may be envisioned as a teachers’ liberator to help reestablish the role and value of the individual classroom teacher to do so, two things must happen. First the perspective of the classroom must change to become learner centered, as shown on figure 2.1. Second, students and teachers must enter into collaboration or partnership with technology in order to create a community that nurtures, encourages, and supports the learning process (Cognition and Technology Group at Vanderbilt, 1992). This shows the need for
technology in aiding teaching and helping the teacher in achieving his or her goals in class.

According to Hooper & Rieber (1995) in their paper on teaching with technology “The capabilities of product technologies are over emphasized.” For example, product technologies are often used to increase cost efficiency by replacing the classroom teacher or by transmitting lessons to larger audiences via satellites and telephone lines. The study indicates that such approaches are often misdirected. Although the importance of increasing access to education should not be devalued, reproducing existing materials is unlikely to improve educational quality. Rather, using technology as delivery media may perpetuate or even exacerbate existing problems. They reckon that the benefit of technology is not simply its potential to replicate existing educational practice, but its ability to combine ideas and product technologies to encourage students to engage in deeper cognitive activity.

The important aspect of using technology in teaching is combining ideas and products to enhance deeper cognitive activity mostly characterized as student engagement and understanding.

This study was done in schools that are relatively well endowed with ICT whereby the benefits of technology were investigated. Although the teachers have all these demanding responsibilities, it is the contention of this study (with insight from documented literature) that the use of technology will be of assistance to the teacher rather than an extra load. The study investigated the benefits associated with GeoGebra with a view of
finding out if it leads to construction of new knowledge and consequently improving understanding among Kenyan students.

The Kenyan classrooms are often composed of students from different backgrounds, with different levels of motivation and a wide ability range. This poses a challenge to the teacher and calls for a variety of teaching methods and approaches and incorporation of a variety of resources. In terms of technology, some of the students may be from humble family backgrounds or from remote areas and their interaction with technology at their homes is limited. Unlike their counterparts from well to do families, this initial interaction with technology will work to the disadvantage and advantage respectively in understanding the various applications. On the other hand if their initial interaction with technology was not associated with any serious academic use, there is likelihood that they will always be tempted to use the technology available in school for non-academic stuff such as playing computer games, visiting social sites or worst of all visiting pornographic sites. Further, those students from humble family backgrounds or rural set-ups may see the presence of technology in their school as a rare opportunity and may look for every opportunity to utilize it to the fullest. It may also not be surprising for such students to be the ones who are likely to be misled into using the technologies in self destructing activities mentioned earlier. This research investigated how the students benefit from the use of technology, particularly GeoGebra in their schools specifically in a mathematics lesson.

A sound lesson on any mathematical topic should involve multiple instructional methods. Incorporating several different instructional techniques increases the possibility of all students developing mathematical understanding through at least one method.
There is need for transforming mathematics lessons into students focused environment with meaningful activities that promote efficient learning of mathematics in our classrooms. Perhaps mathematics education in Kenyan secondary schools could greatly benefit from the use of computers in instruction because of the great potential in teaching mathematical concepts, which are either difficult to teach by conventional methods of instruction or where students motivation is low. Computer is perceived to provide students with the needed opportunity to participate actively in the classrooms (Manoucherhri, 1999). In addition to meeting the need of the students, computers can afford the teacher new ways of teaching a topic. The teacher is also to ensure that there is success for all students in the mathematics being taught. To be able to make full use of technology in a mathematics class it is important for the teacher to be efficient in the use of the technology. According to the advocators of ICT use in mathematics, the issue is no longer “if” ICTs are good for teaching but rather which and how these ICTs can be effectively implemented in the classrooms (Moon, 2004b). The students should also have enough time to learn and appreciate the technology. In this study, the benefits associated with GeoGebra as an application in a mathematics class was investigated. This study was designed to find out how students would respond to and hence benefit from GeoGebra as a relatively new technological advancement in Kenya.

2.4. The teaching and learning of Geometry

Researchers all over the world have tried to understand and explain how learning of geometry takes place and how students’ geometric reasoning develops. The Van Hiele levels of geometric thought described a student’s learning as one that develops through discrete, qualitatively different levels of thinking. These levels are sequential and
hierarchical implying that for students to function adequately at the advanced levels, they must have passed through the lower levels successfully (Clement & Battista, 1992).

According to Van Hiele, there are five Levels of Geometric Thinking (Pierre van Hiele 1986). These include the Visual, Descriptive, Abstract, Formal Deduction and Mathematical Rigor

Level 1: Visual level also known as pre-recognition level: Students at this level recognize figures by their appearance. For example, they may say that the shape on the left is a square and the shape on the right is a diamond ...."Because it looks like a...." the student makes a conclusion based on appearance rather than properties.

Level 2: Descriptive or Analytic

Students at this level recognize or analyze figures by their properties or components. For example, Students will describe figures above as squares because they both have 4 sides, 4 right angles, opposite sides equal....and as many other properties as they know about squares.
Level 3: Abstract or Relational

Students at this level can distinguish between necessary and sufficient conditions for a concept; they can also form abstract definitions, and classify figures by elaborating on their interrelationships. For example, a student at this level may define a square as a rectangle with consecutive sides congruent. A student is able to understand that although a square is a quadrilateral since it has four sides, not all quadrilaterals are squares since a square has other characteristics that qualify it.

Level 4: Formal Deduction

Students establish theorems within an axiomatic system. They recognize the difference between undefined terms, definitions, axioms, and theorems. They are capable of constructing original proofs.

Level 5: Mathematical Rigor

At this level, students reason formally about mathematical systems. Students understand the relationship between various systems of geometry. They are able to describe the effect of adding or deleting an axiom on a given geometric system. These students can compare, analyze, and create proofs under different geometric systems.

Other researchers have come up with theories on how geometric concepts are learnt while others have elaborated further on the Van Heile’s levels. Gutierrez, Jaime, & Fortuny, (1991) extended the levels to include motions and transformations which further clarify the learning process in Geometry. Clement and Battista, (2001) developed a set of waves to show different periods of development. They established that at different periods, different types or waves of reasoning are dominant depending on relative competence
that students exhibit with each type of reasoning. The main problem however associated to learning of geometric concepts is lack of ability to visualize concepts.

According to Webb, (2004), Webb’s Depth of Knowledge (DOK) measures the cognitive complexity and rigor of an item and also looks at how complex a geometry item is. DOK does not view tests items as taxonomy; instead an item is observed as a development from the previous item. Students cannot advance to the next level until they succeed in the lower level. DOK is concerned about the progression of the rigor that is learned and taught.

DOK levels of learning Geometry include,

Level One: Recall and reproduction (recall a fact or procedure, low complexity);

Level Two: Skill and Concept or basic reasoning (conceptual knowledge, low-early moderate complexity);

Level Three: Strategic Thinking or complex reasoning (reasoning, developing a plan, moderate complexity);

Level Four: Extended Thinking or reasoning (analysis and investigation, high complexity) (Williams, 2009).

These levels of learning Geometry by Webb are similar to the Van Hiele levels. They seem to agree on the fact that the lowest level of learning geometry is based on sight, while advancement and deeper understanding of Geometric concepts lead to deeper thinking and further analysis and complex thinking.

Researchers are advocating for computer environments to enhance teaching and hence learning of geometry. Mariotti, (2001) discussing about Dynamic Geometry environments that allow students to explore and manipulate states that
“they provide a revolutionary means for developing geometrical understanding by making exploration of geometrical configurations and the identification of meaningful conjectures more accessible to pupils” p.257.

Dynamic Geometry Environments DGEs such as GeoGebra, Dr Geo, Cabri, and Geometer’s Sketchpad were originally designed for teaching geometry in secondary schools. These applications allow learners to discover patterns, to explore and to test conjectures by constructing their own sketches. Dynamic mathematics software is a powerful teaching and learning medium and it has been reported to (a) enhance mathematics teaching; (b) help with conceptual development; (c) enrich visualisation of geometry; (d) lay a foundation for analysis and deductive proof; and (e) create opportunities for creative thinking (Sanders, 1998). Secondary School students can improve their understanding using software because the dynamic environment improves visualisation skills and ability to focus on interrelationships of the parts of geometric shapes (Clements, Sarama, Yelland & Glass, 2008).

Clearly, geometry as an area of study is unique and one that requires careful attention to enable learners develop from just visualisation, to synthesize to analysis and further be able to make representations. This study used GeoGebra as one of the available computer software to provide a dynamic geometry environment and assess learners’ ability not only to visualize but also to make representations in various geometric situations.

2.5. GeoGebra and teaching of mathematics education

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. 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; Seel, 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 visualisation. 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. Additionally, the McClintock et al (2002), study did not have a control group whereas the present study does.

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 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.” P. viii this study was done in Miami Dade County Public Schools among students in 10th grade.
This study compared the relationship between scores of students who learnt geometry using GeoGebra with the scores of students who learnt using traditional methods in secondary schools among form two students in Kenya.

2.6. Gender differences in technology and mathematics

According to a study by Myers, (2009) in Florida, There was no significant difference between the FCAT mathematics scores of the boys and the girls. This result is important because previous studies that compared the mathematics achievement of girls and boys stated that boys mathematically outperformed girls in high school.

Dix, (1999) conducted a study earlier in USA on eighth grade girls and boys using GSP as a treatment for the experimental group and pencil and paper for the control group. She also administered a computer attitudinal survey. The results of her survey revealed a significant difference in the ways boys and girls thought about the use of computers. The study revealed that boys and girls thought positively about the use of computers. However, an analysis of the survey results revealed that the boys thought more positively about the use of computers. Dix’s study also showed that through the use of technology, girls can improve their thinking on mathematical tasks, thereby giving the girls more inspiration to perform just as well as the boys or possibly even outperform the boys in mathematics. This finding is important to current study as it will help in comparing these findings based on students in countries where technology learning is well established and the findings in a country like Kenya where there is still a struggle in embracing use of technology in schools.
Altermatt & Kim, (2004) stated that boys outperformed girls in mathematics because boys were exposed to hormones in the womb that lead to more analytical thinking in the brain and increased spatial abilities. They also stated that some girls suffered from “low confidence and high uncertainty,” and that these qualities are exposed during mathematical thinking. Martinot & De’sert, (2007) examined a group of fourth and seventh graders to explore whether they were aware of these gender stereotypes. According to the results of the study, seventh grade boys believed that the girls were academically superior in mathematics. The girls, on the other hand, held deep-seated beliefs that their mathematical abilities were lower than that of the boys’. That study opens a window into the minds of girls and boys and provides additional support for claims that boys think differently than girls. Bracey (1994) discovered that boys look at mathematical problems differently than girls do. Boys use a “top-down” approach in which they quickly identify what category a problem belongs to and make adjustments accordingly, whereas girls use a “bottom-up” method in which they look for patterns as they pull together information from the problem. Bracey suggested that girls are more likely than boys to spend time examining “irrelevant” information as they attempt to solve a problem. Bracey stated that boys quickly discard irrelevant information and stick to the rules and algorithms for solving problems. Through the use of Geometers Sketchpads (GSP) students can instantly make and examine conjectures and determine quickly if certain properties are relevant or not. The use of GSP may be able to assist girls in solving the problem more effectively, Forum for African Women Educationalists (FAWE, 2008), (Duflo et al., 2009).
When studying the performance of students in Koibatek District, Baringo County, Mbugua et al. (2012) found that boys performed better than girls in science mathematics and technology (SMT) subjects. Same results can be confirmed from other counties in Kenya (Sifuna, 2006), (Wambua, 2007). Research studies indicate that in Kenya women’s participation and performance in SMT subjects and courses is worse than that of men at all educational levels (Agesa & Agesa, 2002). This is supported by the Gender Policy in Education which reports that scarcity of resources and insensitivity to the needs of girls in many schools creates a gender insensitive infrastructure which adversely affects girls’ performance more than boys (Republic of Kenya, 2007).

Education reports show that in 2003/2004 academic year, only 4% of engineering students enrolled in Kenyan Universities were women (Sifuna, 2006). In national polytechnics only 5% of the women enrolled were in science or engineering programs in 2004/2005 academic year (Republic of Kenya, 2005; UNESCO, 2008)

All the studies reviewed here reported the similar conclusions. All over the world and in Kenya, the trend seems the same. There is a discrepancy in performance of girls and that of boys in mathematics with boys outperforming girls. According to (Myers, 2009) in the lower grades girls outperforms boys in mathematics. As students move into the middle grades, boys are expected to take the lead in mathematical abilities over the girls. Beginning in middle school the boys do take a lead in mathematics achievement. Myers’ study however revealed that there were no significant differences between the FCAT mathematics scores of the boys and the girls when GSP was used. This is similar to findings by Oche, Clement & Abari, (2015) who concluded in a study based in Nigeria.
that GeoGebra would give girls an opportunity to perform just as well as boys or even better. This is also similar to the findings of Dix, (1999). Girls are likely to outperform boys in mathematics in a technology environment.

This study investigated if there was significant difference in scores of boys and that of girls in mathematics when studying using GeoGebra in Kenyan secondary schools.

2.7. Summary of Literature Review and Identified Gaps

From the review of literature, it was noted that many factors affecting the integration of technology in secondary school mathematics and in other institutions of learning. Some of these factors are general to all the subjects and also in administrative matters. These factors include teacher and student preparation to integrate and use technology in education, teacher professional training towards technology and student training on computer literate skills.

There has been an increase in the use of computers in the recent past and this may have changed the attitude of teachers towards use of technology. In addition, some of the teachers who may be relatively younger may have been frequent users of technology during the pre-service training therefore are able and willing to incorporate technology in teaching. Three models on uptake of technology are discussed in this chapter. This study will investigate how teachers respond to a new innovation and assesses their uptake.

Research by NCTM has shown Geometry as being an area that requires careful considerations during preparation and teaching to ensure learners understand the concepts. DGEs are recommended to enhance understanding and improve learning. One would be interested to know the benefits that come with use of GeoGebra in activities
like graph generation as compared to manual drawing. A similar study carried out in USA 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”. It has been seen that not much research has been done on GeoGebra application in teaching and learning mathematics in Kenya. This study specifically addresses the application of GeoGebra in learning mathematics and its effects on the performance of the students in comparison to the performance of students who do not use GeoGebra.

Review has shown that boys generally perform better than girls in mathematics and sciences however; a study based on mathematics learning using a dynamic geometry environment showed that there was no significant difference in performance of boys and girls when learning mathematics using dynamic geometry. Is this the case with other dynamic geometry software such as GeoGebra?
CHAPTER THREE

RESEARCH DESIGN AND METHODOLOGY

3.1. Introduction

This chapter focuses on research methodology. Specifically, it describes; the design, the respondents of the study, the sampling procedure, the research instruments, determination of validity and reliability of the instruments, pilot testing, data collection, data analysis and ethical considerations.

3.2. Research Design

The term “design” has often been used in relation to the planning and conducting of experiments (Mugenda, 2008). Research design therefore defines how any kind of research was conducted. 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.

This study was aimed at investigating the applicability of GeoGebra in the teaching of secondary school Mathematics in the Kenyan curriculum. The study established topics in Geometry in secondary school mathematics and adopted activities that would enhance their teaching.

A quasi experimental design (quantitative procedure) was used to test Hypothesis (1 and 2) of the study. Kothari, (2004) defines this design as “before-and-after with control design”. In this type of design
“Two areas are selected and the dependent variable is measured in both the areas for an identical time period before the treatment. The treatment is then introduced into the test area only, and the dependent variable is measured in both groups for an identical time-period.” P.42

This design involves non-random assignment of participants to two groups namely treatment and control groups. This study compared the performance of students taught using GeoGebra (treatment group) and those taught without GeoGebra. The control group was taught using conventional methods such as teacher demonstrations, assignments and supervised practice. Figure 3.1 shows the groups that were used for the study.

<table>
<thead>
<tr>
<th>Experimental</th>
<th>R</th>
<th>O₁</th>
<th>X</th>
<th>O₃</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control</td>
<td>R</td>
<td>O₂</td>
<td>⊗</td>
<td>O₄</td>
</tr>
</tbody>
</table>

Key: R- Random assignment  O₁ and O₂ – Pre-test  X- treatment/ intervention  ⊗ – No treatment  O₃ and O₄ – Post test

**Figure 3.1: Nonequivalent Pre-test and Post-test Research groups**

According to Mugenda (2008) pre-test and post-test control group kind of study is useful in social research as “the pretest and control add value and reduce threats to internal validity.” P.77

In addition to the quantitative procedures used, a qualitative approach was used to assess the teachers’ response towards technology and their readiness to use GeoGebra in their classrooms. Questionnaires for the sampled mathematics teachers was used as well as observation protocol to respond to objective 1 one this study.
3.3. Location of the study

This study was based in Kajiado County in Kenya. This county is in rift valley province of Kenya. The county has a total of 42 registered public secondary schools. Six schools, three of which were equipped with ICT resources (in this case computers), were sampled for this study. Although Kajiado is well endowed with natural resources, it has both extremes in terms of ICTs in schools for instance some schools are marginalized while others are well fitted with infrastructure. In December 2011, association of commonwealth universities selected five of the secondary schools in marginalized areas and awarded to them computers and other ICT resources in a project meant to improve the use of ICT in the area http://code.google.com/p/ruralcafe/wiki/introduction.

This initiative helped improve the level of ICT among secondary schools in the Kajiado County. It is worth noting that Kajiado County is currently rated second to Nairobi the capital city of Kenya in terms of computer infrastructure among the secondary schools in the country. On the other light, Kajiado County is documented as having the highest level of illiteracy among girls.

Gender discrimination is recognized by Kenya's government and other organizations as the number one cause of persistent poverty among the Maasai, causing a higher than average rate of illiteracy, as well as preventing economic development in the area…. The widespread benefits to societies of educating women are well-documented. This is true in every culture, worldwide. This is true in Kenya. This is true in Kenya's Kajiado County, where two-thirds of its Maasai population lives. www.maasaigirlseducation.org

This study sought to investigate the effect of technology the case of GeoGebra in improving the level of education for the girls besides that of boys in Kajiado County due to its high level of girls’ illiteracy.
3.4. Variables

The dependent variable was the performance of students in geometrical concepts in secondary school mathematics in Kenya which is influenced by the understanding of concepts in the area of Geometry. Since understanding is not measurable, measuring performance and the eventual change in performance, the study made useful conclusion about the change. The independent variables included the uptake and use of technology, in this case GeoGebra in teaching of mathematics in the Kenyan secondary schools. According to Rogers, (1995), the use of new computer application is influenced by some intervening factors such as compatibility, complexity, trial ability, social factors such as gender and most important the relative advantage of the innovation. These factors are expected to play a role in performance of students in the area of Geometry.

3.5. Target Population

Target population refers to the collection of individuals or regions that are to be investigated in a statistical study (Mugenda & Mugenda, 1999). The target population for the study comprised of the 42 public secondary schools in Kajiado County in Kenya. Although there are some private schools in the county, the study focused on public schools since public schools follow a structured program that ensures that the schools are covering similar content around the same time. Some Private schools have a set up program that ensures that students are taught extra hours hence covering more content. Also since the researcher intended to interact with the teachers during the SMASSE training meetings, public schools were considered more suitable as most of the Mathematics teachers were expected to attend.
3.6. Sample and Sampling Procedure

A sample is a finite part of a statistical population whose properties are studied to gain information about the whole (Webster, 1985). When dealing with people, it can be defined as a set of respondents (people) selected from a larger population for the purpose of a survey or study. The process of sampling is that process of selecting the subjects for the purpose of the study.

In this study, sampling was done at two levels. First, 7 secondary schools (2 boys’ schools, 2 girls’ schools and 3 mixed schools) were sampled through purposive sampling. The criterion here was to choose schools that were well equipped with ICT resources whereby teachers were well versed with computer applications and their uses. Schools with adequate computers to serve a class were sampled to ensure that students to computer ratio did not exceed three to one (3:1). This meant that at most three students were sharing one computer. The study determined schools that fit this criterion from the information available at the Ministry of Education e-readiness reports. Secondly, the Form 2 class was selected purposively. Form two was selected since the students 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 as shown in Appendix E; most topics in Form 2 class fall under Geometry. Further, it was expected that the students had settled in secondary school as opposed to form one classes and hence had already acquired basic computer knowledge. Form four classes were not used in the study as they are examination classes. The Form Three mathematics content on the other hand has only three topics falling under Geometry. These topics are spread in the three schools terms which would make it difficult to monitor progress, as compared to
the Form two topics that are all covered during the second term. Out of the seven schools, six were used for the study while one mixed school was used to pilot and help in refining the instruments. Out of the six schools, three were used as experimental group while the other three were used as control groups. There was an average of 50 students per class, in total there were 270 students participating in the study while 50 were involved in the pilot study. The sampling grid on table 3.1 shows the number of schools in the county and the numbers sampled from each category.

Table 3.1: Sampling Grid

<table>
<thead>
<tr>
<th>Category of school</th>
<th>Number of sampled schools</th>
<th>Number of students per class of sampled school</th>
<th>Number of sampled mathematics teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>8 boys schools</td>
<td>1 Experimental, 1 Control</td>
<td>36, 52</td>
<td>10 teachers</td>
</tr>
<tr>
<td>9 Girls’ schools</td>
<td>1 Experimental, 1 Control</td>
<td>45, 50</td>
<td>10 teachers</td>
</tr>
<tr>
<td>25 mixed schools</td>
<td>1 Experimental, 1 Control</td>
<td>36, 51</td>
<td>13 teachers</td>
</tr>
<tr>
<td><strong>Total: 42 schools</strong></td>
<td><strong>Total: 6 schools</strong></td>
<td><strong>Total: 270</strong></td>
<td><strong>Total: 33</strong></td>
</tr>
</tbody>
</table>

To be able to respond to the first objective of the study which is meant to establish the uptake of teachers in technology, a large number of Mathematics teachers in the county were sampled for the sake of training although their schools were not necessarily used in either control or experimental groups in the use of GeoGebra for learning. There were a
total of 149 teachers in Kajiado County out of which the study sampled 33 teachers to establish teacher uptake of technology. The sampling of teachers was done by simple random sampling. The purpose of this was to increase the sample so as to have a way of generalizing the uptake of technology by the teachers.

A similar study carried out in Turkey by (Demirbilek & Özkale, 2013) in 2013 only 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 with GeoGebra software, the control group was exposed to a traditional lecture for four weeks. This study recommended further research using a larger number of students.

This current study used a sample of 270 students with the aim of comparing the findings and making recommendations although in a different country.

3.7. Research Instruments

A research instrument is defined as a testing device that measures a given phenomenon. medical-dictionary.thefreedictionary.com

This study was done using various research instruments; the pretests examinations for the sampled students were administered in order to establish, the learners’ level of knowledge and exposure in the identified topics. Training manual was used to train mathematics teachers from the schools that were used as experimental groups. Post-test were done after exposure to topics in Geometry using GeoGebra for experimental groups while the control groups were used to establish if there was a statistically significant difference in performance after using GeoGebra and those students not using GeoGebra.

To minimize other intervening factors between the control and experimental group, the
two groups were picked from different schools. Observation by the researcher was done using an observation protocol on how different teachers and students (male and female) responded to the training and how they embraced the teaching and learning resource. After the training, a Mathematics teachers’ questionnaire was administered to the teachers in relation to the training and the teaching of mathematics using the computer application.

3.8. Pilot Testing

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”. In piloting the research instruments one is able to evaluate the instruments and see how effective they would be in collecting the data and hence answering the intended research objectives.

The piloting for this study was done in one of the sampled mixed schools, leaving the remaining six schools to be used for the purpose study. The choice of the school used for piloting was through purposive sampling. The rationale for using a mixed school was that it would be possible to look at the girls and boys at the same time and analyze the data in terms of gender differences. This also ensured that less time was used and at the same time ensuring that the instruments were refined appropriately. The main aim of the pilot study was to refine the research instruments. Through piloting corrections on the research instruments were done (Orina, 2000).
3.9. Determination of Validity and Reliability

Measurement errors could arise from faults in the instruments, incorrect interpretations of obtained values or instability in the behavior of respondents. These errors could be systematic or random. Systematic errors or bias occur when the errors are made in one direction away from the true score. Random errors on the other hand are attributable to chance factors. Reliability is defined as the extent to which a questionnaire, test, observation or any measurement procedure produces the same results on repeated trials (Kothari, 2004). In short, it is the stability or consistency of scores over time or across raters. In this study the researcher ensured the measurement instruments used measured the true score by; first, testing them on a small group to check for any inconsistencies and errors. After doing this -pilot testing, the researcher was able to make relevant adjustments consequently administer the instruments to the sampled subjects.

3.9.1. Internal Consistency

Internal consistency for the pretest and posttest was estimated through the *split-half reliability* index. The split-half estimate entails dividing up the test into two parts (e.g., odd/even items or first half of the items/second half of the items), administering the two forms to the same group of individuals and correlating the responses. This was done during pilot testing with a mixed school that had 50 students. According to (Feldt & Brennan, 1989) when piloting to test for reliability, the statistic takes into account the number of scores that are used. Fewer scores mean a lower likelihood of achieving good reliability. For the purposes of technical skill assessment, you should strive to have at least one full class of students.
The oldest and probably most widely used split-half coefficient calculates the correlation between scores on two halves of the test ($X_1$ and $X_2$) and estimates the correlation – reliability – for a full length test with the Spearman–Brown “prophecy” formula, assuming strictly parallel test halves:

$$SB_{rxx}' = \frac{2r_{x_1x_2}}{1+r_{x_1x_2}}$$ (Feldt & Brennan 1989).

Each of the students was scored and analysis done using Ms Excel. A Pearson Product Moment Correlation of 0.725217 and Reliability of 0.840726 were obtained for the Mathematics achievement test used. The test items were therefore found to be reliable as Webb, Shavelson & Haertel (2006) indicates that reliability of 0.8 and above is acceptable.

The mathematics teachers’ questionnaire was tested for reliability using the Cronbach alpha test. The instruments were found to have an alpha of 0.79 which implied that the questionnaire had internal consistency. Reliability was ensured by use of triangulation whereby different instruments were used, including Mathematics teachers questionnaire and observation Observation protocol.

### 3.9.2. Validity

Validity on the other hand is defined as “the degree to which an instrument measures what it purports to measure” (Mugenda 2008 p.256). Validity of data depends on the degree to which extraneous variables have been controlled in the study to ensure that the change observed in the dependent variable is actually as a result of the treatment.

In this study, the sampled groups- control and experimental were selected from different schools to minimize interaction between students after and before the treatment or
intervention. The decision to use various instruments in collecting data was also meant to ensure the validity of the instruments used. An observation protocol was used in the Mathematics classes and pictures were taken of the GeoGebra classes to justify the students’ results in the post test examinations and to show the uptake of technology among teachers and learners.

3.10. Data Collection

The first step towards data collection was to hold familiarization meetings with the teachers and the schools. April holiday SMASSE training sessions that bring together all mathematics teachers from Public Secondary Schools in the county were used so as to meet and create a rapport with teachers. During this period, schools were visited to assess their ICT levels and hence made informed selection of favorable schools to be used in the study.

Data was then collected in the following procedure; A pretest examination (on Appendix A) was administered to the Form 2 students to assess them in the area of Geometry and establish their entry behavior. Secondly, training of mathematics teachers (in schools selected as experimental) was done by the researcher. The training was done in one day using Gerrit Stols training guide for GeoGebra (GerritStols GeoGebra in 10 lessons). The teachers who were trained on GeoGebra use then taught their students the respective identified topics in Geometry, at the same time the students in schools selected as control groups were taught the same content. During this process observation was done using the observation protocol provided on Appendix C, pictures and videos taken to show how students interacted with the learning resource. After the process of intervention by training and teaching, the post-tests (shown on Appendix D) were administered by the
subject teacher to assess the learned concepts. To respond to second and third objectives, the study teachers taught their students and administered the tests in duration of 5 school months (specifically second term and part of third term) during which several topics in geometry are taught in Form 2. These topics are shown on table 3.2 which is extracted from Appendix E.

Table 3.2: Form 2 Topics Involving Geometry and Algebra

<table>
<thead>
<tr>
<th>Topic</th>
<th>Lessons</th>
</tr>
</thead>
<tbody>
<tr>
<td>27.0.0 Equations and Straight Lines (12 Lessons)</td>
<td>Algebra and Geometry</td>
</tr>
<tr>
<td>28.0.0 Reflection and Congruence (12 Lessons)</td>
<td>Geometry</td>
</tr>
<tr>
<td>29.0.0 Rotation (12 Lessons)</td>
<td>Geometry</td>
</tr>
<tr>
<td>30.0.0 Similarity and Enlargement (19 Lessons)</td>
<td>Geometry</td>
</tr>
<tr>
<td>31.0.0 Pythagoras Theorem (4 Lessons)</td>
<td>Geometry</td>
</tr>
<tr>
<td>32.0.0 Trigonometry (19 Lessons)</td>
<td>Geometry</td>
</tr>
<tr>
<td>33.0.0 Area of a Triangle (7 Lessons)</td>
<td>Geometry</td>
</tr>
</tbody>
</table>

From the list of topics, the study appreciates that the order is suitable for research as the topics are taught in succession within one school term. This made the choice of form two, second term appropriate for the study.

Three groups (as shown on Figure 3.1) were taught using GeoGebra while the respective cohorts from three different schools were taught without using GeoGebra. For sampled schools that had more than one stream in Form two class, only one stream was involved in the study although all Mathematics teachers in the school would be trained. The results of the tests for the two groups were analyzed. Objective one that required the study “to assess teacher’s up-take of technology in the process of teaching mathematics” was
answered through observation of the teachers during training. An observation protocol was used during the mathematics lessons. Multimedia such as pictures and videos were used to show the classroom activities using GeoGebra. A questionnaire administered to teachers after training helped to respond to this objective.

3.11. Data Analysis

The study produced both quantitative data and qualitative data, showing scores of students in the control group and also the experimental group. In analyzing the data collected, split plot analysis of variance ANOVA was used to establish how the performance of students using GeoGebra varied with those learning without using GeoGebra. ANOVA was used to test the stated hypothesis at a statistical significant level of $p<0.05$. The tests of significance were done to establish the difference between the performances of students in geometrical concepts taught. The questionnaire administered to teachers during and after training was also be analyzed using descriptive statistics.

3.12. Logistical and Ethical Considerations

An authorization letter was obtained from the graduate school of Kenyatta University as well as permission from the ministry of Education to conduct the research in Kenya. Permission was also sought from the principals of the sampled schools to allow the research to be conducted in their schools. Before administering the instruments, the researcher talked to the teachers and students to be involved in order to create a rapport. The information collected was kept confidential and used only for the purposes of the study.
CHAPTER FOUR

PRESENTATION OF FINDINGS, INTERPRETATION AND DISCUSSIONS

4.1. Introduction

This chapter details the findings, interpretations, implications and discussions according to the objectives and hypotheses of the research conducted in sampled secondary schools in Kajiado County between May 2014 and March 2015.

4.2. General and Demographic Information

4.2.1. Teachers’ population by gender and type of school

Kajiado county had 149 mathematics teachers by 2nd term 2014, this number was however not static due to a high mobility of teachers from one school to another and by others exiting the service. The study sampled 22% of the total mathematics teachers in the county this included both male and female teachers. Table 4.1 shows the population of male and female mathematics teachers in Kajiado County and table 4.2 shows the gender of sampled teachers. The study sought to investigate the teachers’ perceptions towards GeoGebra and relate these attitudes to actual use of the technology.
Table 4.1: Population of Mathematics Teachers in Kajiado County

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>107</td>
<td>71.8</td>
</tr>
<tr>
<td>Female</td>
<td>42</td>
<td>28.2</td>
</tr>
<tr>
<td>Total</td>
<td>149</td>
<td>100.0</td>
</tr>
</tbody>
</table>

SOURCE: TSC office Kajiado County.

Table 4.2: Sampled Teachers by Gender

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>23</td>
<td>21.5 of male</td>
</tr>
<tr>
<td>Female</td>
<td>10</td>
<td>23.8 of female</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td></td>
</tr>
</tbody>
</table>

As Table 4.2 shows, the teachers’ sample comprised of 23 male and 10 female teachers. These figures represent 21.5% of all the male teachers and 23.8% of the female mathematics teachers. This shows that there was a fair distribution in terms of percentage of the total male and total female teachers. The sampled teachers were proportionately picked through simple random sampling. Preliminary findings, as shown on Table 4.1 indicate that out of a total of 149 mathematics teachers in the county, only 28% comprised of female teachers while the higher percentage of mathematics teachers were males. This is a reflection on the documented culture of the people in this particular county with respect to girls’ education www.maasaigirlseducation.org. The low number of the female mathematics teachers was however not something this study could ignore, although it was not the core of the study. According to the report by Hill, Corbett and St. Rose in AAUW (2008) on “Where the girls are:” the report shows that there are few women in STEM; Science, Technology Engineering and Mathematics. The study sought
to determine if GeoGebra is a tool that can be used by both boys and girls to learn mathematics on a common platform. A further study aimed at finding out if there is a correlation between the gender of teachers and the attitude of girls towards the subject would be useful.

4.2.2. Type of Schools from which teachers were sampled

The study incorporated teachers from three types of schools, namely: boys’ schools, girls’ schools and mixed schools. Table 4.3 shows how the teachers’ sample was distributed in the three types of schools.

Table 4.3: Teachers’ Distribution in the Three Schools

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Boys School</td>
<td>9</td>
<td>20.0</td>
</tr>
<tr>
<td>Girls School</td>
<td>9</td>
<td>20.0</td>
</tr>
<tr>
<td>Mixed School</td>
<td>15</td>
<td>60.0</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>100.0</td>
</tr>
</tbody>
</table>

A look at Table 4.3 reveals that nine teachers were drawn from boys’ schools, nine from girls’ schools and 15 from mixed schools. A half of these teachers were teaching boys and the other half were teaching girls. This was important for the study because the study required the perspectives of teachers teaching both male and female students.

4.2.3. Sampled Teachers’ Teaching Experience

The researcher included teachers who had taught for varied periods of time in the sample. This ensured that the sample was all inclusive and hence a representative of mathematics
teachers in general. Figure 4.1 shows the duration (in years) for which the teachers had been teaching mathematics by the time the study was conducted.

**Figure 4.1: Duration in years that Respondents had been Teaching Mathematics**

An examination of figure 4.1 reveals that 21 of the teachers, accounting for 64% of the sampled teachers had been teaching mathematics for more than 15 years. Only four of the teachers had taught for less than ten years. The study benefited from the fact that the teachers sampled had many years teaching experience. They not only had teaching skills developed over many years, they also understood the challenges of teaching mathematics in secondary school and could identify the most difficult and poorly performed topics.

**4.3. Assessment of sampled teachers’ competences on ICT**

In line with the first objective, the sampled teachers were requested to state the highest level of professional training they had undergone. Their responses are summarized in Table 4.4
Table 4.4: Teachers’ Level of Training

<table>
<thead>
<tr>
<th>Degree</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Masters Degree</td>
<td>7</td>
<td>21.0</td>
</tr>
<tr>
<td>Bachelors Degree</td>
<td>25</td>
<td>76.0</td>
</tr>
<tr>
<td>Diploma</td>
<td>1</td>
<td>3.0</td>
</tr>
<tr>
<td>Total</td>
<td>33</td>
<td>100.0</td>
</tr>
</tbody>
</table>

Table 4.4 reveals that 25 teachers had bachelor’s degrees while five had masters’ degrees in various fields. Only one teacher had a diploma. Therefore, the teachers who participated in this study could be said to be sufficiently qualified to teach mathematics by virtue of their levels of training. In addition, teachers were asked about their qualifications in computer use. All the teachers except one had computer related training and qualification. Figure 4.2 shows the computer related skills the teachers have mastered.
Figure 4.2: Teachers’ Computer Skills

Figure 4.2 reveals teachers computer skills. All the teachers were capable of using Microsoft word and all but two are capable of using PowerPoint and preparing assignments and exercises on computers. Eighteen teachers were able to use formulas in spreadsheets. This information leads to the conclusion that most of the teachers are skilled in using computers therefore they would have no problems using teaching software such as GeoGebra.

4.3.1. Areas of Mathematics Teachers found Difficult to Teach

The teachers participating in this study were asked to state the areas of mathematics they found difficult to teach and note the reasons behind the challenges in teaching those areas. Despite the fact that teachers were trained to teach Mathematics and had some knowhow on technology use, performance in mathematics as indicated in problem
statement of this document remained poor. Teachers admitted that they had problems teaching some areas of secondary school mathematics as presented in Figure 4.3

![Pie Chart: Teachers having Difficulties Teaching Mathematics](image)

**Figure 4.3: Teachers having Difficulties Teaching Mathematics**

The responses summarized in Figure 4.3 show that only four teachers were not facing problems teaching mathematics. Geometry was reported to be the most challenging area to teach followed by algebra. It was established that more than half of the teachers face difficulties in teaching geometry and six of them face difficulties teaching algebra – the two topics GeoGebra is designed to help teach. The teachers who said they had trouble teaching geometry cited lack of resources for teaching, the abstract nature of geometry and students’ inability to visualize 3-dimensional images as the main impediments. For algebra, they cited students’ difficulties comprehending complicated expressions and the abstract nature of the topic.
4.4. Extent to which GeoGebra is used in teaching geometry concepts in secondary schools in Kenya

This section responds to the research question: To what extent is GeoGebra used in teaching geometry concepts in Secondary schools in Kenya?

Through observation and Mathematics teachers’ interviews, the study revealed that mathematics teachers in Kajiado County were not using GeoGebra before this study. Only 2 out of 33 interviewed teachers said they were using GeoGebra for setting exams and practice questions for their students. However, they were not in the habit of using the resource for teaching.

For the purpose of this study, the sampled mathematics teachers were trained for one day on use of GeoGebra using the Gerrit Stols training guide which is simple, precise and easy to use. A prototype training guide was developed to help Kenyan mathematics teachers to use GeoGebra in the geometry topics. Exercises and questions from the form two Mathematics content in Kenyan secondary school curriculum were incorporated in the training guide. Through this, the study assumed that the teachers would own the process. Through discovery approach, teachers explored the power of GeoGebra in learning Geometry based on Form Two content, a context they were familiar with. GeoGebra has icons which provide a list of steps required to achieve required goals. For example, when you click on the reflection icon, it tells you the steps to follow so as to reflect an object about a line of a point. Teachers seemed to be better engaged with these activities. Figure 4.4 shows an example of activities teachers did using GeoGebra and how the screen appears. The dropdown menu shows all the activities one can do given an
object. These include, reflecting about a point, reflecting about a line, reflecting about a circle, rotation and also enlargement. Due to ease of use of the application, teachers were able to explore and learn within a short time and transfer the same to their students with a little variation from training module.

Figure 4.4: Geometry view of GeoGebra

4.4.1. Teachers’ Perception of their Competence in using GeoGebra

The study sought to find out teachers’ perception of their competence with GeoGebra after they received training on how to use it to teach mathematics. The teachers were presented with five items to gauge their competence by responding on each item using a Likert scale on a continuum. The information summarized in Figure 4.5 reveals teachers’ perceptions of their competence with GeoGebra after they received training on how to use it. It is possible to discern teachers’ intentions for using the software and how
competent they feel about using the software. To start with, 23 teachers intended to use the software to develop and construct new questions while two teachers were not sure, 19 teachers intended to use the software to make sketches for tests and exams with five teachers not sure and one disagreeing and 15 teachers intended to use the software frequently in class with eight not sure and one disagreeing. These findings showed that after training using the training manual used in GeoGebra, teachers were able to appreciate its usefulness and most of them were willing to adopt it for teaching Mathematics.

Figure 4.5 presents a summary of the teachers’ perception of GeoGebra and what they intend to use it for in their classes.
Researchers in other parts of the world on teachers’ use of technology in their mathematics classrooms have found similar responses from teachers. Just as Thomas, (2006) found in his survey of New Zealand teachers, many respondents to this study indicated that it was difficult to book their classes into computer laboratories because of the high demand from other subject areas. 10 of the respondents in this study were willing to use the computer laboratories for their lessons. This study sought to determine the extent to which this was implemented.
However, as Cuban et al. (2001) and Wallace (2004) pointed out, it is a mistake to assume that simply supplying schools with hardware and software will increase teachers’ use of technology and encourage more innovative teaching approaches. According to Wallace (2004), teacher competence is basic and should be the key towards uptake of technology in mathematics classes. There were over 50% of teachers in this study who intended to use the technology to construct new questions, plan their lessons and also engage their learners. The study further investigates if this took place in the actual mathematics lessons.

4.4.2. Teachers’ Perception of GeoGebra’s Usefulness

After training the teachers on using GeoGebra to teach mathematics, the researcher sought to find out whether the teachers considered it useful. The teachers were asked to state their opinion on how GeoGebra would be useful on five items in the questionnaires using a Likert scale on a continuum. Their responses are summarized in Figure 4.6.
The information presented in Figure 4.6 reveals how teachers rated GeoGebra’s usefulness in tackling various aspects of geometry. Only one teacher was unsure whether the software would enable learners visualize edges and hidden faces of three-dimensional figures, two teachers were unsure whether it would help learners visualize transformation of functions and two teachers were unsure that the software would help learners understand the transformation of functions. All the other teachers believed the software...
was useful in achieving these goals. This finding shows that teachers perceive that GeoGebra software has the potential to improve the learners’ ability to grasp concepts in geometry that are difficult to understand. This is in agreement with Hiebert (2000) who defines understanding as a situation when a mathematical idea or procedure or fact becomes part of an internal network of representations. Teachers felt that GeoGebra was able to build such connection within their minds and hence believed that the same would apply to learners. Hiebert says that “the degree of understanding is determined by the number and the strength of the connections” (Hiebert, 2000, p.65.). It is expected that if actually GeoGebra enhances relational understanding, then there would be better performance in the area of Geometry. The information in Figure 4.6 also reveals that teachers find the software to be efficient in that it does not consume too much time. Twenty three teachers out of the 33 teachers (69.7%) felt that it would save time when used in the classroom and only one teacher felt using it in the lab would waste time. This quality of GeoGebra is important because it will enable teachers save time hence cover the syllabus more efficiently. This is consistent with other similar studies which have described GeoGebra as raising the enthusiasm for the effective and wise application of technology to the teaching or learning enterprise (Fahlberg-Stojanovska and Stojanovski, 2009;Hewson, 2009). According to (Goos & Bennison, 2008) teachers’ own perceptions of their professional development needs in this area centered on finding enough time and getting enough help from colleagues so that they could explore planning and pedagogy to integrate technology into their everyday classroom practice. These findings have clear implications for resourcing of schools with respect to equipment and in-service education. On average there was an 85% response in affirmative that GeoGebra was
useful in teaching mathematics. This implies that 85% of the mathematics teachers in Kajiado County appreciate the usefulness of GeoGebra and were willing to use the application in teaching. The study further investigated the benefits these teachers associated with the use of GeoGebra in their mathematics classes. Having found out teachers’ perceptions about the application’s potential, there was need to know if these teachers personalized these benefits and whether they felt they could benefit from GeoGebra in their respective school environment.

4.4.3. Benefits of GeoGebra as perceived by the teachers

The study sought to find out whether the teachers thought GeoGebra could be successfully used in their respective schools, how the software would help in their school and whether any factors in their schools could aid or hinder the use of the software. All the teachers who were sampled for this study stated that GeoGebra would be useful in their school and classrooms. Table 4.5 presents the reasons why the teachers felt GeoGebra would be useful in their schools.

Table 4.5: Benefits of using GeoGebra in mathematics lessons

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Frequency</th>
<th>Percent of teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Improves understanding of abstract concepts</td>
<td>24</td>
<td>72.7</td>
</tr>
<tr>
<td>Introduces ICT to schools</td>
<td>10</td>
<td>30.3</td>
</tr>
<tr>
<td>Makes mathematics interesting</td>
<td>24</td>
<td>72.7</td>
</tr>
<tr>
<td>Changes students’ attitude and increases participation</td>
<td>22</td>
<td>66.6</td>
</tr>
<tr>
<td>Improves students’ manipulative skills</td>
<td>20</td>
<td>60.6</td>
</tr>
<tr>
<td>Assists in revision and making use of learning aids</td>
<td>6</td>
<td>18.2</td>
</tr>
<tr>
<td>Saves time hence syllabus completion</td>
<td>6</td>
<td>18.2</td>
</tr>
</tbody>
</table>
As Table 4.5 shows, more than a half of the teachers felt that GeoGebra could enable students comprehend difficult and abstract concepts in geometry. The teachers were also of the view that using the software would help introduce ICT to school, make mathematics more interesting and change students’ attitudes to mathematics. The findings reveal that 30.3% of the teachers felt that since they had not been using technology in mathematics, GeoGebra would be a way of introducing ICT to their schools. The study further sought to find out if all these teachers actually used the computer application.

4.4.4. Actual use of GeoGebra by the study mathematics teachers

After going through training, teachers went back to their schools. The study focused on follow up of the trained teachers to establish if they used GeoGebra in their classes. The schools of all the teachers who had been trained on GeoGebra use were visited and observation protocol used to assess their use of the application. The observation protocol assessed the teachers and students engagement during the lessons. Table 4.6 shows the population of teachers who actually used GeoGebra during their mathematics lessons.

Table 4.6: Actual Use of GeoGebra by the trained teachers

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percentage of the sampled teachers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>10</td>
<td>50%</td>
</tr>
<tr>
<td>Female</td>
<td>4</td>
<td>20%</td>
</tr>
<tr>
<td>Total</td>
<td>14</td>
<td>42.42%</td>
</tr>
</tbody>
</table>

Out of the sampled mathematics teachers on use of GeoGebra, only half of the male teachers used GeoGebra regularly in their mathematics lessons. A total of 20% of the
female teachers used the application in their mathematics lessons. Although some teachers failed to use the software due to hindrances that were not within their control, such as lack of computers, lack of electricity and shortage of time, the findings here will be used to generalize the uptake of technology among mathematics teachers of Kajiado County. According to Diffusion of Innovation, (Rogers, 1995), there are 5 stages of adoption of innovation. The first stage is knowledge, followed by persuasion and decision to use of technology. Having trained 33 mathematics teachers on GeoGebra use, the study sought to evaluate how they implemented what they had learnt from the training. From the earlier findings, trained teachers seemed enthusiastic about using GeoGebra in their classes. As indicated in table 4.6.

According to Table 4.5 more than half of the sampled teachers felt that GeoGebra could enable students comprehend difficult and abstract concepts in geometry, however, only half of the male teachers used GeoGebra in their mathematics classrooms and only 20% of the female teachers practically used the software. It was observed that there were other teachers who were willing to use the software but were not able to, due to factors within the environment. Some of the hindrances such as attitude, lack of support and large numbers of students in classes were some of the factors revealed by teachers who were asked to note factors that could aid or hinder adoption of the dynamic geometry software in their schools. Their responses are summarized in Table 4.7 which shows that about a half of the teachers stated that availability of computers and other equipment would enable them use the software. The other half noted absence of equipment as an impediment to implementing the software. Availability of computer literate teachers and
a positive attitude towards ICT were also among the factors that teachers said would help them introduce the software to their schools. Absence of electricity and the large ratio of students to available computers were among the obstacles to using the software in some schools.

There was a 63.63% response that a large number of students would hinder the use of the software in teaching mathematics at secondary school level. A large number of teachers 78.78% felt that support from school administration would be necessary to facilitate use of GeoGebra in Kenya. Most important, teachers agreed on the fact that knowledge on the use of the resource was necessary to use the resource in their classrooms.

Table 4.7: Factors that could Aid or Hinder Adoption of GeoGebra

<table>
<thead>
<tr>
<th>Factors</th>
<th>Frequency</th>
<th>Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Factors that aid</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Availability of equipment like computers</td>
<td>16</td>
<td>48.4</td>
</tr>
<tr>
<td>Support from school management</td>
<td>26</td>
<td>78.78</td>
</tr>
<tr>
<td>Positive attitude to ICT by teachers and</td>
<td>26</td>
<td>78.78</td>
</tr>
<tr>
<td>students</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer literate students</td>
<td>2</td>
<td>6.4</td>
</tr>
<tr>
<td>Factors hindering adoption</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Insufficient resources like computers</td>
<td>18</td>
<td>54.54</td>
</tr>
<tr>
<td>Lack of knowledge by the teacher on how to</td>
<td>33</td>
<td>100</td>
</tr>
<tr>
<td>incorporate the resource</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Lack of electricity</td>
<td>4</td>
<td>12.12</td>
</tr>
<tr>
<td>Large number of students</td>
<td>21</td>
<td>63.63</td>
</tr>
<tr>
<td>Teachers reluctance to adopt ICT due to</td>
<td>30</td>
<td>90.9</td>
</tr>
<tr>
<td>negative attitude</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Computer illiterate students</td>
<td>1</td>
<td>3.03</td>
</tr>
</tbody>
</table>
It is clear that the teachers were positive about the benefits they could get from GeoGebra; however there were only 42% of the teachers who actually used the application as observed on table 4.6. This is a discrepancy from the 85% teachers who were willing to use GeoGebra due to its perceived usefulness. This therefore implies that uptake of technology in the county was low. The figure 4.7 shows the levels of uptake of technology.

![Diffusion of Innovation](http://webstanford.edu/class/symbsys205/Diffusion)

**Figure 4.7: Diffusion of Innovation showing adoption of an innovation.**

Source: [http://webstanford.edu/class/symbsys205/Diffusion](http://webstanford.edu/class/symbsys205/Diffusion).

According to the diffusion of innovation theory, Rogers, (1995), diffusion of new innovation takes in four stages namely; knowledge, persuasion, decision, implementation and confirmation. Being at 42% of adoption of GeoGebra, the teachers are at the “early majority” which is characterized by enthusiasm towards use of an innovation. This implied that if all the teachers are trained to use the resource, they are likely to adapt it at a high rate. However, training is key for the adaption to take place.
Other researchers have tried to explain technology adoption and many models have been developed to explain how people respond to new technologies and what causes them to respond the way they do. According to Davis (1989) the main contributor to actual use of a new technology is its perceived usefulness. Hence, people primarily adopt new technologies based on their functions, rather than based only on how easy it is to perform the functions.

Users are, for instance, willing to adopt a difficult system if it captures a critical function. However, in practical terms, about 90% of research done on Technology Adoption Models (TAM) also shows that there are direct effects of perceived ease of use on actual use (Schepers & Wetzels, 2007). However according to, Godoe & Johansen (2014) the personality dimensions of technology readiness index (TRI) influences cognitive dimensions of Technology Adoption Model (TAM), more emphasis is on the readiness of the users. The knowledge stage is passed through training of the users then they may be persuaded about the usefulness of the resource. This gives way to making of a decision as to either adopt or reject the innovation.

Having trained the mathematics teachers, it is believed that they have gone past the knowledge and persuasion stages of Rogers’s model since they were able to use GeoGebra and were aware of the need for the application since they listed Geometry as one of the areas of secondary mathematics they found hard to teach. Also from table 4.5 most of the teachers who went through training felt that GeoGebra would enhance understanding of geometry concepts. The diffusion of Innovation Model highlights five factors that may influence an individual to use or reject an innovation. Most of these
factors were directly mentioned by the interviewed teachers while others were implied in their responses. The question therefore would be, why then did some of the trained teachers not implement the idea? Just as Diffusion of Innovation model indicates, some teachers will reject the idea completely, while others will postpone the adoption. This seems to have been the case in the use of GeoGebra in teaching Geometry at secondary school level in Kajiado County.

Teachers who did not implement the use of GeoGebra said that there was insufficient time to do it and would do it with the next class. Other teachers felt that introduction of such a resource would make Mathematics more complex than it already was. According to Robinson, (2009) on Enabling Change, www.enablingchange.com.au Diffusion of innovations take place at different rates depending on qualities of the innovation, peer to peer communications and the extent to which the innovation meets the users’ needs. In the case of GeoGebra uptake in Kajiado County, and generally in Kenya, the interpersonal communication among the mathematics teachers played a role among the teachers who used the application.

A case study conducted by Shunguyia, (1995) on instruction technology in the curriculum of the education program revealed that the instructional media were meager and limited hence student-teachers were not using technology. In this study by Shunguyia, 54.5% of teachers felt that insufficient supply of technology would hinder the uptake of technology. This could have contributed to low uptake of technology as earlier observed by (Shunguyia, 1995). According to Rogers, a new innovation takes time to get accepted and be used by majority of the potential users but as the word from those who
have used it spreads through socioeconomics and communication behavior, the adoption of the technology is likely to rise. It is expected that more people will appreciate the innovation, as they get to hear about it from their colleagues.

An adoption model in this case would have to combine various factors in the Kenyan setup, including, readiness to use the technology, perceived ease of use, perceived benefits, and also usefulness in the secondary schools’ environment.

4.5. Relationship between Students’ achievement in Geometry and the Use of GeoGebra in Teaching and Learning

This section shows the response to the null hypothesis: H0: There is no statistically significant difference in performance of students learning mathematics using GeoGebra and those not using GeoGebra.

To respond to second objective, the study sought to compare scores of students in tests involving geometry. The students were categorized into 2 major groups; namely, those that used GeoGebra (experimental group) and those that did not use GeoGebra (control group) hence learnt using conventional methods of learning such as demonstration, group discussions, lecture methods and question-answer methods. The students who used GeoGebra were allowed to explore in the dynamic geometry environment and eventually apply the learnt ideas in their school practice exercises. This was done by form 2 classes in the geometry topics including rotation and congruence, similarity and enlargement and also reflection.

The data collected from pretest examinations given to students before learning the topics of Geometry as planned in this study were recorded in terms of scores. The scores were required to be normally distributed so as to be analyzed using t tests and ANOVA.
According to Keith M. Bower, M.S. in their article on Analysis of Variance (ANOVA) Using Minitab, many researchers overlook the assumptions required for ANOVA to be used in a data distribution.

ANOVA was developed by the English statistician, (Fisher R.A.1890-1962). Though initially dealing with agricultural data, this methodology has been applied to a vast array of other fields for data analysis. Despite its widespread use, some practitioners fail to recognize the need to check the validity of several key assumptions before applying an ANOVA to their data. www.manilab.com These assumptions are stated as the assumptions needed for the t-test are also needed for ANOVA. As Dale Berger of Claremont Graduate University http://wise.cgu.edu states, we need to ensure that the following assumptions hold before using ANOVA tests.

i. Random, independent sampling from the k populations;

ii. Normal population distributions;

iii. Equal variances within the populations.

This study ensured there was independent sampling during data collection and also ensured that the distribution of the data obtained was normal. A normality test of Shapiro-Wilk was done.

In testing for normality, the relevant tests were carried out. A Shapiro-Wilk’s tests showed that the data in all conditions were normally distributed (W’s ≥ 0.90, p’s ≥ 0.11) and a visual inspection of the respective histograms (shown on figure 4.8) showed that the scores for pretest exams were approximately normally distributed hence fit for analysis using the indicated analysis techniques. The female scores had a skewness of 0.025 (SE=0.1106) and a Kurtosis of -0.254(SE=-0.568) and the male scores had a skewness of 0.040 (SE=0.184) and kurtosis of 0.198 (SE=0.469) (Cramer, 1998). The
Histogram for scores of female students shown in figure 4.8 reveals that the data had a normal distribution. The variances of the pre-test and posttest examinations were also checked to fit the assumptions.
Figure 4.8: Histograms of students’ scores in the pretest examinations

Although the post-tests scores were quite diverse since each category of students had their own different intervening factors. One group of female and male students used GeoGebra while the other did not. Further, a group of female was girls’ only schools
while others were in mixed schools. However, the test of normality was done for each of the groups and so the data qualified to be analyzed using ANOVA and other descriptive statistics such as mean, median and standard deviation. The information obtained was documented on Table 4.8.

**Table 4.8: Descriptive statistics of the Pre-test examination from ANOVA.**

<table>
<thead>
<tr>
<th>Gender of students</th>
<th>Statistic</th>
<th>Pretest score</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Mean</strong></td>
<td>2.07</td>
</tr>
<tr>
<td>Female</td>
<td>Median</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Variance</td>
<td>1.399</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>1.183</td>
</tr>
<tr>
<td></td>
<td>Skewness</td>
<td>0.25</td>
</tr>
<tr>
<td>Male</td>
<td><strong>Mean</strong></td>
<td>2.21</td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>2.00</td>
</tr>
<tr>
<td></td>
<td>Variance</td>
<td>0.817</td>
</tr>
<tr>
<td></td>
<td>Std. Deviation</td>
<td>0.904</td>
</tr>
<tr>
<td></td>
<td>Skewness</td>
<td>0.040</td>
</tr>
<tr>
<td></td>
<td>Kurtosis</td>
<td>1.98</td>
</tr>
</tbody>
</table>

In testing the second objective which was “To establish the relationship between students’ performance in Geometry and the use of GeoGebra in teaching and learning”, the null hypothesis was stated as “there is no statistically significant difference in performance of students taught mathematics using GeoGebra and those taught using conventional methods”. In testing this hypothesis, pretests were given to 6 secondary schools in Kajiado County, as indicated in the sampling table in chapter 3. These included the two main groups of students; the experimental and control group. In each of the groups, the study involved a girls’ school, boys’ school and a mixed school. The test was marked out of 30 and is attached as Appendix A: Pre-test Examination for Form 2 Students). This test was aimed at establishing the learners’ entry behavior and initial knowledge of the intended learning areas. The test therefore tested knowledge of
geometry 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 2.07 for girls and 2.21 for boys as shown on Table 4.8 For the entire set of students, the maximum score was 5 and minimum score was 0. These mean scores were relatively low since the test covered the content from topics were yet to be covered in class. Only questions based on general knowledge of geometry were well answered. The learners at this point were required to identify various shapes which are basic learning points in Geometry. An example of a question in the pre-test examination was as indicated on Table 4.9

Question: Identify the following figure and justify your answer

![Figure 4.9: Sample question testing levels of learning in Geometry](image)

Over 80% of the learners identified the diagram as a rhombus regardless of the fact that all the angles were right angles in addition to the sides being equal hence qualifying the figure to be a square. This among many other figures that required more than just visual identification were important to this study. According to Van Hiele (Clement & Battista, 1992) there are five Levels of Geometric Thinking (Pierre van, Hiele 1986). These
include the Visual, Descriptive, Abstract, Formal Deduction and Mathematical Rigor. The learners seemed to be at the visual stage in learning Geometry. According to (Van Hiele, 1986), Language at the Visual Level serves to make possible communication for the whole group about the structures that students observe. The vocabulary representing the figures helps in describing the figures. Any misconceptions identified may be clarified by the use of appropriate language. The language of the next level, e.g., congruence, will not be understood by students who are at the Visual Level. The students however need to move to the next level, the Descriptive stage. The language of the Descriptive Level includes words relating to properties within a given figure, e.g., parallel, equal, perpendicular, and congruent. Various properties can be used to describe or define a figure. A concise definition, using a sufficient number of properties rather than an exhaustive list, is not possible at this level. Students functioning at the Visual Level are not able to understand the properties of the Descriptive Level even with the help of pictures. The students only make conclusions from what they can see and do not seek further explanations. As shown on Figure 4.10 an interconnection of concepts could lack meaning at face value. This is a topic learnt at Form two classes in Kenyan secondary school curriculum and this is among topics that are not well performed in KCSE.
Figure 4.10: Description of the concept of reflection

The line of reflection bisects the parallel segments which connect corresponding points on the object and image. This property describes and defines a reflection. The congruency symbols, the perpendicular symbol, and the corresponding symbols used in written descriptions, become part of the language at the Descriptive Level. This is the most important level in learning Geometry. As indicated in (Van Hiele, 1986), the relational level is based on the Descriptive level. The language of the Relational Level is based on ordering arguments which may have their origins at the Descriptive Level. For example, a figure may be described by an exhaustive list of properties at the Descriptive Level. At the Relational Level it is possible to select one or two properties of the figure to determine whether these are sufficient to define the figure. The language is more abstract with its causal, logical and other relations of the structure. A student at the Relational Level is able to determine relationships among figures, and to arrange arguments in an
order in which each statement except the first one is the outcome of previous statements. The student is able to relate figures and make generalizations.

Having noted the lack of this kind of relational learning among the students, it was concluded that these students were at the visual level of leaning geometry. This gives an explanation to the poor performance in geometry questions at KCSE level as indicated earlier in this study. The researcher on introducing GeoGebra hoped to find out if it would help resolve this problem among learners at secondary school level in Kenya.

After the pretests examination, the mathematics teachers in both the control and experimental groups embarked on teaching the geometry topics using GeoGebra in the mathematics lessons. At this point, the researcher visited these schools and observed the mathematics lessons guided by the observation protocol on Appendix C: Observation Protocol for the Mathematics Lessons). Some of the activities that students engaged in included solving questions involving reflection, rotation and enlargement. Using the observation protocol on classroom activities, it was noted that students explored with GeoGebra and remained engaged throughout the lesson as opposed to the students learning using conventional methods of chalk and talk. In the experimental group, 100% of the students used GeoGebra and explored activities that could enable solve the exercises in class textbooks. The teachers in experimental group played the role of a facilitator while the teacher in the control group did much of demonstration and lecture. 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 were as shown on Figure 4.11: a, b and c.
a. Simple basic reflection along the line $x=y$

b. Four subsequent reflections on the line $x=y$ and $-x=y$
c. A rotation of a figure with the origin as the center of rotation at an angle of 90°

Figure 4.11: Students activities in GeoGebra in different secondary schools

After this rigorous process that took around 8 months due to the fact that different schools covered these particular topics at different times, all the students were once again subjected to a post-test examination attached as Appendix D: Post Test Exam for Form 2 Students. The results of the two tests were recorded and analyzed to establish if there was a statistically significant difference in scores of these two groups of students. The data obtained was analyzed by split plot Analysis of Variance and the results were as shown on Table 4.8.

In comparing the performance of students in the tests, the gained score for those students who used GeoGebra in learning was seen to be statistically significantly higher than those that were in the conventional group, t(237) = -12.943, p=0.000. The mean of a total of 131
students who used GeoGebra was 19.25 compared to a mean of 8.89 for 108 students who used conventional method of studying mathematics as seen on Table 4.9.

**Table 4.9: Group Statistics- mean scores of post-test examinations**

<table>
<thead>
<tr>
<th>Use of GeoGebra in Learning Mathematics</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Post test score</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>108</td>
<td>8.89</td>
<td>4.896</td>
<td>.471</td>
</tr>
<tr>
<td>Yes</td>
<td>131</td>
<td>19.25</td>
<td>7.032</td>
<td>.614</td>
</tr>
</tbody>
</table>

The mean differences in the post test scores of the two groups of students, namely the control group and the experimental groups are significant. The control group had a mean of 8.89 while the experimental group had a mean of 19.25. This shows a mean difference of 10.36, which in simple terms implies that the experimental group had a bigger mean than the control group by 10.36.

It is clear that both the experimental and control groups improved in performance after learning the topics in Geometry. The study however focused on gained scores by the two groups. To establish this, mixed design analysis of variance (also known as split plot ANOVA) was done to establish significance in the gained scored for two groups. This is shown on figure 4.8 of estimated marginal means. From the plot, it is evident that both groups increased in performance. Did the experimental group increase more or less than the control group? It is also noticed that the covariance matrix between pretest and post-test is at p=0.020 implying that the correlation between the two times is not significant.

The students ranking was not very different. This is a good characteristic of a data set in comparing the means.

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Further the plot of the gained means scores for both the control and experimental groups was as shown on Figure 4.12

Figure 4.12: Estimated marginal mean

From the plot, it is clear that there was a gain in mean scores of both categories of students. It shows that the gap between the group that used GeoGebra and the one that did not use widened with increase in the gained scores. The line graph for students who used GeoGebra is however steeper, implying greater gain in the means of students using GeoGebra as compared to those who did not use the application.

The relationship of the values of the gained scores and the use of GeoGebra was found to be significant as shown on the ANOVA table 4.10.
From the analysis, all the four multivariate tests also show similar results, a significant interaction between pre-test and post-test scores among the control and experimental groups. There was a statistically significant interaction in performance based on gained scores after using GeoGebra in learning. After pairing the gained score versus the use or not use of GeoGebra the Wilks’ Lambda, \(F (4, 130.912) = 13.74, p < 0.05\); Wilk's Λ = 0.644, partial η2 = .000 was obtained. These findings are supported by the Roy’s Largest Root, and Hotelling's Trace which have partial η2 = .000.

The null hypothesis is therefore rejected. This leads to the finding that there is statistically significant difference in the performance of students using GeoGebra and those using conventional methods in learning Geometry.

### Table 4.10: ANOVA table on multivariate tests results.

<table>
<thead>
<tr>
<th>Effect</th>
<th>Value</th>
<th>F</th>
<th>Hypothesis</th>
<th>Sig. df</th>
<th>F Hypothesis</th>
<th>Sig. df</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gained score</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pillai’s Trace</td>
<td>0.779</td>
<td>834.635b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks' Lambda</td>
<td>0.221</td>
<td>834.635b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotelling's Trace</td>
<td>3.522</td>
<td>834.635b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roy's Largest Root</td>
<td>3.522</td>
<td>834.635b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gained * with GeoGebra</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Pillai’s Trace</td>
<td>0.356</td>
<td>130.912b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wilks' Lambda</td>
<td>0.644</td>
<td>130.912b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hotelling's Trace</td>
<td>0.552</td>
<td>130.912b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Roy's Largest Root</td>
<td>0.552</td>
<td>130.912b</td>
<td>1.00</td>
<td>.001</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Discussions based on related literature

This finding is in agreement with the findings of Escuder & Furner (2012), writing on the impact of GeoGebra in Math Teachers’ Professional Development states,

> With the availability of dynamic mathematics software, like GeoGebra, teachers are able to make graphical representations of math concept. As the concepts are introduced with pictorial representations, teachers and their students are able to make connections between the pictures, the math concepts and the symbolic representation.

This aspect of GeoGebra leads to better performance in mathematics Examinations since it results to relational understanding as opposed to rote learning. This result is in agreement with (Ahmed & Rohani, 2010) who conducted a quasi-experimental study with non-equivalent control group to examine the effect of GeoGebra in the learning of coordinate GeoGebra among secondary school students in Malaysia and found out that there was a significant difference in mathematical achievement between the GeoGebra group and the traditional teaching strategy group. His findings showed that the students in GeoGebra group performed better than the students in the traditional group.

In a similar study titled ‘Investigating the effectiveness of using GeoGebra’, by Demirbilek, & Özkale, (2013) in Turkey indicates that “During the data collection, it was observed that the experimental group students were interested and enjoyed exposing GeoGebra lessons. They also expressed their interest describing the GeoGebra lesson as more constructive, concrete and interactive.” GeoGebra has the effect of keeping students interested in the learning points which is likely to result to better performance. The level of interaction between learners as observed in the experimental classes was high and suitable for learning. According to their study, (Demirbilek & Özkale, 2013)
The use of GeoGebra does not lead to any statistically significant difference in performance of students. The results demonstrated that teaching algebra with GeoGebra software increased the experimental group students’ attitude significantly towards mathematics and GeoGebra software. However the experimental and control groups did not differ between students’ success in mathematics. P100

This finding by Demirbilek, & Özkale, (2013) differs from the findings of this study, this could be as a result of different levels of learning used as the earlier study was based on degree students who are likely to have gone past the basic levels of learning Geometry such as visual descriptive and analytic stage. Also, the study by Demirbilek & Özkale, (2013) is not based purely on Geometry rather on mathematics in general. This implied that the post-test (which was not shown on the journal paper) contained questions from many topics in University mathematics. Although Demirbilek & Özkale, (2013) show that there is no difference in performance between the groups, their study indicates that there is a significant increase in attitude among the learners. This study was based on geometry in the learning process and hence used questions from Geometry topics only for the post-test examination.

Various authors have shown that GeoGebra has the potential to transform the learning of mathematics. Bu, (2011) indicates the need for a mathematics student to be able to co-ordinate various representation of a mathematical idea in visualisation. Further (Alessi, 2000) shows modes of learning mathematics using GeoGebra to enhance conceptual understanding of mathematics in the real world. This study sought to establish if these positive aspects of GeoGebra would translate to better performance among secondary school students in Kenya. The gained scores in the post-test examinations among students in the experimental group of this study is an important factor. Since students in the
experimental group and control groups were picked from different schools, it is valid to say that the difference in the mean scores for each student was mostly due to the teaching resources and methods used. There was no interaction between the students in the experimental and control groups during the course of the treatment or intervention period.

Having observed the great potential that GeoGebra has had as a teaching and learning resources, as shown in studies conducted in other parts of the world, it would be appropriate to use it more often in the secondary school mathematics in Kenya as this could be the solution to the poor performance in Geometry questions at KCSE level in Kenya as indicated earlier in this study.

**4.6. Gender Differences in Learning Using GeoGebra**

The fourth objective in this study was to establish gender differences in terms of how students respond to computer applications such as GeoGebra in learning or to any dynamic geometry environment. To establish this, a null hypothesis was stated as; “There is no relationship in the mean scores of girls and that of boys in tests involving geometry after learning using GeoGebra”. The study compared the means of the gained scores among girls with those of boys. The results showed the gained mean scores by gender with the use of GeoGebra during learning of Geometry. The variables were as shown on table 4.11: Number of respondents who used GeoGebra by Gender. It shows the total of students (boys and girls) who participated in the study.
Table 4.11: Number of Respondents who used GeoGebra

<table>
<thead>
<tr>
<th>Value Label</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender of students</td>
<td></td>
</tr>
<tr>
<td>Female</td>
<td>115</td>
</tr>
<tr>
<td>Male</td>
<td>124</td>
</tr>
<tr>
<td>Use of GeoGebra in learning Mathematics</td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>108</td>
</tr>
<tr>
<td>Yes</td>
<td>131</td>
</tr>
</tbody>
</table>

A total of 239 students, 115 girls and 124 boys participated in this study. Out of this number 108 belonged to schools that were used as experimental groups while 131 were in schools used as control groups. Although all students in the classes for both experimental and control groups participated in the learning of the geometry topics, not all students sat for the pre-test and post-test examination. Some students, precisely 31 in number, did not submit their exam papers or opted not to do the test hence the results analyzed belonged to 239 students as opposed to the 270 shown on the sampling grid in chapter 3 Table 3.1. The study further looked at each of these groups in terms of their performance and obtained the mean scores of the gained scores. The gained scores were obtained from difference between each individual’s pretest and post-test examination score. These means were represented in graphical representation on Figure 4.13.
From the graphical representation, the mean of girls is close to that of boys both for the experimental and control groups. Analysis of variance done on the scores of the two groups of students shows that there was no statistically significant difference between the scores of girls and that of boys both before and after learning the topics in question. The tests of ‘between –subject’ effects showed the interaction between Gender and use of GeoGebra in table 4.12.

Figure 4.13: Mean of Gained Scores by Gender
Table 4.12: Effects between Gender

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>6364.365&lt;sup&gt;a&lt;/sup&gt;</td>
<td>3</td>
<td>2121.455</td>
<td>54.743</td>
<td>.000</td>
</tr>
<tr>
<td>Intercept</td>
<td>33768.225</td>
<td>1</td>
<td>33768.225</td>
<td>871.374</td>
<td>.000</td>
</tr>
<tr>
<td>Gender</td>
<td>6.445</td>
<td>1</td>
<td>6.445</td>
<td>.166</td>
<td>.684</td>
</tr>
<tr>
<td>GeoGebra</td>
<td>6332.932</td>
<td>1</td>
<td>6332.932</td>
<td>163.418</td>
<td>.0001</td>
</tr>
<tr>
<td>Gender * GeoGebra</td>
<td>3.743</td>
<td>1</td>
<td>3.743</td>
<td>.097</td>
<td>.756</td>
</tr>
<tr>
<td>Error</td>
<td>9106.924</td>
<td>235</td>
<td>38.753</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>52553.000</td>
<td>239</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>15471.289</td>
<td>238</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<sup>a</sup> R Squared = .411 (Adjusted R Squared = .404)

A 2x2 mapping (gender of student x use of GeoGebra) between –groups ANOVA analysis was done between performance gain. With alpha being set at the gender x GeoGebra interaction was found not to be statistically significant, F (1,235) =0.075, ($\eta^2$=0.756), partial. The main effect of gender was also not statistically significant at F (1,235) = 0.166, $\eta^2$=0.684. However, the main effect of GeoGebra was found to be statistically significant F (1,235) = 163.418, ($\eta^2$=0.000). This implies that there was no statistically significant difference in changes of means scores of girls and that of boys in tests involving Geometry after learning using GeoGebra. Both boys and girls gained almost equal scores after using GeoGebra in learning the Geometry topics at form 2
levels. This is shown on table 4.13: mean scores gained by the students after the learning process.

**Table 4.13: Mean Scores of the Students in the post-test examination**

<table>
<thead>
<tr>
<th>Gender of students</th>
<th>Use of GeoGebra in learning Mathematics</th>
<th>Mean(x)</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>No</td>
<td>6.82</td>
<td>4.754</td>
<td>50</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>17.43</td>
<td>7.655</td>
<td>65</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12.82</td>
<td>8.398</td>
<td>115</td>
</tr>
<tr>
<td>Male</td>
<td>No</td>
<td>6.74</td>
<td>4.033</td>
<td>58</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>16.85</td>
<td>7.149</td>
<td>66</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12.12</td>
<td>7.758</td>
<td>124</td>
</tr>
<tr>
<td>Total</td>
<td>No</td>
<td>6.78</td>
<td>4.361</td>
<td>108</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>17.14</td>
<td>7.382</td>
<td>131</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>12.46</td>
<td>8.063</td>
<td>239</td>
</tr>
</tbody>
</table>

The mean of the gained scores for girls in the control group was 6.82 compared to that of boys in the same category which was recorded at 6.74; the girls gained an average of 0.06 more that of boys after learning using conventional methods of learning. In the experimental group, girls had a mean gained score of 17.43 while boys had a mean of 16.68, a difference of 0.75. This shows that the technology environment gives a competitive environment for both girls and boys. It may also be true that more use of technology may benefit girls more than boys. The notion that mathematics and STEM is
not for girls is dispelled in this study as it has demonstrated that girls can equally perform well in a technology environment. This study has established that GeoGebra environment allows girls and boys to learn mathematics at the same level and the result of this is a gain for both genders with no bias. GeoGebra is therefore nondiscriminatory on gender. This is in agreement with a similar study done earlier in Nigeria, although this earlier study was based on the learning of Statistics using GeoGebra. Oche, Clement, & Abari (2015), observed that male and female students in the GeoGebra teaching method group achieved more and showed more interest in learning statistics than the male and female students in conventional teaching method. It therefore means that this method of instruction enhanced both the male and female students’ achievement and interest in statistics equally. Also according to Dix, (1999) through the use of technology, girls can improve their thinking on mathematical tasks, thereby giving the girls more inspiration to perform just as well as the boys or possibly even outperform the boys in mathematics.

This finding fills a gap shown by American Association of University Women (AAUW) in a research by Corbett, Hill and St. Rose, (2008) on “Where the girls are;” the report indicates that environmental and social barriers, including stereotypes, gender bias and climate of science are factors that are seen to block women’s progress in Science Technology, Engineering and Mathematics. GeoGebra affords a friendly interphase that allows learners to learn mathematics in a balanced environment.
4.7. Summary of Findings

The findings in this chapter have been recorded as summary here in terms of the three objectives.

The first objective sought to investigate the uptake of technology among teachers at secondary school level. To respond to this, teachers were trained and it was found that teachers agreed on the fact that knowledge on the use of the resource was necessary to use the resource in their classrooms. The teachers were positive about the benefits they could get from GeoGebra; however there were only 42% of the teachers who were actually using the application in their classroom. This led to the conclusion that there was low uptake of technology at the beginning which is in agreement with Diffusion of Innovations model.

The second objective sought to compare performance of students in the experimental and control groups in mathematics tests. There was a greater gain (difference between post-test scores and pre-test scores) in the mean scores of students in the experimental group than those students in the control group. The gained scores in the post-test examinations among students in the experimental group of this study is an important factor and it implied that GeoGebra had a positive impact in the learning of Geometry.

The third objective based on gender differences in performance in Geometry after learning using GeoGebra tested using the hypothesis as “there is no relationship in the mean scores of girls and that of boys in tests involving geometry after learning using GeoGebra”. This hypothesis was accepted since this study found no significant difference between the gained mean scores of female and male students. It was established that both
male and female students learnt mathematics and equally performed better using GeoGebra.
CHAPTER FIVE

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

5.1. Introduction

This study sought to document the uses of technology among Mathematics teachers of Kajiado County in line with the DIM. It revealed that there exists a relationship between use of GeoGebra and performance of students in Geometry and gender differences in use of technology. This chapter gives the summary of the study, conclusions, recommendation for policy and practice and recommendations for further studies.

5.2. Summary of the Findings of the Study

This study set to assess teachers’ competences and training in teaching mathematics and using technology. Secondly, the study assessed the extent to which mathematics teachers used GeoGebra in their lessons. Further, the study tried to establish the relationship between use of GeoGebra and achievement of students in geometry. Finally, the gender differences in achievement in Geometry after learning in a technology environment were assessed.

5.2.1. Teacher’s up take of technology, specifically GeoGebra in teaching mathematics

The study was motivated by the teachers’ feedback that geometry and algebra were the most challenging areas to teach in secondary school mathematics. It was noted that more than half the mathematics teachers face difficulties in teaching geometry. This explains the fact that questions involving Geometry are the most poorly performed in KCSE.
Sampled teachers were trained in a dynamic Geometry Software involving use of GeoGebra, their perceptions towards use of GeoGebra as a tool for teaching was assessed. It was found that most of the teachers who went through training felt that GeoGebra would enhance understanding of geometry concepts. Teachers felt that GeoGebra was able to build a connection between mathematics concepts and the physical representations within their minds and hence believed that the same would apply to learners.

Although the teachers perceived GeoGebra to be useful and applicable in their mathematics lessons, more than 50% of the sampled teachers did not adopt the innovation, as only 42% used the application in their classes despite being trained on the use of GeoGebra. From the Rogers Model, Adoption of GeoGebra in Kenya is at the early adopters’ stage due to the low pace of adoption. A word of mouth (communication as indicated in TAM) among mathematics teachers from different secondary schools is likely to improve this pace and get more teachers to use the innovation. 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 mathematics teachers in Kajiado County and generally in Kenya even though most teachers were perceived to be comfortable using the new innovation. This is in spite of inhibitive factors such as the learning environment which includes availability of computers, crowded curriculum and large classes. Those who used conventional methods of teaching said that these methods of teaching are effortless and more of routine, hence less time consuming.
5.2.2. Relationship between students’ performance in Geometry and the use of GeoGebra in teaching and learning

This was responded to comparing the students learning Geometry using GeoGebra and those learning without GeoGebra in a quasi-experimental set up.

The Null hypothesis was tested using Analysis of Variance (ANOVA) which showed that there was a significant difference in the scores of students who learnt using GeoGebra and those who did not learn using GeoGebra. Although both the experimental and control groups gained from being taught, the study established that the experimental group gained more.

The study reveals that GeoGebra leads to better performance in mathematics examinations involving Geometry. GeoGebra use ensures there are pictorial representations hence teachers and their students are able to make connections between the pictures, the mathematics concepts and the symbolic representation. By using it, learners are able to visualize the diagrams easily. It is expected that GeoGebra will be useful in topics such as 3-d Geometry which is taught in form four classes. This therefore could be the solution to the poor performance in Geometry questions at KCSE level in Kenya.

5.2.3. To establish gender differences in terms students’ response to computer apps such as GeoGebra in learning.

The study sought to find out if there were gender differences in the use of technology during teaching and learning of mathematics. The mean of the gained scores for girls in the control group was observed (M= 6.68) compared to that of boys which was (M=6.74); the girls gained an average of 0.06 more that of boys after learning using
conventional methods of learning. In the experimental group, girls had a mean gained score of (M= 17.43) while boys had a mean of (M=16.68) implying that the girls gained 0.75 (mean difference) more than the boys. These findings revealed that the technology environment gives a competitive learning environment for both girls and boys. It may also be true that more use of technology may benefit girls more than boys in mathematics lessons.

This study revealed that GeoGebra environment allows girls and boys to learn mathematics at the same level and the result of this is a gain for both sexes with no bias.

### 5.3. Conclusions

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

On the uptake of technology, the study concludes that mathematics teachers were not keen to apply modern technologies in their classes. Several reasons were given including broad mathematics curriculum and time indicating that use of GeoGebra could prevent them from completing their syllabus at the expected time. Both the male and female teachers had these perceptions. The issue of technology being complex was also raised even though it was very compatible with the mathematics content, teachers felt that knowledge to apply the technology was necessary for them to adopt the technology. Also 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 Kenyan secondary schools would have to combine various factors in the Kenyan set up, including, readiness to use the technology,
perceived ease of use, perceived benefits and also usefulness in our secondary schools environment.

The study concludes that GeoGebra is one sure solution to the poor performance in questions involving Geometry as it enhances understanding which is key to good mathematics learning and hence improved performance in the area of Geometry at secondary school level.

When it comes to gender equity, this study also concludes that technology benefited both girls and boys in learning mathematics since learning in the dynamic geometry environment did not discriminate against the students by gender. The mean gained in was slightly higher for the girls as compared to the boys. This means that the girls can equally do well in mathematics as compared to the boys.

The study concludes that if GeoGebra is introduced to the teaching and learning of Geometry concepts in secondary schools in Kenya and teachers trained using Gerrit Stols training manual, contextualized by the Kenyan curriculum using and the training guide provided in this study, there is expected to be improvement in performance in Mathematics.

5.4. Recommendations for Policy and Practice

From the study there was a strong indication that the learning of Geometry in Kenya is poor and requires immediate intervention. This study revealed issues that led to the following recommendations.

1. There should be continuous in servicing of the mathematics teachers regularly 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 among the mathematics teachers in Kenya. The government having introduced calculators use at secondary school level opened the avenue for use of technology in our mathematics classrooms. It is recommended that the government further directs and supports the use of computers for learning mathematics hence breaking way from the traditional methods of learning mathematics. This will make mathematics more exciting and interesting for the learners.

4. It is advocated that GeoGebra be incorporated in the learning of mathematics first by introducing it to teachers during SMASSE sessions and also to mathematics teachers at pre-service training stage. The use of GeoGebra has been shown to be useful in improving the performance of Geometry in secondary school mathematics. This will definitely lead to an improvement in the national mean score of mathematics at KCSE level.

5. In areas of mathematics in which girls are challenged, dynamic geometry is likely to improve attitude and hence improve achievement in mathematics. Teachers should therefore use appropriate technology in teaching girls. This might bring more gains in girls' schools.

6. During introduction of GeoGebra in the teaching and learning process, the teachers should be trained using the Gerrit stols training manual since it is easy to use and compliment it with the additional material provided in this study.
5.5. 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 leaning of Geometry. There is need for a study on other computers applications that can be used to enhance the learning of Geometry. It would be useful to find out if a combination of various computer applications would lead to better learning of Geometry.

2. The study majored on the use of GeoGebra in teaching and learning of Geometry. A further study may be done to check if GeoGebra will be useful in other areas of mathematics such as algebra and calculus in the secondary school curriculum in Kenya.

3. From the findings, there seemed to be a gain in the mean performance in both male and female students, however there was a slight indication that the girls gained more than boys. A further study could be done to clarify this.

4. A study that clearly details GeoGebra activities of each topic in the secondary school mathematics curriculum would be useful to ease the teachers’ work of preparation. This would mean development of a manual that can be used by the teachers and students in GeoGebra environment.

5. Further research that investigates how and under what conditions teachers learn to effectively integrate technology into their practice could be done to guide teachers’ trainers on best practices when training in-service teachers.

6. A study needs to be done to establish the usefulness of GeoGebra in other areas of secondary schools mathematics other than geometry. Since GeoGebra can be used for statistics, calculus and also Algebra. It would be useful to investigate the effect on performance in these areas when students are taught using GeoGebra.
7. A study needs to be done to establish the usefulness of GeoGebra in other levels of learning mathematics in Kenya; such as University level as it is seen to have led to improved performance in the area of Geometry at secondary school level.
REFERENCES


IPS (2003). Teacher Training on ICT use in Education in Asia and the Pacific: Overview from Selected Countries. Bangkok: UNESCO.


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Kenya National Examinations Council report on 2009 KCSE performance (c2010)
Kenya National Examinations Council report on 2008 KCSE performance (c2009)

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Research instruments, [medical-dictionary.thefreedictionary.com](http://medical-dictionary.thefreedictionary.com)

Retrieved 10/1/2014.


Shunguyia, N. (1995). Factors Relevant To Teachers Training Improvement: A Case Study Of Instructional Technology in the Curriculum of the Teacher Education Programme of Kenyatta University. University of Toronto. Canada


Appendix A: Pre-test Examination for Form 2 Students

The following examination is aimed at obtaining information about the teaching of mathematics specifically Geometry at secondary school level. The results obtained will be used for research purpose only and will be treated with confidentiality. Your cooperation will be highly appreciated. Please respond to all the questions as honestly as possible.

1. Identify the following diagrams giving reason/justification for your answer

   4marks
2. Enlargement

i. Enlarge the shape shown by a scale factor of 1.5, with origin as the center of enlargement and indicate the co-ordinates of the image and indicate the coordinates of the image (3 marks)
ii. Enlarge the triangle by a factor of 2 from the origin and indicate the coordinates of the image (3 marks)
iii. Enlarge the triangle A by a factor of 3 from center point D and indicate the coordinates of the image (3 marks)
Rotation

i. Rotate triangle shown by $90^\circ$ about the point (-1, 0), label the image U and record the coordinates of its image. (3 marks)
ii. Rotate the figure by $180^\circ$ anticlockwise about the point $(1, 2)$ label it B.  
(3marks)

iv. Rotate the figure by $90^\circ$ anticlockwise about the point $(0,0)$ label it V and indicate the coordinates of the image  
(3marks)
REFLECTION

i. Reflect the image in the y-axis. Label it A’B’C’D’E’F’ and indicate the coordinates of the image (3 marks)
ii. Reflect the figure in the x-axis. Label it D and indicate the coordinates of the image (2 marks)
iii. Reflect the triangle in the line $y=x$ and label it V and indicate the coordinates of the image (3 marks)
Appendix B: Questionnaire for the Mathematics Teachers after Training

Please read each question carefully and answer them to the best of your ability. There are no correct or incorrect responses; we are merely interested in your personal point of view. All identifying information will be removed from this questionnaire as soon as all data has been collected.

Personal data

Name of the school:…………………………………Teacher’s sex: male ( ) female( )

School currently teaching: Boys school ( ) Girls school ( ) Mixed school ( )

Teaching experience (tick where appropriate):

Less than 1 year ( ), 1-5 years ( ), 5-10 ( ), 11-15 years ( ) Above 15 years ( )

Questions in relation to training

1. What is your level of professional pre-service training? Masters degree— Bachelors Degree— diploma— Others ( ) specify

2. Do you have any computer related training and qualifications? Yes— No---

3. What skills have you acquired (through training or experience) in terms of computer use?

Tick where applicable to you.
4. Which of the following areas in secondary school mathematics that you find difficult to teach? Give a reason for your answer

Statistics, Algebra, Probability, Geometry,

5. What do you feel after the going through the training in use of GeoGebra? In a scale of 1 to 5, (with 5 being the highest rating) rate yourself in the use of GeoGebra as a dynamic geometry software for teaching mathematics in each of the following statements

<table>
<thead>
<tr>
<th>Skills acquired</th>
<th>Tick</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ability to use Microsoft word</td>
<td></td>
</tr>
<tr>
<td>Ability to use PowerPoint</td>
<td></td>
</tr>
<tr>
<td>Ability to use formulas in spreadsheet</td>
<td></td>
</tr>
<tr>
<td>I can prepare mathematics assignments and exercises for students on the computer</td>
<td></td>
</tr>
<tr>
<td>Ability to use Microsoft Excel</td>
<td></td>
</tr>
</tbody>
</table>
PERCEIVED USEFULNESS.

As a teacher, having understood how to use GeoGebra; what do you think would be the use and benefits of GeoGebra to your students? In a scale of 1 to 5 (with 5 being the highest beneficial), indicate which effects you would attach to the DGS.

<table>
<thead>
<tr>
<th>Rating in terms competence to use Geometry software</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>I feel competent to use dynamic geometry software in the computer lab this term</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I feel competent to use dynamic geometry software in the classroom this term</td>
<td></td>
<td></td>
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<tr>
<td>I intend to use dynamic geometry software frequently in my classroom this term</td>
<td></td>
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<td></td>
</tr>
<tr>
<td>I intend to use dynamic geometry software to make sketches for test and exams</td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>I intend to use dynamic geometry software to develop and construct new questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected usefulness of GeoGebra after training</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
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<td>---------------------------------------------------------------------------------------------------------------</td>
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<tr>
<td>It leads to better understanding of transformation of functions by the learners</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The use of dynamic geometry software in the classroom saves time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The use of dynamic geometry software will help the learners to visualize the transformation of functions</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>The use of dynamic geometry software in the lab will waste time</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Use of dynamic Geometry enables learners to visualize edges and hidden faces of a 3 dimensional figures</td>
<td></td>
<td></td>
<td></td>
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<td></td>
</tr>
</tbody>
</table>

6. In your school and classroom environment, do you think this software will be useful? Give a brief explanation on how useful this software will be.

7. What factors in your school set up do you think will aid or hinder the use of this Dynamic Software?
Appendix C: Observation Protocol for the Mathematics Lessons

Type of school: Experimental ___________ Control______

<table>
<thead>
<tr>
<th>Topic taught</th>
<th>Teachers activities</th>
<th>Learners activities</th>
</tr>
</thead>
<tbody>
<tr>
<td>Reflection</td>
<td></td>
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<td></td>
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<tr>
<td>Rotation</td>
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<td></td>
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<tr>
<td>Similarity and enlargement</td>
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<td></td>
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<tr>
<td>Pythagoras theorem</td>
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<td></td>
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</tbody>
</table>
Appendix D: Post Test Exam for Form 2 Students

You are required to answer the following questions in the spaces provided to the best of your knowledge.

1. Enlargement

i. Enlarge the shape shown by a scale factor of two, with origin as the center of enlargement and indicate the co-ordinates of the image and indicate the coordinates of the image (3marks)
ii. Enlarge the triangle A by a factor of 3 from center point O and indicate the coordinates of the image (3 marks)
i. Rotate triangle shown by $180^0$ about the point (-1,0), label the image U and record the coordinates of its image. (3marks)

ii. Rotate the figure by $90^0$ anticlockwise about the point (1,2) label it B. (3marks)
REFLECTION

i. Reflect the image in the y-axis. Label it A’B’C’D’E’F’ and indicate the coordinates of the image (3 marks)
ii. Reflect the figure in the x-axis. Label it D and indicate the coordinates of the image.

(3 marks)
iii. Reflect the triangle in the line $y=x$ and label it V and indicate the coordinates of the image (3 marks)

iv. Fully describe the single transformation which will take shape A to shape B (3 marks)
v. Fully describe the single transformation which will take shape V to shape W (3 marks)
## Appendix E: Mathematics Topics in Secondary Syllabus

<table>
<thead>
<tr>
<th>TOPIC</th>
<th>DOMAIN</th>
<th>GEOGEBRA APPLICABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1.0 Natural Numbers (4 Lessons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2.0.0 Factors (4 Lessons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3.0.0 Divisibility Tests</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4.0.0 Greatest Common Divisor (GCD)/Highest Common Factor (4 Lessons)</td>
<td></td>
<td></td>
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<tr>
<td>5.0.0 Least Common Multiple (L.C.M) (5 Lessons)</td>
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<td></td>
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<tr>
<td>6.0.0 Integers (12 Lessons)</td>
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<td></td>
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<tr>
<td>7.0.0 Fractions (12 Lessons)</td>
<td></td>
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<tr>
<td>8.0.0 Decimals (12 Lessons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>9.0.0 Squares and Square Roots (12 Lessons)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>10.0.0 Algebraic Expressions (14 Lessons)</td>
<td></td>
<td></td>
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<tr>
<td>11.0.0 Rates, Ratio, Percentages and Proportion (18 Lessons)</td>
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<td></td>
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<tr>
<td>12.0.0 Length (6 Lessons)</td>
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<tr>
<td>13.0.0 Area (6 Lessons)</td>
<td>Geometry</td>
<td></td>
</tr>
<tr>
<td>14.0.0 Volume and Capacity (6 Lessons)</td>
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<td></td>
</tr>
<tr>
<td>15.0.0 Mass, Density and Weight (4 Lessons)</td>
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<td>16.0.0 Time (4 Lessons)</td>
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<td>17.0.0 Linear Equations (12 Lessons)</td>
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<td>18.0.0 Commercial Arithmetic (6 Lessons)</td>
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<td>19.0.0 Co-ordinates and Graphs (14 Lessons)</td>
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<td>Subject</td>
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<td>Common Solids (18 Lessons)</td>
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<td>Reciprocals (7 Lessons)</td>
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<td>39.0.0</td>
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<td>Compound Proportions and Rates of Work</td>
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<td>Differentiation (19 Lessons)</td>
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<td>67.0.0</td>
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</tr>
<tr>
<td>68.0.0</td>
<td>Integration (19 Lessons)</td>
<td>Applicable</td>
</tr>
</tbody>
</table>

SOURCE:

Appendix F: Research Permit

THIS IS TO CERTIFY THAT:
MS. IRENE MUKIRI MWINGIRWA
of KENYATTA UNIVERSITY, 0-200 Nairobi,
has been permitted to conduct research in Kajiado County.

on the topic: USE OF GEOGEBRA IN THE
TEACHING AND LEARNING OF
GEOMETRIC CONCEPTS IN SECONDARY
SCHOOL MATHEMATICS IN KAJIADO
COUNTY, KENYA

for the period ending:
25th September, 2015

Applicant’s Signature

Secretary
National Commission for Science,
Technology & Innovation
Appendix G: Study Contribution: Training guide on GeoGebra

Teachers are taken through introduction by Gerrit stols manual for GeoGebra

Geometry activities customized from the Kenyan 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 KENYAN CURRICULUM

Step1. Drawing basic shapes

<table>
<thead>
<tr>
<th>Figure</th>
<th>Instruction</th>
<th>Illustration</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Triangle</td>
<td>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</td>
<td>![Illustration of a triangle created in GeoGebra]</td>
</tr>
</tbody>
</table>

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<table>
<thead>
<tr>
<th>155</th>
<th>form a triangle</th>
</tr>
</thead>
<tbody>
<tr>
<td>2. Regular polygon</td>
<td>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. eg, for a pentagon enter 5, triangle=3, square =4</td>
</tr>
<tr>
<td>3. Irregular polygon</td>
<td>On the same icon, select Rigid polygon. On the screen, select the 5 points joining them. Do not forget to join the 1st point to the last selected point</td>
</tr>
</tbody>
</table>

![Diagram of an irregular polygon with selected points and lines connecting them]
Step 2. Translation of Objects

<table>
<thead>
<tr>
<th>Step</th>
<th>Instruction</th>
<th>Description</th>
<th>Command</th>
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</thead>
</table>
| 1    | **Draw a vector** $\vec{AB}$  
  - Click on Line Tool  
  - Select Vector  
  - Click on the graphics window twice | A vector from Point A to Point B |        |
| 2    | **Draw a triangle** CDE  
  Choose on the Polygon Tool  
  Create 3 Free Points C, D and E  
  Click on C, D, E then C | A triangle whose vertices are C, D and E | ![Polygon Tool](image.png) |
| 3    | **Translate Triangle CDE by Vector** $\vec{AB}$  
  - Click on Triangle CDE  
  - Click on Vector | | |
Translation Vector \( \left( \frac{2}{2} \right) \)
### Step 3. Reflection of objects

<table>
<thead>
<tr>
<th>Step</th>
<th>Instruction</th>
<th>Description</th>
<th>IMAGES</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Select the object you want to reflect. Then, click on a line to specify the mirror/line of reflection (also see command Reflect).</td>
<td>click on the triangle, then reflection icon, then click on the mirror line.</td>
<td><img src="image1.jpg" alt="Images" /></td>
</tr>
<tr>
<td>2</td>
<td>Select the object you want to reflect. Then, click on a point to specify the mirror line/point of reflection (also see command Reflect).</td>
<td>A triangle whose vertices are C, D and E.</td>
<td><img src="image2.jpg" alt="Images" /></td>
</tr>
<tr>
<td>3</td>
<td>This tool allows you to invert a point in a circle. Select the point you want to invert. Then, click on a circle to specify the mirror/circle of inversion.</td>
<td><img src="image3.jpg" alt="Images" /></td>
<td></td>
</tr>
</tbody>
</table>
Step 4. Enlargement of figures

<table>
<thead>
<tr>
<th>Step</th>
<th>Instruction</th>
<th>Description</th>
<th>IMAGES</th>
<th>Command</th>
</tr>
</thead>
</table>
| 1    | Select the Polygon Tool and construct a triangle ABC of your choice. or as given  
      Remember to click the first point again in order to close the polygon when constructing  
      Select the triangle ABC and then the centre of enlargement say (0, 0).  
      The screen for enlargement will appear indicating enlargement factor  
      Click OK. |          | ![Image](image1.png) |        |
| 2    | **Given a polygon**  
      select the polygon by clicking on  
      click on the enlargement icon  
      enter the factor of enlargement | A triangle whose vertices are C, D and E | ![Image](image2.png) |        |
## Step 5. Rotation of Geometrical shapes

<table>
<thead>
<tr>
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<th>Command</th>
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</table>
| 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 | ![Image](image1.png)  
a triangle is rotated about one of its points at 180 degrees. |  |
| 2    | **Draw a triangle CDE and rotate it**  
Choose triangle icon on the Polygon Tool  
Create 3 Free Points C, D and E | centre of rotation eg Point A(0,0) on the cartesian plane | ![Image](image2.png) |  |
Useful features in GeoGebra. From the toolbar, each item gives a drop down menu of its functions
Each icon on the tool bar (below the main toolbar) provides a dropdown menu of its functions as shown (Next 7 diagrams)
Each icon on the tool bar (below the main toolbar) provides a dropdown menu of its functions.
Using the icons, we plot a point, then proceed to draw a regular polygon such as a triangle.
In reflection

- Select the reflection icon
- Select on the figure you want to reflect
- Select the line of reflection
- The image will show on the other side of the mirror line

*Note: Similar steps are followed for rotation and also Enlargement*

Some Worked activities.

A reflection of triangle ABC along the Y-axis
A reflection of triangle ABC along the Y-axis and further along the X-axis
A reflection of triangle ABC along the Y-axis showing connecting lines.

A reflection of triangle ABC along the Y-axis, 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 $A'B'C'_{1}$ 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
Figure ABCDE is rotated about one of its point c about 45 degrees while figure FGHI is rotated about point J at 90 degrees