EFFECT OF GEOGEBRA AND GRAPES ON STUDENTS' ACHIEVEMENT IN THE TEACHING AND LEARNING OF MATHEMATICS IN SECONDARY SCHOOLS IN BOMET COUNTY, KENYA.

BY

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DECLARATION

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DEDICATION

This Thesis is dedicated to my beloved wife, Emmy, and our great kids, Faith, Caleb, Joan, Eddah and Mirriam, thanks for all your support, love and encouragement during the entire period while undertaking my PhD programme.

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ABSTRACT

The poor performance of students in Mathematics at KCSE level has been an issue of concern to parents, the Kenyan government and all the education stakeholders. Mathematics teaching and learning is crucial to the future of Kenya's knowledge economy and deserves a special focus and attention in our education system. This poor performance in mathematics prompted the researcher to investigate the role which GeoGebra and Grapes can play in the teaching and learning of Geometry in secondary school mathematics. The objectives of the study were to determine the effectiveness of using Grapes and GeoGebra on students' learning of graphs as compared to the traditional approach, to establish whether the use of GeoGebra and Grapes can improve the performance in mathematics for both boys and girls, to determine students' perceptions on the use of Grapes and GeoGebra in the teaching and learning of graphical work and to determine whether the teaching method influence the performance of students in mathematics. This study was guided by Technology Acceptance Model (Davis, 1989). Technology Acceptance Model (TAM) explains computer-usage behavior that relates to reasons why some people use computers and their attitudes towards them. This study adopted Solomon four group experimental research design. The respondents were selected using both stratified and simple random sampling. The study adopted post positivist world view where knowledge is developed through careful observation and measurement of the objective reality that exists out there in the world. Data was collected through the use of students' questionnaires, pre-test and post-test. Analysis of data was done using both descriptive and inferential statistics. For descriptive statistics, frequency tables, means and percentages were used. Anova, t-test and Multiple Regression Analysis were employed for the inferential statistics. The study found out that the students who were taught using Grapes and GeoGebra performed much better than those who were taught using the conventional method. The study also found out that gender differences were not seen to affect the performance of students in mathematics after being taught using Grapes and GeoGebra. It is recommended that ICT integration in the teaching of Mathematics should be included in the curriculum of pre-service teachers at the university level. It is also recommended that the teaching and learning of Mathematics should involve a lot of practical activities which engage both boys and girls equally through out the lesson. GeoGebra and Grapes should be used in the teaching and learning of Mathematics in Kenyan secondary schools as the study found out that the two softwares helped the students to understand difficult and abstract concepts in Geometry. The findings of this study would be useful to the quality assurance and standard officers within the ministry of education in Kenya. The findings will enable them to come up with better methods of teaching and learning of mathematics in Kenyan secondary schools and hence achieving better results at KCSE level. The study will also benefit Kenyan secondary school mathematics teachers by giving them insight on how GeoGebra and Grapes can be used to improve the teaching and learning of mathematics.

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LIST OF ACRONYMS

AIR	American Institute of Research
ANOVA	Analysis of variance
ASAL	Arid and Semi-Arid Lands
ASEI	Activity, Student, Experiment, Improvisation
CAS	Computer Algebra Systems
CBC	Competency Based Curriculum
CEMASTEA	Centre for Mathematics, Science and Technology Education in Africa
CK	Content Knowledge
CLE	Constructivist Learning Environment
DGS	Dynamic Geometry Software
DMS	Dynamic mathematics software
EFA	Education-For-All
E-learning	Electronic Learning
Email	Electronic mail
ESF	Economic stimulus Fund
GRAPES	GRAph Presentation & Experiment System
IBL	Inquiry based learning
ICME	International Congress on Mathematical Education
ICT	Information Communications Technology
ILS	Integrated Learning Systems
INSET	In-service Education and Training
JICA	Japan International Co-operation Agency
KNEC	Kenya National Examination Council
MOEST	Ministry of Education Science and Technology
NCST	National Council for Science and Technology
NCTM	National Council of Teachers of Mathematics
PBL	Project based learning
PCK	Pedagogical content knowledge
PDSI	Plan, Do, See, Improve
PK	Pedagogical Knowledge
SD	Standard Deviation
SMASSE	Strengthening of Mathematics and Science in Secondary Education
STI	Science, Technology and Innovation
TAM	Technology Acceptance Model
TCK	Technological content knowledge
TIMSS	Third International Mathematics and Science Study

TIVET	Technical, Industrial Vocational and Entrepreneurship Training
TK	Technological Knowledge
TNA	Training Needs Assessment
TPACK	Technological pedagogical content knowledge
TPB	Theory of Planned Behaviour
TPK	Technological pedagogical knowledge
TRA	Theory of Reasoned Action
UCSMP	University of Chicago School Mathematics Project
UNESCO	United Nations Educational, Scientific and Cultural Organisation
WECSA	Western, Eastern ,Central and Southern Africa

CHAPTER ONE: INTRODUCTION TO THE STUDY

1.1 Introduction

This chapter presents background to the study, statement of the problem, purpose of the study, objectives of the study, research questions, research hypotheses, assumptions of the study, significance of the study delimitations and limitations theoretical and conceptual framework, operational definitions of terms and summary of the chapter.

1.2 Background to the study

GeoGebra is relatively new dynamic mathematics software that integrates the possibilities of dynamic geometry, computer algebra and calculus in one tool for teaching and learning mathematics. It affords opportunities for mathematical investigation encouraging interaction and collaborative learning, making mathematics open, practical, accessible, tangible and manageable to more pupils (Hohenwarter& Fuchs, 2004). GeoGebra is a freely available dynamic mathematics software (DMS) that affords dynamically linked multiple mathematical representations, computational utilities, documentation tool and a technical tool to support teaching and learning; as a psychological tool (instrument) it potentially enhances the teacher’s instructional plans and strategies, and also a pedagogical tool that facilitates classroom practices in its many diverse forms (Hohenwarter& Jones, 2007; Bu, Mumba&Alghazo, 2011). GeoGebra is designed specifically for educational purposes and has the added advantage of enabling students to visualize mathematical concepts, foster rich and active student-centred learning by affording opportunities for mathematical experimentations, interactive explorations, conceptual and visual feedbacks, support guided discovery learning, produces flexible results, enable multi-lingual classroom and generate mathematically accurate diagrams for problem sheets and does very well what it sets to achieve (Bruner, 1961; Sangwin, 2007; Preiner, 2008).

GRAPES (GRAph Presentation & Experiment System) is a free software that can be downloaded, distributed and used without any restriction. It can be used to draw the graphs and the loci of most of the functions which appear in the upper secondary school mathematics curriculum, and to analyze them from diverse aspects. Grapes is graphing software developed at the Centre for Research on International Cooperation in Educational Development (CRICED), University of Tsukuba, Japan. The graphing software may support a way of mathematical reasoning not developed before, and which may help different students to learn in different ways. The availability of easy-to-use graphing software highlights the role of the graphical representations of functions and relations. The graphs of most of the functions encountered at the secondary school mathematics can be drawn easily by use of Grapes software.

Mathematics achievement is the competency shown by the student in the subject mathematics. Its measure is score on an achievement test in mathematics. Students' mathematical achievements in secondary school have an influential effect on their performance in college and their future careers. Having a solid background in mathematics help students develop sophisticated perspectives and offers more career options. The quality of teaching and learning of mathematics is an issue of concern to all mathematics educators (Ma & Bradley, 2009).

For students to accomplish learning, teachers should provide meaningful and authentic learning activities to enable students to construct their understanding of this subject domain. Instructional strategies where students actively participate in their own learning are critical for success. Instructional strategies shape the progress of students' learning and accomplishment. Instructional strategies and methods that provide students with learning situations where they can develop and apply higher order thinking are critical for mathematics.

According to Tuncay and Omur (2009), students' achievement in mathematics requires teachers to have a firm understanding of the subject matter and the epistemology that guides mathematics education. Understanding of different kinds of instructional activities that promote students' achievement are important in mathematics education. Competent mathematics teachers provide a road map to guide students to an organized understanding of mathematical concepts, to reflective learning, to critical thinking and ultimately to mathematical achievement. New instructional design techniques that can produce individuals who can understand and apply fundamental mathematics concepts are required in mathematics education. A central and persisting issue is how to provide instructional environments, conditions, methods, and solutions that achieve learning goals for students with different skills and ability levels. Innovative instructional approaches and techniques should be developed to ensure that students become successful learners.

There is a general misconception and belief that mathematics is a masculine subject. Girls should overcome the myth that mathematics and sciences are masculine subjects. There is need to remove gender insensitive materials in the curriculum and teaching methodologies. Teachers should not only expect boys to do wonderfully well in mathematics and sciences while they expect girls to be just average or below. Girls should not be considered to be inferior in doing mathematics. The basic idea behind the gender issue is equity. The teacher should give equal opportunities to both boys and girls. At no time should the teacher be seen to be promoting one sex as opposed to the other. No one sex is superior to the other.

According to Ajai and Imoko (2015), their study showed that female students outperformed their male counterparts in mathematics achievements though the difference was not statistically significant. They argued that the reason for equal performance of male and female students may be connected with the fact that both see themselves as equals and capable of competing and collaborating in classroom activities. They pointed out that both sexes are capable of competing and collaborating in classroom activities.

Ajai and Imoko (2015) pointed out that there is need to give boys and girls exactly the same opportunities and challenges in mathematics. Male and female students need to compete, collaborate and gain from one another in mathematics teaching and learning. They recommended that teacher professional development programs should make more concerted efforts to advise teachers about the ways in which to approach the teaching of mathematics so as to avoid disadvantaging particular groups of girls or boys. They also pointed out that mathematics teaching and evaluation should be gender bias free. This way, boys and girls will tend to see themselves as equals capable of competing and collaborating in classroom activities. They also recommended that male and female teachers should work jointly with boys and girls and adopt a more socially just and inclusive approach to creating equal opportunities for all students.

According to the research conducted by Kaiser and Zhu (2022), boys performed better than girls in overall mathematics achievement but the difference was insignificant. On average, a Shanghai boy would achieve significantly higher marks than a girl in programme for International student Assessment 2012 mathematics test.

Research has shown that gender differences in mathematics performance are diminishing (Frost, Hyde & Fennema, 1994; Hyde, Fennema & Lamon, 1990). Piere, Moran and Lutkus (2005) found out that the gap has been narrowing in the United States of America. Research in Australia indicated that the gender differences in mathematics achievement are reducing and shifting (Forgasz, Leder & Vale, 2000).

According to Vale (2009), many studies conducted between 2000 and 2004 in Australia showed significant differences in mathematics achievement between male and female students though males were more likely to obtain higher mean scores.

Feminists researchers have tried to make meaning of the experiences of girls and boys in mathematics classrooms and to interpret male-female power relations (Jungwirth,1991; Waiden & Walkerdine,1985). Their findings revealed that girls are often marginalized and given subordinate status in the mathematics class. The findings suggest that perceptions of teachers are that girls' performances in mathematics are dependent on rote learning, hard work and perseverance rather than natural talent, flexibility and risk taking which are the learning styles of the boys.

The National Council of Teachers of Mathematics (NCTM), which is the world's largest association of teachers declared technology as one of the six principles for school mathematics. According to the National Council of Teachers of Mathematics position statement regarding technology, appropriate use of technology allows more students access to mathematical concepts (NCTM, 2008). Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning. According to Schifter and Fosnot (1993), students' mathematical understanding requires the provision of time and opportunities to participate in a process of concept construction and active interpretation within meaningful contexts.

ICT integration in education is a policy priority by the Ministry of Education (Ministry of Education, 2006; Ministry of Education, Science and Technology, 2005). The ICT options were based on Sessional Paper No. 1 of 2005 and KESSP and outlined among others, priorities on improving quality teaching and learning, improving educational policy and coordination and considering costs and benefits of educational interventions. There are eight options which included quality teaching and learning through ICT with a focus on e-content development; ICTs in teacher training colleges; computers in secondary schools; computers in primary schools cluster centres; ICT for in-service teacher training; and video for in-service teacher training among others.

According to Centre for Mathematics, Science and Technology Education in Africa (CEMASTEA) (2017), CEMASTEA has made several initiatives towards effective teaching and learning of mathematics and sciences. One such initiative has been to embrace technology in all its training programmes. ICT integration in teaching and learning of mathematics and sciences has become a key and integral component of Activity, student, Experiment, Improvisation-plan do see and improve (ASEI-PDSI) teaching and learning of mathematics and science paradigm shift. In an endeavour to improve the quality of teaching and learning, CEMASTEA has been capacity building teachers on ICT integration at the county level. The facilitation is done by CEMASTEA trainers in selected county centres with adequate ICT facilities.

The training on ICT integration in teaching and learning and particularly in STEM was meant to enhance efficiency, effectiveness and innovativeness, provide interactive learning experiences, under difficult concepts and processes and enhance collaboration and group work. CEMASTEA hope that the training will go a long way in changing the classroom practices in making learning more meaningful, relevant and applicable to real life by promoting 21st century skills.

According to CEMASTEA (2017), effective teaching and learning largely depend on the teaching and learning strategies teachers adopt. One of the strategies is in designing appropriate teaching and learning activities that can enhance achievement of lesson objectives. The teaching and learning activities that can enhance the effectiveness of the teaching and learning process and achieving the intended lesson objectives. According to the Training Needs Assessment (TNA) report (CEMASTEA, 2015), majority of teachers did not adequately arouse learner's interest and curiosity through innovative and real life situations nor did they involve learners in developing creative ideas. Furthermore, a large number of teachers rarely develop activities that enable learners interpret, analyze and evaluate new information.

Technology use in mathematics teaching helps students to easily acquire basic mathematical skills. Organized and well planned supports as well as enough practice would greatly help students to improve their skills particularly in exploring their potential in information technology to the maximum (Zulnaidi & Zamri,2017). Students need guidance in applying the latest technology to solve various mathematical problems (Oldknow & Taylor,2000). The computer is now widely used as a teaching aid in mathematics in order to enhance students' self-motivation and self-confidence (Sivin-Kachala & Bialo,2000). The use of computer in teaching and learning mathematics is actually a sophisticated method as opposed to conventional methods to produce a brilliant generation in the aspects of physical, emotional, spiritual and intellectual development (Norazah & Effandi, 2007).

Teachers should embrace the current changes and strive to realize the use of the latest technology in the classroom. Educators should try the hardest in making mathematics a very interesting subject in order to attract students' interest and at the same time to help them consciously focus on important mathematical concepts (Zamri & Zulnaidi, 2017). It is the teacher's responsibility to prepare students to focus on the future world which undoubtedly would depend on mathematics, science and technology (Furner & Marinas, 2007). Technology based learning provides symbols , formula , tables , graphs , numbers , equations and manipulative materials to link them with various real life ideas and those are indeed parts of conceptual and procedural knowledge (Post,1998). Technology application in teaching and learning mathematics helps students to better understand basic mathematical concepts and to experience intuition in solving certain mathematical problems (Rohani et al, 2009).

1.3 Statement of the problem

Mathematics teaching and learning is crucial to the future of Kenya's knowledge economy and deserves a special focus and attention in our education system. Mathematics educators and the government have put in a lot of effort aimed at identifying and addressing the major problems associated with secondary school mathematics in Kenya. With the intervention measures such as the ASEI movement and PDSI approach, which have been introduced in the teaching and learning of mathematics since 2003 (SMASSE PROJECT, 1998) to address the issue of poor performance in mathematics, the performance of candidates in Mathematics at KCSE level is still low as shown in the table below.

Table 1. 1: KCSE Results Analysis

Year	Candidature	Mean score (%)
2005	259280	19.69
2006	238684	19.04
2007	273504	18.23
2008	304908	21.30
2009	335615	21.13
2010	356072	23.04
2011	409887	24.79
2012	433017	28.66
2013	444774	27.58
2014	481286	24.02
2015	520274	26.88

Source: KNEC 2015

Analysis of KNEC reports show that candidates perform relatively poor in Geometry questions in KNEC examinations. The reports also show that very few students attempt the questions on this area of Geometry. The teaching of this area did not arouse learner's interest and curiosity. The findings further indicated that there was inadequate use of innovative activities that relate to real life situations during the teaching of this area.

In the KCSE report 2012, a number of questions that required the application of construction skills were considered for analysis. The report reveals that candidates are ill prepared to answer questions on this concept of Geometry. In the KCSE KNEC Report (2015), the analysis identified questions that were considered to be difficult to the candidates. The report is based on comments from the chief examiners reports and an analysis of the students' responses from sampled scripts. Major weaknesses have been observed in some areas of the syllabus for both Alternative A and Mathematics

Alternative B .These areas include angle properties of a circle, chords and tangents, area approximations, Geometry and transformations (KCSE Report, 2015). Application of the learned concepts to real life situations was observed to be a challenge to many students. The findings from the KCSE reports of 2012 and 2015 prompted the researcher to investigate how best the area of Geometry can be taught in Kenyan secondary schools. Geometry was identified as one of the difficult and challenging area where the candidates have consistenly performed poorly over the years.

1.4 Purpose of the study

The main purpose of this study was to investigate the effect of Geogebra and Grapes in the teaching and learning of Mathematics in Kenyan secondary schools.

1.5 Objectives of the study

The objectives of this study were:

(1) To determine the effectiveness of using Grapes and Geogebra on students' learning of graphs as compared to the traditional approach.

(2) To establish whether the use of Geogebra and Grapes can improve the performance in mathematics for both boys and girls.

(3) To determine whether the teaching method influence the performance of students in mathematics.

(4) To determine students' perceptions on the use of Grapes and Geogebra in the teaching and learning of graphical work.

1.6 Research Questions

(1) What is the effectiveness of using Grapes and Geogebra on students' learning of graphs as compared to the traditional teaching approach?

(2) Does the use of Geogebra and Grapes improve the performance in mathematics for both boys and girls?

(3) Does the teaching method influence the performance of students in mathematics?

(4) What are the students' perceptions on the use of Grapes and Geogebra in the teaching and learning of graphical work in secondary schools Mathematics?

1.7 Research hypotheses

The following research hypotheses, as derived from the research questions and stated in their null form, were tested using Anova, t-test and regression analysis at alpha level of significance 0.05.

HO_1: There is no significant difference between the pre-test mean score of both the control and the experimental group.

$HO_{2:}$ There is no significant difference between the use of Grapes and Geogebra and the traditional approach in teaching graphical work.

$HO_{3:}$ There is no significant difference between the scores of boys and girls when they are taught using Grapes and Geogebra.

HO_4: There is no significant difference between the teaching method and the performance of students in mathematics.

1.8 Assumptions of the study

Assumptions are basic, fundamental conditions that must exist in order for the research to proceed. They are basic premises required in the study and the researcher does everything possible to increase the credibility of the assumptions, but does not have absolute control. Assumptions could be made about (1) the motivation of the subjects, (2) whether subjects responded truthfully, (3) the validity of the measuring instrument, and (4) whether subjects followed directions correctly.

In this study, the following assumptions were made:

(1) All the schools that were selected for the study have mathematics teachers who have undergone training on ICT integration.

(2) All the schools that were selected for the study have acquired resources for ICT projects.

(3) All the schools that were selected for the study have the basic knowledge of how to integrate ICT into the curriculum.

(4) The respondents accurately and honestly responded to the pretests and posttests that were administered to them.

(5) The schools selected for the study had the basic infrastructure for ICT integration.

(6) The use of GeoGebra and Grapes was going to improve the performance of Mathematics at secondary school level.

1.9 Significance of the study

The findings of this study would be useful to the quality assurance and standard officers within the ministry of education in Kenya. The findings will enable them to come up with better methods of teaching and learning of mathematics in Kenyan secondary schools and hence achieving better results at KCSE level. The study will also benefit Kenyan secondary school mathematics teachers by giving them insight on how GeoGebra and Grapes can be used to improve the teaching and learning of mathematics.

The scholars in the field of mathematics education will also benefit from the findings of this study as it will add to the body of knowledge. The secondary school principals will also benefit from this study as it will enable them see the importance of embracing the new technology in the teaching and learning of mathematics and hence be able to make informed decisions on acquiring the correct type of the ICT infrastructure for their schools. The secondary school mathematics teachers will also benefit from the study as it will give them insights on how GeoGebra and Grapes can be used to improve the teaching and learning of mathematics. The students would also be the greatest beneficiaries of this study since they would be able to learn about GeoGebra and Grapes and use them to achieve better understanding of some concepts which are considered to be difficult and abstract in geometry.

1.10 Delimitations and Limitations of the study

Delimitations define the scope of the study. That is, they set the boundaries of the study. Delimitations are normally under control of the researcher. The limitations of the study are those characteristics of design or methodology that impacted or influenced the application or interpretation of the results of the study. They are the constraints on generalizability and utility of findings that are the result of the ways in which one chooses to design the study and/or the method used to establish internal and external validity. Limitations are very similar to delimitations, but they tend to focus on potential weaknesses of the study. Limitations are possible shortcomings of the study which are usually not being controlled by the researcher. The researcher will, of course, try to eliminate extremely serious weaknesses before the study is commenced. No study is perfect hence the researcher should recognize the potential weaknesses in the study.

The study was carried out in Bomet County and targeted form four students in randomly selected homogenous schools. The study focused mainly on the secondary schools within Bomet County. The generalizations and the conclusions were limited to secondary schools within the county which were considered to be homogenous and are purely boys' and purely girls' schools. The study mainly focused on the use of GeoGebra and Grapes in the teaching and learning of graph work in secondary school mathematics. The study did not attempt to find out the effect of GeoGebra and Grapes in the teaching and learning of mathematics in schools which are mixed and heterogenous. The study also did not also attempt to find out how learning of mathematics in other areas of the mathematics other than Geometry takes place.

Few researches on the use of GeoGebra and Grapes have been carried out in Kenya. The few researches that have been carried out mainly touch on the use of GeoGebra in teaching other areas of the syllabus other than Geometry and Algebra. There was limited information available on the use of Grapes in teaching Geometry. The reaearcher optimized the scarcity of time and resources to ensure that the study was completed in good time. The level of ICT skills amongst the teachers and learners was another limitation. There was therefore the need to train the teachers and the students of the selected schools.

1.11 Theoretical framework

This study was guided by Technology Acceptance Model (Davis, 1989). Technology Acceptance Model (TAM) stands out in examining issues affecting users' acceptance of modern technology. The Technology Acceptance Model is an information system theory that propagates the different stages to be followed by information seekers or learners in the acceptance, inculcating and utilization of new technology to achieve information literacy skills. The model suggests that when users are presented with a new software package, a number of factors influence their decision about how and when they will use it.

Technology acceptance model includes perceived ease of use (PEOU) and perceived usefulness (PU) which are important determinants of technology acceptance and user behavior. Understanding technology acceptance will lead to better prediction of the use of new technology. Perceived usefulness is relevant to this study because the use of GeoGebra and Grapes enhanced the academic achievement in mathematics as compared to to the traditional method. The students can learn graph work faster and better with the use of technology.

Perceived ease of use is also relevant to this study. The ability of the students to accept and use GeoGebra and Grapes will ease their usefulness of the new technology in learning mathematics. Efforts of doing graphwork using the traditional method are reduced automatically with the use of technology. Technology acceptance model is related to the problem under investigation.

The technology acceptance model assumes that when someone forms an intention to act, that they will be free to act without limitation. In the real world there will be many constraints, such as limited ability, time constraints, environmental or organisational limits or unconscious habits which will limit the freedom to act. Concentration on the positive aspects of ‘usefulness’, both to the organisation and to the individual, and ‘ease of use’ will help users develop a positive attitude. It is in this area that the early adopters can have a powerful influence of their conservative and pragmatic peers. The Technology Acceptance Model is an information systems theory that models how users come to accept and use a technology.

Davis et al. (1989) have developed a theory of action called the Technology Acceptance Model (TAM) to explain computer-usage behavior that relates to reasons why some people use computers and their attitudes towards them. Their model links the perceived usefulness and ease of use with attitude towards using ICT and actual use. They discovered that people's computer use was predicted by their intention to use it and that perceived usefulness was strongly linked to these intentions. A positive attitude towards performing certain behaviors was related to the perceived value of those behaviors. According to Malhotra and Galletta (1999), TAM has emerged as one of the most influential models in Information Systems research. The theoretical basis of TAM was Fishbein and Ajzen's (1975) Theory of Reasoned Action (TRA). TRA is a widely studied model from social psychology, which is concerned with the determinants of consciously intended behaviors.

Technology acceptance model postulates that the acceptance of technology is predicted by the user’s behavioral intention which is , in turn , determined by the perception of technology usefulness in performing the task and perceived ease of its use. Technology acceptance model is a useful theoretical base to predict and understand users’ intentions to use a technology. Users’ education and involvement in the technology decision making can improve on the acceptance and use of new technology.

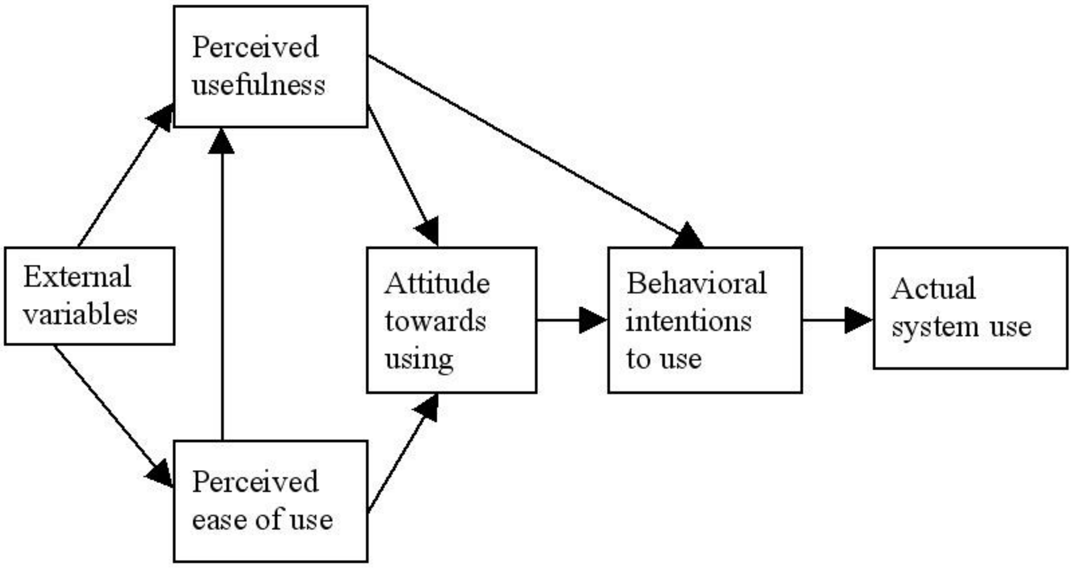


Figure 1. 1: Technology Acceptance Model

Bagozzi, Davis and Warshaw say:

Because new technologies such as personal computers are complex and an element of uncertainty exists in the minds of decision makers with respect to the successful adoption of them, people form attitudes and intentions toward trying to learn to use the new technology prior to initiating efforts directed at using. Attitudes towards usage and intentions to use may be ill-informed or lacking in conviction or else may occur only after preliminary strivings to learn to use the technology evolve. Thus, actual usage may not be a direct or immediate consequence of such attitudes and intentions. (Bagozzi, 1992).

The research was also underpinned by the concept of teachers' pedagogical technology knowledge (PTK),developed by Thomas and Hong (2005) ,as a useful way to think in outline about what teachers need to know in order to teach mathematics well with technology.

1.12 Conceptual Framework

A conceptual framework is an analytical tool that is used to get a comprehensive understanding of a phenomenon. It is the researcher's own perception of the problem and how variables operate in influencing each other. It is most commonly used to visually explain the key concepts or variables and the relationships between them that need to be studied. Conceptual framework provides an explicit explanation why the problem under study exists by showing how the variables are related to each other graphically or diagrammatically. It is a hypothesized model identifying the concepts under study and their relationship (Mugenda & Mugenda, 2003). The purpose of a conceptual framework is to help the reader to quickly see the proposed relationships.

According to Miles and Huberman (1994), conceptual framework is a written or visual presentation that:

- "explains either graphically, or in narrative form, the main things to be studied – the key factors, concepts or variables
- and the presumed relationship among them".

A conceptual framework provides the structure/content for the whole study based on literature and personal experience. According to Camp (2001), a conceptual framework is a structure which the researcher believes can best explain the natural progression of the phenomenon to be studied. It is linked with the concepts, empirical research and important theories used in promoting and systemizing the knowledge espoused by the researcher (Peshkin, 1993). It is the researcher's explanation of how the research problem would be explored. The conceptual framework presents an integrated way of looking at a problem under study (Liehr & Smith, 1999). In a statistical perspective, the conceptual framework describes the relationship between the main concepts of a study. It is arranged in a logical structure to aid provide a picture or visual display of how ideas in a study relate to one another (Grant & Osanloo, 2014). Interestingly, it shows the series of action the researcher intends carrying out in a research study (Dixon, Gulliver & Gibbon, 2001). The framework makes it easier for the researcher to easily specify and define the concepts within the problem of the study (Luse, Mennecke & Townsend, 2012).

Conceptual framework provide a graphic presentation that is self-explanatory showing how various variables interact and the direction of the outcomes from such interactions. Below is the diagrammatic representation of the conceptual framework involving the variables that were considered in this study.

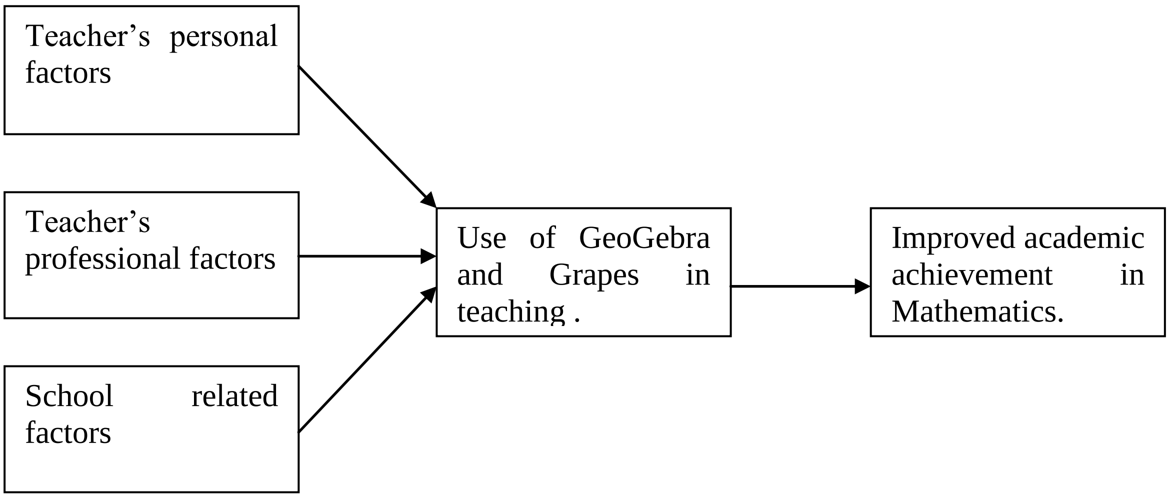


Figure 1.2. Conceptual Framework

For the use of GeoGebra and Grapes to be successful in the teaching of mathematics , several factors come into play. The most important are the teacher's personal factors.

These are the factors which are inherent in the teacher. Interest in technology is an important factor which the individual teacher need to have so as to integrate technology in his /her teaching. The other factor is the technological knowledge the teacher posses on how to use technology. Without the prerequisite knowledge on the use of ICT it will be difficult for a teacher to use technology in planning for instruction. The other requirement for the teacher is oppeness to innovation. In the twenty first century , a teacher must be innovative in his/herteaching. A teacher can't use the old methods of teaching and expect their students to succeed in their academic work. Teachers must be adaptive in their teaching sytles. There has to be a paradigm shift in the way lessons are prepared and planned. Teachers can't teach the same way they were taught in high school. The other thing which is expected of a teacher is the self confidence when it comes to using technology and handling of ICT resources in teaching mathematics.

Teacher professional factors include awareness of technology, the purpose of using technology and the professional improvement of the teacher. Teachers are expected to be aware of the various types of the latest technology such as GeoGebra and Grapes that can be used to teach mathematics. At the same time a teacher is expected to know the purpose of integrating ICT in teaching mathematics. Certain topics in mathematics are abstract and therefore a teacher should be in a position to use ICT in teaching those topics that are considered to be abstract. Professional improvement is factor expected of every teacher if he/ she want to remain relevant in the teaching of mathematics. New knowdge is emerging every now and again and therefore the only way to get be updated is through teachers's professional seminars such as the ones organised by CEMASTEA at the national level. Seminars for mathematics teachers can also be organised at county or sub-county level. Such seminars equip teachers with the requisite skills on the latest and emerging trends in mathematics teaching such as the use of GeoGebra and Grapes.

School driven factors that can enhance the integration of ICT in teaching of mathematics include the technical support and the ICT infrastructure available in the school. Technical support of a teacher plays a critical role in ICT integration within the school setup. There should be a technical person present in the school so as to assist the teacher incase of any challenge. When one fails the first time while using the ICT gadgets and nobody is available to assist , such a teacher is unlikely to use ICT again in future. The ICT infrasrtucre of a school play a key role in the the process of ICT integration .Without presence of the basic resources such as computers ,laptops , the soft ware for use in teaching , internet connectivity , reliable source of electricity and the projector, implementing ICT integration in the teaching of Mathematics is not possible. Acquisition of the basic ICT resources is also affected by the economic status of the school. Schools which are financially endowed can easily acquire the basic resources for implementing the ICT integration. Teachers in such schools are most likely to integrate ICT in their teaching.

According to Wassie and Zergaw(2019), technological literacy is an essential skill of teaching with the power to motivate and create opportunities for students to comprehend , construct and explore new approaches to problem-solving.Integration of technology with learning has the advantage of enriching the processing power of students' mind to a new domain of knowledge representation through modelling , simulation and visualization. The new technology is used as a medium of addressing conceptually rich topics such as Geometry in mathematics in a way that makes the teaching and learning of some abstract concepts to become easier. The use of ICT can create an innovative learning environment that transform the teaching and learning of mathematics in the classroom. The teacher's role in the integration of ICT is to facilitate critical student inquiry and not to provide knowledge , skills and anwers to problems in mathematics. The use of ICT in the teaching and learning of mathematics can serve as a tool for creating contexts in which students engage in mathematical thinking leading to better understanding. Use of the new technology can illustrate abstract concepts and make objects that are invisible to the naked eye to become visible and clear to the learners. The integration of ICT in the teaching of mathematics reduces the level of abstraction that is normally the characteristic of our mathematics classrooms with the use of the traditional teaching approach.

1.13 Operational Definition of Terms

There are few terms used in this study which merit some definition:

Attitude: This is taken to mean the student's acquired internal state or feeling influencing their choice towards learning.

Behaviour: An individual's observable response in a given situation with respect to a given target

Impact: Any effect, whether anticipated or unanticipated, positive or negative, brought about by an intervention.

GeoGebra : GeoGebra is a dynamic mathematics software that affords dynamically linked multiple mathematical representations, computational utilities, documentation tool and a technical tool to support teaching and learning of Mathematics.

Grapes : Grapes is a mathematical graphing software that can be used to teach functions and relations in geometry.

Normative belief : An individual's perception about particular behaviour, which is influenced by the judgment of significant others

Performance: This refers to the status of students with respect to acquired skills and knowledge as compared with other students or other schools, adopted standards or national educational standards.

Secondary school: An institution of learning that offers four years of formal schooling preceding university education.

The education offered at this level is based on the four year curriculum which is broad based and builds on concepts, principles, skills and attitudes established at the primary level.

Policy in Education: Refers to a government-issued document which sets

out the principles, guidelines and strategy for ICT in education.

Questionnaire: Information data collection to be undertaken that Consists of students, teachers and administrators on the resources required and ICT assisted educational support.

ICT tools A diverse set of information, communication and, technological information and resources used to transmit, store, create, share or exchange information.

Student-Centred Teaching: Teaching that allows students to develop critical thinking and problem-solving skills, fosters independent learning and enables students to be responsible for learning, and collaborate with other contacts

Behavioural intention: An indication of an individual's readiness to perform a given behaviour

1.14 Summary

This chapter has outlined the background to the study, statement of the problem, objectives of the study, research hypotheses, theoretical framework, significance, assumptions, scope and limitations of the study. It also presented the operational definition of terms. In the next chapter, a review of related literature is presented.

CHAPTER TWO: LITERATURE REVIEW

2.1 Introduction

This chapter has reviewed literature that is related to ICT integration in the teaching of Mathematics. Review of related literature has been done extensively, covering both local and international current research studies on using the new technology to teach Mathematics. Some of the literature reviewed was obtained from several journals and websites on the internet. The study sought to investigate the role of Grapes and GeoGebra on students' achievement in the teaching and learning of Mathematics in secondary schools in Bomet County, Kenya.

2.2 Conventional /Traditional method of teaching

Conventional teaching normally focuses on mathematics procedures, as students are taught and given practice on procedural type of questions in preparing for the national examination. Hence, the students would have the tendency to solely depend on the learning process that they have experienced in school. Consequently, students' mathematical knowledge is shallow and not well developed (Zulnaidi & Zamri,2017). Normally, teachers who resort to conventional teaching would rarely apply conceptual-based teaching strategies. It is indeed convenient to use conventional teaching as all the learning materials are readily available in the textbooks (Martunis,1989). Textbooks do not really require teachers to change their traditional teaching style. Years of teaching experiences would strengthen a kind of routine and teaching habit especially in the ways of delivering the teaching and learning contents and mathematical tasks. On the other hand, students are also comfortable with the traditional learning style as they do not really face difficulty in adjusting themselves to their teacher's teaching style (Zulnaidi & Zamri, 2017).

According to Biashara (2015), traditional method refers to all study groups in a homogenous manner, where the teacher is at the centre of the study process teaching all the students in the same manner, in other words, without considering their individual differences with no pertinence to the differences among them.

According to Smith (1996), the teacher's role in the traditional classrooms is to provide clear step by step demonstrations of each procedure, restate steps in response to student questions, provide adequate opportunities for students to practice the procedures, and offer specific corrective support when necessary, and the ultimate mathematical authority is the textbook from where the answers to all the mathematical problems are known and found. While behaviourism emphasizes students' passive absorption of observable behaviours, constructism asserts that individuals approach a new task with prior knowledge, assimilate new information and subsequently construct their own meaning (Amit &Fried, 2002).

As children construct their own understanding based on the relationship between prior knowledge, existing ideas and new experiences, they must be encouraged to wrestle with new ideas, to work at fitting them into existing networks, and to challenge their own ideas and those of others so as to subsequently enlarge the framework from which new ideas may be formulated (Van De Walle, 2007). Once one accepts that the learner must himself or herself actively explore mathematical concepts in order to build the necessary structures of understanding, it then follows that the teaching of mathematics must be reconceived as the provision of meaningful problems designed to encourage and facilitate the constructive process (Schifter &Fosnot, 1993).

In traditional teaching approach, teachers usually maintain the status quo within their mathematics classrooms as opposed to the new teaching approach where teachers use a lot of manipulative materials and hands on activities. The National Council of Teachers of Mathematics (NCTM) , which is the world's largest association of teachers declared technology as one of the six principles for school mathematics. Technology is essential in teaching and learning mathematics; it influences the mathematics that is taught and enhances students' learning. According to Schifter and Fosnot (1993), students' mathematical understanding requires the provision of time and opportunities to participate in a process of concept construction and active interpretation within meaningful contexts.

2.3 Introduction to Information Communication and Technology (ICT)

Many people consider ICT Integration as 'having a computer in the classroom' or 'doing the basic operations on the computer'. These, however, are common misconceptions about Integration of ICT in teaching and learning. Often, teachers are just expected to integrate technology without having a working definition of the concept (Dias, 1999). Therefore, let us first define what ICT Integration is.

Information and Communication Technologies (ICTs) are commonly defined in education as "a diverse set of technological tools and resources used to communicate, and to create, disseminate, store, and *manage information."* (Blurton, 2002). These technologies include computers, the Internet, broadcasting technologies (radio and television), and (mobile) telephony.

In recent years the interest has mainly been on how computers and the internet can best be harnessed to improve the efficiency and effectiveness of education at all levels and in both formal and non-formal settings. But ICTs are more than just these technologies and especially in Kenya the older technologies, such as the telephone, radio and television, although now given less attention, have a longer and richer history as instructional tools (See for example Cuban, L. (1986). KICD has been using radio and audio and videotapes for content delivery. In 2006 KICD started developing digital content and in 2009 a digital broadcasting center was launched (current span limited to Nairobi and its environs). In Kenya the different technologies are used in combination rather than as the sole delivery mechanism. The use of computers and the Internet is still in its infancy in Kenya as is the case in other developing countries, if used at all, due to limited infrastructure and the attendant high costs of access.

Educational technology is the study and ethical practice of facilitating learning and improving performance by creating, using and managing appropriate technological processes and resources. The term educational technology is often associated with, and encompasses, instructional theory and learning theory. While instructional theory covers the processes and systems of learning and instruction, educational technology includes other systems used in the process of developing human capability. Educational Technology includes, but is not limited to, software, hardware, as well as Internet applications and activities.

ICT integration is broadly defined as a process of using any ICT (including information resources on the web, multimedia programs in CD-ROMs, learning objects, or other tools) to enhance student learning (Williams, 2003). The purpose of integrating ICT is to improve the quality of teaching and learning and to equip learners with 21st century skills.

In today’s society students have to be prepared to use ICT to become competent professionals in their field of expertise. ICT plays a role in acquiring problem solving skills by students and facilitates their understanding of difficult parts of the curriculum. To provide students with the necessary ICT skills, teachers need to be prepared to use technology-supported learning opportunities. They need to be prepared to use the technology in supporting student learning.

Interactive computer simulations, digital and open educational resources, and sophisticated data-gathering and analysis tools are some of the resources that enable teachers to provide previously unimaginable opportunities for conceptual understanding, and classroom management. ICT can support curriculum delivery in various ways.

ICT integration in education is a policy priority by the Ministry of Education (Ministry of Education, 2006; Ministry of Education, Science and Technology, 2005). The ICT options were based on Sessional Paper No. 1 of 2005 and KESSP and outlined among others, priorities on improving quality teaching and learning, improving educational policy and coordination and considering costs and benefits of educational interventions. There are eight options which included quality teaching and learning through ICT with a focus on e-content development; ICTs in teacher training colleges; computers in secondary schools; computers in primary schools cluster centres; ICT for in-service teacher training; and video for in-service teacher training among others.

Information and communication technologies (ICTs) have the potential to enhance access, quality, and effectiveness in education in general and to enable the development of more and better teachers in Africa in particular. As computer hardware becomes available to an increasing number of schools, more attention needs to be given to the capacity building of the key transformers in this process, namely, teachers.

2.4 ICT and Teacher Education

Dawes and Selwyn (1999) found that a major deterrent to use the computer by teachers was computer phobia. The teachers' anxieties could be caused by a few factors. The first one is psychological factor such as having little or no control over the students' activity. Teachers do not want to be seen as incompetent in the eyes of their students. They have the fear that the students possess more knowledge of computers than they do. The second factor is sociological factor such as ICT being regarded as a solitary activity, needing to be clever to use one, and being replaced by the computer in the long term. Stoll and Fink (1996) define school culture as a combination of the realization of relationships, beliefs, attitudes and ideologies of all those that work in the establishment. The culture may be intangible but it is a very powerful force in determining the direction of the school. The principal and the senior management play important roles in building a professional culture of teaching, which is responsive to change (Hargreaves & David, 1990) as these senior members of staff help to set the values for all and attributes such as commitment and hard work can be made to filter through all aspects of school life. On the other hand, according to Fullan and Hargreaves (1992), when experienced teachers are subjected to changes, they may experience three particular clusters of feelings as follows:

(a) Loss of firmly held beliefs and ideas, established patterns and behaviours, comfortable habits and confidence and self-esteem;

(b) Anxiety about required levels of understanding, new skills, future prospects, being able to cope and being seen as different and;

(c) Struggle to survive intact, acquire new competence and gain respect and recognition.

In a report on the barriers that exist in schools that prevent teachers from

> making full use of ICT in teaching, Jones (2004) has summarised some of the key findings as follows: a very significant determinant of teachers' levels of engagement in ICT is their level of confidence in using the technology; there is a close relationship between levels of confidence and many other issues which themselves can be considered as barriers to ICT; levels of access to ICT are significant in determining levels of use of ICT by teachers; inappropriate training styles result in low levels of ICT use by teachers; teachers are sometimes unable to make full use of technology because they lack the time needed to fully prepare and research materials for lessons; technical faults with ICT equipment are likely to lead to lower levels of ICT use by teachers; resistance to change is a factor which prevents the full integration of ICT in the classroom; teachers who do not realise the advantages of using technology in their teaching are less likely to make use of ICT;

There are close relationships between many of the identified barriers to ICT use; any factors influencing one barrier are likely also to influence several other barriers.

Many researchers from the U.K, U.S.A, Australia, Canada and the Netherlands have provided data for the review written by Jones (2004). Some of these sources are Harrison et al. (2002), Somekh et al. (2002), BESA (2002), Kirkwood et al. (2000), Office for Standards in Education (2002), Preston et al. (2000), Butler and Sellbom (2002), Cuban et al. (2001), Granger et al. (2002), Russell and Bradley (1997) and Veen (1993). The findings of another study by MohdYunus (2007: 93) regarding the main challenges to ICT integration perceived by ESL teachers who teach in Malaysian technical schools comes to the conclusion that ICT integration in teaching

"…is dependent upon adequate access, adequate computer resources, teacher development opportunities, and onsite support – all of which require funding, thought, planning and support."

ICTs are one of the major contemporary factors shaping the global economy and producing rapid changes in society. They have fundamentally changed the way people learn, communicate, and do business. They can transform the nature of education – where and how learning takes place and the roles of students and teachers in the learning process. Education in the East African region faces a number of problems. These problems include the shortage of qualified teachers, very large student populations, high drop-out rates of students and teachers, and weak curricula. All of these negative aspects result in poor delivery of education. The education crisis is worsened by the devastating effects of the HIV/AIDS pandemic, increasing poverty, a brain drain in the teaching community, budgetary constraints, poor communication, and inadequate infrastructure.

While societies in the region undergo rapid changes as a result of increased access to information, the majority of the school-going youth continue to undergo traditional rote learning. Very little is done to take advantage of the wealth of information available on the Internet.

Whereas the processing of information to build knowledge is one of the essential literacy skills vital for the workforce in the 21st century, it is often overlooked in current educational practices.

In order to function in the new world economy, students and their teachers have to learn to navigate large amounts of information, to analyse and make decisions, and to master new knowledge and to accomplish complex tasks collaboratively. Overloaded with information, one key outcome of any learning experience should be for learners to critically challenge the material collected in order to decide whether it can be considered useful input in any educational activity. This is the basis for the construction of knowledge. The use of ICTs as part of the learning process can be subdivided into three different forms: as object, aspect, or medium (Plomp, ten Brummelhuis, &Pelgrum, 1997).

- As object, one refers to learning about ICTs as specific courses such as 'computer education.' Learners familiarise themselves with hardware and software including packages such as Microsoft Word, Microsoft Excel, and others. The aim is computer literacy.
- As aspect, one refers to applications of ICTs in education similar to what obtains in industry. The use of ICTs in education, such as in computer-aided design and computer-aided manufacturing, are examples.
- ICTs are considered as a medium whenever they are used to support teaching and learning.

The use of ICT as a medium is rare (Plomp, et al., 1997), in sub-Saharan Africa where the availability of resources is a major obstacle to the widespread integration of ICTs in education.

Technology is not new to education. However, contemporary computer technologies, such as the Internet, allow new types of teaching and learning experiences to flourish. Many new technologies are interactive, making it easier to create environments in which students can learn by doing, receive feedback, and continually refine their understanding and build new knowledge. Access to the Internet gives unprecedented opportunities in terms of the availability of research material and information in general. This availability of research material and information happens to both inspire and threaten teachers.

The computer equipment in the few fortunate schools that have them tends to be underused and lacks appropriate education content. Commonly, the computer equipment is used as objects in computer lessons. A few other subject teachers undertake courses in software packages but are unable to integrate or meaningfully insert this knowledge in their daily teaching work. A worrying tendency is that boys are the targets rather than girls when investments in ICT hardware and training are made (Kinyanjui, 2002). If not taken seriously, this will increase gender disparities in education in the sub-region.

Respective governments in Eastern Africa recognise that ICTs have a critical role to play in improving education and are engaged in drafting ICT policies or ICT chapters in a number of development plans across economic sectors. The policies tend to clearly link development to a forward-looking educational sector and increased investment in human resources and ICTs.

In the education sector, curriculum review efforts are geared towards modernisation, including the incorporation of important ICT components. However, even the reviewed curricula tend to treat ICT as a subject rather than as an application tool that can be used in all other subjects, in teaching and learning. Very recent discourse indicates that future curriculum reviews may consider a fully fledged ICT mainstreaming process.

Teacher education institutions and programmes have the critical role to provide the necessary leadership in adapting pre-service and in-service teacher education to deal with the current demands of society and economy. They need to model the new pedagogies and tools for learning with the aim of enhancing the teaching-learning process. Moreover, teacher education institutions and programmes must also give guidance in determining how the new technologies can best be used in the context of the culture, needs, and economic conditions of their country.

2.5 Technological Pedagogical Content Knowledge (TPACK)

According to Sherman (2010), in order to make the best use of GeoGebra, teachers must have a deep, integrated knowledge of the content to be taught, the students who are to learn it, and the affordances and constraints of GeoGebra in relation to both. Most mathematics teachers did not learn mathematics using technology, and have few images of meaningful use of technology for mathematics instruction (Cuban, Kirkpatrick, & Peck, 2001; Kaput, 1992; Manoucherhri, 1999; Russell, Bebell, O'Connor, 2003). Furthermore, teachers' beliefs about the use of technology for instruction may be the most important factor in whether or not they use it, and how (Drier, 2001; Russell et al., 2003). According to Sherman (2010), one way that a teacher education course can address teachers' knowledge and beliefs is by developing their technological content knowledge (TCK). That is, by providing teachers with the experience of learning mathematics with technology that they often did not have as students, they can begin to understand the value of a dynamic environment like GeoGebra for their own students to discover mathematics.

There seems to be emerging consensus that the integration of ICTs into teaching and learning requires balancing different sets of knowledge and skills. Inglis, Ling and

Joosten (1999, in Shephard, 2004), for example, identify three zones of expertise: expertise in information technologies, expertise in instructional design and expertise in a subject area. Based on Shulman's (1986) notion of pedagogical content knowledge (PCK) Mishra and Koehler (2006) developed a theoretical framework that not only corresponds closely with the zones of expertise identified by Inglis et al., but also identifies four additional sets of teacher knowledge bases by focussing on the areas of overlap between each pair in this triad, as well as the interplay of all of three of these primary knowledge bases . For Mishra and Koehler,

TPCK represents a class of knowledge that is central to teachers' work with technology. This knowledge would not typically be held by technologically proficient subject matter experts, or by technologist who know a little of the subject or of pedagogy, or by teachers who know little of that subject or about technology .

As described by Mishra and Koehler (2006) ,Technological Pedagogical Content Knowledge (TPCK) is the basis of good teaching with technology and requires not only content knowledge or pedagogical knowledge but an understanding of the representation of concepts using technologies , how to teach these mathematics concepts using technology , knowledge on the challenges their students will face when presented with this new pedagogy , and how technology can be used to build on existing knowledge and develop knew knowledge .

With the availabity of dynamic mathematics software like GeoGebra and Grapes ,teachers are able to make graphical representations of mathematics concepts .As the concepts are introduced with pictorial representations , teachers and their students are able to make connections between the pictures , the mathematics concepts and the symbolic representations . when presented with a new concept , students need to think

, visualise and explore relationships and patterns .This is consistent with the CRA (concrete ,Representational and Abstract) Model for teaching mathematics currently in better reaching students as they learn and understand mathematical concepts .Technology makes all of these possible for them in a short amount of time .Technology is one of the principles for teaching mathematics set out by the National Council of Teachers of Mathematics standards (NCTM,2000).

Claiming that this framework enables a deeper understanding of a range of contextually bound and complex relationships, Mishra and Koehler (2006) argue that :

‘‘a conceptually based theoretical framework about the relationship between technology and teaching can transform the conceptualisation and the practice of teacher education, teacher training, and teachers’ professional development’’

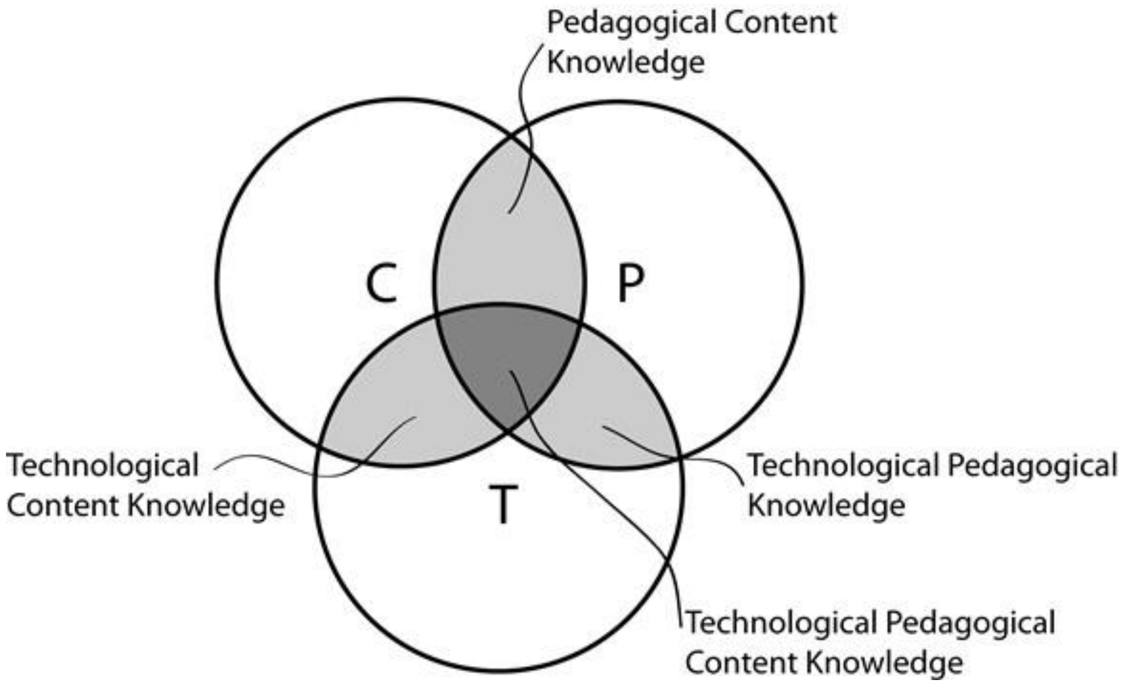


Figure 2. 1:Technological Pedagogical Content Knowledge (Mishra & Koehler,2008)

As explained above, much of the earlier theorising about the use of technology in education involved viewing technology as being separate from both content and pedagogy. A number of scholars have pointed to the failings of traditional add-on methods for teaching the use of technology. Mishra and Koehler, for example, regard these methods as "ill suited to produce the 'deep understanding' that can assist teachers in becoming intelligent users of technology for pedagogy …" and suggest that it is necessary to integrate the use of educational technology with sound pedagogy and that doing this requires the development of "a complex situated form of knowledge that [they] call Technological Pedagogical Content Knowledge (TPCK)" . TPCK emphasises "the connections, interactions, affordances, and constraints between and among content, pedagogy, and technology" .

According to Bas & Senturk (2018), ICT integration should go beyond the skills of information and communication technologies and develop an understanding in terms of the complex relationships between pedagogy, technology and content.

In practical terms, apart from looking at the three types of knowledge in isolation, Mishra and Koehler suggest that it is necessary to examine them in pairs: pedagogical content knowledge (PCK), technological content knowledge (TCK), technological pedagogical knowledge (TPK) and the three combined as technological pedagogical content knowledge (TPCK). Substantially expanded from Shulman's initial three categories, this model is useful for helping researchers to decide which research questions they need to ask and what data it is necessary to collect.

Content knowledge alone is not enough for a teacher to have inorder to effectively teach so that their students understand. Pedagogical knowledge goes beyond knowledge of subject matter to subject matter knowledge needed for teaching.

Pedagogical knowledge empowers the teacher to ‘‘use the most useful forms of representation for a given concept , the most powerful analogies , illustrations, examples, explanations and demonstrations –in a word, the ways of representing and formulating the subject that make it comprehensible to others’’(Shulman,1986). Pedagogical knowledge also allows a teacher to understand what makes the learning of specific concepts easy or difficult for students to understand (Shulman,1986).

Transforming pedagogical practice in mathematics:

Moving from telling to listening

“The depressing thing about arithmetic badly taught is that it destroys a child’s intellect and, to some extent, his integrity. Before they are taught arithmetic, children will not give their assent to utter nonsense; afterwards they will. Instead of looking at things and thinking about them, they will make wild guesses in the hopes of pleasing a teacher.” (W.W. Sawyer, *Mathematician’s Delight*)

For more than three decades perspectives in mathematics education have strongly promoted developing an understanding of mathematical concepts, procedures, connections, and applications through problem solving (National Council of Teachers of Mathematics [NCTM], 1989, 2000; National Research Council, 1989; Silver, Ghousseini, Gosen, Charalambous, & Font Strawhun, 2005). However, facilitating the development of mathematical understanding through problem solving remains a challenge for teachers. The use of technology enables teachers to move from traditional pedagogies of teacher explanation to pedagogy of teacher and student exploration of mathematical ideas within a problem-solving environment.

Collaboration between pupils

ICT seems to provide a focal point which encourages interaction between pupils, as well as between pupils and the technology itself. Goos (2001) found that the use of graphic calculators facilitated communication and the sharing of knowledge between pupils. It was both a stimulus and partner in discussions during group work. Pupils also shared their findings in a whole-class discussion using a data projector, and demonstrated further cooperation during the presentation, by co-coordinating use of the computer keyboard, projector, remote control and laser pen. As well as co-operating, pupils may also disagree more when using ICT, but they are likely to successfully resolve these disagreements, often by using ICT to prove a point (Clements, 2000). Hennessy (2001) describes how a graphic calculator was used in this way by pupils, to mediate during collaboration over a problem-solving activity. It provided an external reference point in discussions, a means for comparison of ideas which supported a highly productive investigation. Hudson (1997) investigated the use of a particular curriculum software package, and once again found a rich interaction occurring, both between pupils and with the software, under relatively unsupervised conditions, for much longer periods of time than had been achieved previously.

Effect on teachers and their pedagogical beliefs

Collaboration between pupils using ICT clearly alters the nature of the classroom as relationships between pupils and teachers change. At times the teacher will be more of a leading team player than a sole dispenser of knowledge, and this may conflict with their pedagogical beliefs. Jarrett (1998) reports three changes among teachers using technology:

- Raised expectations of pupils
- A more student-centred approach to teaching
- Greater willingness to experiment.

This implies that ICT supports constructivist pedagogy, where pupils use technology to explore and reach an understanding of mathematical concepts. Connell (1998) investigated the effect of the teacher’s pedagogical beliefs on the effectiveness of ICT, comparing a classroom run along constructivist principles (where pupils were encouraged to explore and test) with one where the technology was used primarily as a presentational tool for pre-packaged material, more akin to a behaviourist approach. At the end of the study, pupils in the constructivist class showed a marked improvement relative to the other class, suggesting that it is necessary to align the Philosophy of the classroom with the use of ICT. Ruthven and Hennessy (2002) examined the pedagogical ideas behind maths teachers’ use of ICT. What they found though, suggested that the opposition between constructivist and behaviourist philosophies is unhelpful in the UK context: teachers were using both approaches in their teaching, and finding them to be complementary. It was clear to teachers that the use of ICT was changing classroom conditions, but they accepted this, and welcomed the fact that it assisted the conducting of investigations by pupils.

2.6 ICT and mathematics problem solving

Amarasinghe and Lambdin (2000) described three different varieties of technology usage:

I. Using technology as a data analysis tool,
II. Using technology as a problem-solving/ mathematical modeling tool, and

III. Using technology to integrate mathematics with a context.

Meanwhile researchers (Balacheff & Kaput, 1996; Kilpatrick & Davis, 1993) have discussed the impact of technological forces on learning and teaching mathematics. Researchers argued that with the introduction of technology, it is possible to de-emphasize algorithmic skills; the resulting void may be filled by an increased emphasis on the development of mathematical concepts. Technology saves time and gives students access to powerful new ways to explore concepts at a depth that has not been possible in the past. The power of computers leads to fundamental changes in mathematics instruction. For example, the ability to build and run complex mathematical models, and easy exploration of "what if" questions through parametric variation has opened up new avenues for mathematics (Dreyfus, 1991). Furthermore, as Munirah (1996) observes, the teaching of calculus has seen a dramatic change now that activities such as exploring data or graphical data analysis have been revolutionized by the computer technology. The new role of computers is clearly expressed by Peters, O'Brian, Briscoe and Korth (1995). It is also reported that weaker students often are better able to succeed with the help of technology, and thereby come to recognize that mathematics is not just for their more able classmates

(Wimbish, 1992). Although there has been much written about the potential of technology to change how mathematics is taught, there does not seem to be much written about the how the use of technology changed students perception about mathematical problem solving. We are interested to know whether the use of technology could change students’ perceptions of problem solving. However, we are aware that students were not exposed and didn’t have the experience of using technology during their school mathematics lessons.

Problem solving is characteristic of mathematical activity and an important way of developing mathematical knowledge. A main purpose of mathematics teaching and learning is to develop the ability to solve a wide variety of complex mathematics problems. However, the process of problem solving in mathematics has not been given the proper recognition, probably due to the fact that teachers themselves are not comfortable with problem solving. As a result, teachers do not teach the process and technique of problem solving as an integral part of mathematics learning process. This move is actually an effort to integrate Information Communication Technology in a Mathematics Teaching Methods Course with the intention of changing the student teachers' beliefs and perception about problem solving so that they can become better problem solvers themselves and also to encourage students to develop a broad range of problem solving strategies. The process of problem solving, according to Polya (1957), involves four steps: understanding the problem, devising a plan (solution), implementing the plan and looking back (examining the solution). These processes demand the ability to develop a deep understanding of the problem and to devise a plan to solve it. Problem solving (Polya, 1973; Schoenfeld, 1985) has been advocated as revealing more of the strategies employed by children in the course of solving mathematical problems. While problem solving can be described through the use of heuristics and meta-cognitive strategies, the underlying assumption is that all mathematical entities consist of well-organized structures, waiting to be discovered. Teachers of Mathematics should inculcate in children the inclination to develop strategies in the process of solving Problems and to value its importance. However, the process of problem solving has not been given proper emphasis in schools, possibly due to the fact that teachers themselves are not very competent problem solvers and the burden of syllabus to finish and public examinations to prepare the students for.

Current approaches to mathematics education emphasize the development of mathematical understanding through students solving problems and sharing solutions and strategies (NCTM, 2000). In terms of understanding number sense and operation, while operational procedures are still important, developing an understanding of the operations that those procedures represent is seen as essential and is best developed through students developing their own strategies for solving problems (Carpenter, Ansell, Franke, Fennema, &Weisbeck, 1993; Forman & Ansell, 2001; Kamii, 1985, 1989, 1994, 2008).

This view is supported by evidence that mathematical procedures have often been imposed on students in ways that do not necessarily develop mathematical thinking or understanding (Carpenter et al., 1993; Huinker, 1998). Further, despite hours of instruction and practice, students often fail to master basic school algorithms or to apply them correctly in problem solving situations (Brown &VanLehn, 1980; Carroll, 1996; Silver, Shapiro, & Deutsch, 1993; VanLehn, 1986). Burns (1994) suggests that imposing the standard algorithms on children gives students the idea that mathematics is a collection of mysterious and often magical rules and procedures that need to be memorized and practiced.

Students' multiple strategies

Accompanying this perspective is support and research (Baek, 1998; Boufi & Skaftourou, 2004; Huinker, 1998; Kamii, 1985, 1989, 1994; Kamii & Lewis, 1993) for more attention being paid to students' development of their own strategies for arithmetic operations and less attention given to the teaching and practicing of traditional school algorithms. Studies suggest that children develop a deeper and more flexible understanding of operations through doing their own thinking and developing procedures that have meaning for them (Carpenter, Franke, Jacobs, Fennema, &Empson, 1998; Fuson et al. 1997). Further, when students develop their own strategies, they are more aware of place value and there are fewer conceptual errors (Carpenter et al., 1998; Carroll & Porter, 1998; Kamii& Lewis, 1993). The understanding developed through creating their own strategies is also extended to solve unfamiliar or non-routine problems more readily than strictly a procedural knowledge (Hiebert, 1986; Hiebert& Carpenter, 1992; Hiebert& Wearne, 1996). Gravemeijer and van Galen (2003) suggest that whether these semi-informal methods develop into the conventional algorithms, the quality of the students' understanding is much greater than if merely taught conventional algorithms.

However, students do not develop strategies in isolation. Methods of solution are constructed in a social context in which students share their strategies with one another. In Baek's study (1998) of student development of algorithms for multi-digit multiplication, students develop their own procedures through sharing different ways of solving problems and discussing the mathematical meaning underlying their inventions. Students may use mental procedures, manipulatives (play money or bingo chips), pictures, or written procedures to solve their problems. Students work on problems individually or in small groups, and then share their personal strategies or algorithms, discuss similarities or differences among them, and explore underlying mathematical concepts. Further, as students share their strategies they provide teachers with a window into how they think about the operational composition of numbers (Baek, 1998; Carroll, 1996; Willis &Fuson, 1988).

The Role of the Teacher

Teachers have an important role in guiding students' mathematical development by engaging them in problems, facilitating the sharing of their solutions, observing and listening carefully to their ideas and explanations, and discerning and making explicit the mathematical ideas presented in the solutions (Ball, 1993; Lampert, 2001; NCTM, 2000). Several research projects (see for example, Cobb, Wood, &Yackel, 1990; Fennema et al., 1996; Franke&Kazemi, 2001; Simon &Schifter, 1991) have found that when teachers attend to their students' mathematical thinking there are many benefits which include higher levels of conceptual understanding by students and more positive attitudes held by both teachers and students towards mathematics.

In particular, the encouragement of students' methods of solution requires that the teacher develops a listening orientation. Such an orientation promotes a learning environment conducive to and respectful of students' own sense making and intellectual autonomy (Davis, 1996; Kamii, 1989). Listening to students' mathematical thinking is one of the central tasks of mathematics teaching (NCTM, 1991). However, listening to students' thinking is hard work, especially when students' ideas sound and look different from standard mathematics (Ball, 1993; Morrow, 1998; Wallach & Even, 2005). Davis (1996) suggests that there are various ways that teachers listen to students' mathematical ideas and not all forms of listening are conducive and respectful of students' thinking.

Implementing this vision of mathematics classes where students' autonomous sense making and problem solving are facilitated challenges previous held notions of what it means to teach mathematics (Silver et al., 2005; Manouchehri & Goodman, 2000). The notion of teaching as telling (speaking, explaining, demonstrating) rather than listening (hearing, seeing, interpreting) still pervades most mathematics classrooms. Despite the many benefits seen by listening to students' mathematical thinking, focusing on students' thinking is challenging for several reasons (Ball, 2001; Schifter, 2001; Wallach & Even, 2005). One of the reasons is that students present a variety of ways of thinking about a mathematical problem and teachers may worry whether they will recognize mathematical understanding in all of the representations presented. Although a student may not appear to a teacher to understand a concept, there may actually be sense in their thinking and explanation. When teachers do not attend to student thinking they tend to dismiss what students bring to the mathematical community and instead impose traditional formalized procedures on students.

Professional Development

While there is evidence of the value of new teaching practices in mathematics, there is also evidence that mathematics teachers have not easily adapted to these changes and in many cases, little has changed (Manouchehri& Goodman, 2000; Silver, et. al., 2005). Designing professional development that helps teachers develop the practices that promote problem solving and students' multiple solutions poses several challenges. Most teachers have experienced traditional school mathematics programs and in their minds, mathematics largely consists of meaningless memorization of mathematical facts, rules, and procedures and they see their role as delivering such procedures (Carroll, 1996; Carroll & Morrow, 1998). It takes time for teachers to see the importance of posing problems, providing opportunities for students to explore the problems, and listening to their solutions. Even when they are convinced of the importance of these practices, it takes time for teachers to learn to incorporate them.

There are several components to professional development that have been viewed as positively supporting teachers in shifting practice. Carroll, Fuson, and Diamond (2000) highlight the importance of sustained professional development when teachers are working towards developing their skills at listening and interacting with students' mathematical thinking. Some researchers (Ball, 1988; Crespo, 2000) have noted that introducing teachers to unfamiliar mathematical tasks ensures that teachers genuinely engage with mathematical content. By introducing unfamiliar problems to teachers and engaging teachers in exploring new mathematical ideas themselves, teachers shift from looking at students' work in merely an evaluative manner to listening for changes in meaning (Ball, 1988; Crespo, 2000). Engaging teachers in examining student work and (Simonsen&Teppo, 1999), connecting professional development to actual classrooms through reflection and analysis of concrete classroom episodes (Scherer &Steinbring, 2006) and supporting teachers as they attend to their own students' thinking (Steinberg, Empson, & Carpenter, 2004) helps teachers develop a better understanding of children's mathematical learning processes, and mathematics teaching and learning in general.

2.7 Twenty First (21st) Century Skills

In the current world there are certain skills that have been identified that students need to have in order to cope with the world in and out of the classroom. These skills in the educational literature are referred to as the 21st Century Skills and include: Creativity and Innovation, Critical Thinking and Problem-solving, Communication and Collaboration, Information, Media and Technology, Life and Career skills among others. (Partnership for 21st Century Skills in Intel Corporation, 2008).

Kenya's vision 2030 envisages a globally competitive and prosperous nation with a high quality of life by the year 2030. The vision is founded on economic, social and political pillars focusing on adding value to products and services, investing in the People of Kenya, moving to the future as one nation respectively. The social pillar of Vision 2030 includes education sector whose vision is "*globally competitive quality education, training and research for sustainable development*". Within this vision, CEMASTEA addresses the goal of raising the quality and relevance of education.

On the other hand, Science, Technology and Innovation (STI) play a critical role in the realization of Vision 2030. The STI vision is *"harnessing Science, Technology and Innovation for regional and global competitiveness".* Focus in STI relevant to CEMASTEA and SMASE programmes include improving quality of scientific and technological learning; encouraging individual creativity and broadening opportunities and support for students to pursue STI studies and adapting curricula to changing skill demands.

In order for the Kenyan education sector to remain globally competitive and relevant, there is need to align educational processes to the global agenda and trends. Education that would remain relevant in the information societies and knowledge-based economies must significantly inculcate new ways of thinking- problem solving, critical thinking and creativity; new ways of working-collaboration and communication; and new tools for working- capacity to harness the potential of new technologies. SMASE programmes and INSETs must also remain relevant to these global educational trends. ASEI-PDSI has invariably promoted learner-centred instruction, which is the hallmark of 21st Century Education.

The education system in any country is expected to fulfill its responsibility of preparing the students for the world outside the school where they will live and work. This is achieved through inculcation of certain skills, knowledge, attitudes and values that are requisite for success in such environment. In any educational system the content or curriculum is the vehicle through which such skills are developed.

Modern learning theories emphasize that learners learn better if they are accorded autonomy in the classroom, time and facilities to construction knowledge for themselves and others. There are various technologies available in the classroom for teaching and learning. These technologies include blackboards, whiteboards, computers, video and recorders among others. Teachers require the competency to use effectively all technologies in the classroom for the benefit of the learners. This agrees well with Mishra and Koehler's (2006) assertion that teachers require technological pedagogical content knowledge (TPCK) to be able to effectively facilitate learning in the classroom. One of the most versatile technologies in the classroom today is the computer and related digital systems. It is believed that these digital systems have a potential to be items of choice in the teaching and learning mostly because they can be used as tools for sharing and collaboration within and outside the classroom. Also digital tools are popular with learners because most of them are used for entertainment. It is possible to combine learning with entertainment using digital media and this would result in a more powerful learning environment.

ICT integration in teaching and learning of mathematics and science is regarded as an innovative and powerful method of instruction. ICT integration provides teachers with interesting activities to teach concrete as well as abstract concepts. This session offers participants an opportunity to further understand the concept of ICT integration in teaching and learning of mathematics and hopefully get motivated enough to start practicing in their teaching.

The primary factor that influences the effectiveness of learning is not the availability of technology, but the pedagogical design for effective use of ICT. The computer should be fitted into the curriculum, not the curriculum into the computer (Earle, 2002). Therefore, effective ICT integration should focus on pedagogy design by justifying how the technology is used in such a way and why.

Effective ICT integration into the learning process has the potential to engage learners. For instance, using multimedia to present authentic and ill-structured problems in problem-based learning can motivate and challenge students and hence develop their problem-solving skills. The use of ICT can support various types of interaction, which are propagated through the use of ASEI-PDSI. Learner-content, learner-learner, learner-teacher, and learner-interface

These types of interaction make the learning process more interactive and learners more active and engaged. Research evidence has also confirmed that effective ICT integration can promote student-engaged learning. In another study exploring the use of ICT tools to engage students in higher-order thinking in a Singapore school, Lim and Tay (2003) observed higher students' engagement in higher order thinking by using ICT tools.

According to CEMASTEA (2017), CEMASTEA has made several initiatives towards effective teaching and learning of mathematics and sciences. One such initiative has been to embrace technology in all its training programmes. ICT integration in teaching and learning of mathematics and sciences has become a key and integral component of ASEI-PDSI teaching and learning of mathematics and science paradigm shift. In an endeavour to improve the quality of teaching and learning, CEMASTEA has been capacity building teachers on ICT integration at the county level. The facilitation is done by CEMASTEA trainers in selected county centres with adequate ICT facilities.

In 2016, CEMASTEA was able to roll out an ICT integration manual with five modules targeting teachers of all subjects in 18 counties. The five modules were on: understanding STEM, productivity tools in STEM, integrating STEM in teaching and learning, Project Based Learning (PBL) and the use of social media in teaching and learning. The objectives of the manual were:

- To spark learners' interest in Science Technology Engineering and Mathematics (STEM).
- To enable learners apply STEM to make connection between school, community, work and global enterprise and be able to compete in the new world economy.
- To improve teachers' innovativeness in lesson delivery.
- To promote implementation of STEM in schools.
- To promote Project Based Learning (PBL) in schools.

The training on ICT integration in teaching and learning and particularly in STEM was meant to enhance efficiency, effectiveness and innovativeness, provide interactive learning experiences, under difficult concepts and processes and enhance collaboration and group work. CEMASTEA hope that the training will go a long way in changing the classroom practices in making learning more meaningful, relevant and applicable to real life by promoting 21st century skills.

According to CEMASTEA (2017), effective teaching and learning largely depend on the teaching and learning strategies teachers adopt. One of the strategies is in designing appropriate teaching and learning activities that can enhance achievement of lesson objectives. The teaching and learning activities that can enhance the effectiveness of the teaching and learning process and achieving the intended lesson objectives. According to the Training Needs Assessment (TNA) report (CEMASTEA, 2015), majority of teachers did not adequately arouse learner's interest and curiosity through innovative and real life situations nor did they involve learners in developing creative ideas. Furthermore, a large number of teachers rarely develop activities that enable learners interpret, analyze and evaluate new information.

CEMASTEA being mandated to teacher capacity development emphasize the use of Activity , Student , Experiment and Improvisation –Plan , Do , See and Improve (ASEI-PDSI) principles in teaching and learning of mathematics and sciences to enhance the learning process through well planned lesson activities . Just like ASEI-PDSI principles, Inquiry Based Learning (IBL) is a teaching strategy that allows learners to take control of their own learning (Carin & Bass,2001) . This implies that inquiry based learning is consistent with the principles of ASEI-PDSI. When learners are given an opportunity to learn the content in the school curriculum through inquiry , their ability to develop a variety of skills that include questioning , predicting , observing , manipulating , inferring and critical thinking are enhanced . It is therefore important for teachers to build their capacities and abilities in enacting teaching that incorporates inquiry based approaches.

According to CEMASTEA (CEMASTEA, 2017) inquiry based learning (IBL) is widely accepted as a method of teaching and learning that places students' ideas , questions and observations at the centre of the learning experience. Through IBL, learners are engaged in authentic investigations in which they identify problems, asks questions, propose solutions, make predictions, design procedures, collect, and organize data and draw conclusions. In enacting teaching that embraces this method, Scardamalia (2002) argues the need for teachers to establish a classroom culture where ideas are respectfully challenged, tested, redefined and improvable. He further notes that the culture in the classroom should be one that allows moving children from a position of wondering to a position of understanding and further questioning. Based on this argument, it seems that raising questions and working towards looking for solutions to the questions are important components of teaching that embrace inquiry based learning. Besides raising questions, other components of IBL includes data collection, data analysis and drawing of conclusions.

According to CEMASTEA (2017), IBL allows students to:

- Be more engaged with the subject where learning is perceived as being more relevant to their own needs , thus they are enthusiastic and ready to learn .
- Expand on what they have learned by following their own research interests.
- Develop a more flexible approach to their studies, giving them the freedom and the responsibility to organize their own pattern of work within the time constraints of the task.
- Develop a variety of skills that include: hypothesizing, questioning, data collection, analysis and inferring.

- Develop 21st century skills such as collaboration, communication, teamwork and problem solving.

According to CEMASTEA (CEMASTEA, 2018), the education sector in the country is shifting towards Competency Based Curriculum that requires learners to engage in IBL to develop the requisite competencies. Developing competency in an area of inquiry requires a foundation of factual knowledge, understanding facts and ideas in the context of a conceptual framework and organizing knowledge for retrieval and application. The findings of Training Needs Assessment (TNA) (CEMASTEA, 2015) showed that the teaching and learning was still teacher centred . This teacher centredness led to lack of interest among learners during the teaching and process. Inquiry Based Learning (IBL) was identified as one way of addressing this concern.

According to TNA (CEMASTEA, 2017), there exists a gap between learners' beliefs, misconceptions, cultural practices and the reality. Teachers rarely use learners' experiences and scenarios (which are crucial in IBL). Inquiry Based Learning generates excitement in students and triggers curiosity. The students become more inquisitive and are able to answer their own questions.

Framework for Infusing ICT into Teaching and Learning

Since it is not possible to reach every student on the same level during a lesson, it is possible to give every student to learn by using a variety of learning styles. By doing so, it will be possible for a student to be taught in a style that may match his or her learning style.

A question that begs answers from educators and INSET providers is: How do students learn best? To best answer this question, a teacher may ask one self, "How do I learn best?” The answer to this question may be explained by the constructivist learning theory, which states that learning is an active process of creating meaning from different experiences (Brooks, J. and Brooks, M., 1993). In other words, students will learn best by trying to make sense of something on their own with the teacher as a guide to help them along the way.

Use of ICT in the teaching and learning of mathematics

Bosco (2004) observed that there was a change in the interaction pattern between teacher and students with the use of ICT in the teaching of mathematics: the students' focus moved from the teacher to the computer. "...closed programs tended to promote a type of interaction that did not favour the discussion of ideas. In fact, the exchanges produced among the children in the 'drill and practice' classes never went beyond cumulative chats" (Bosco, 2004). By contrast, the use of open programs promotes learning through construction rather than passive reception.

According to Schellenberg (2009), technology plays an important part in the learning of mathematics. Students must become familiar with the technological tools utilized in mathematics, whether that be an abucus or a graphing calculator. Modern technology allows for easier exploration of mathematics than was previously possible. The speed of computers and calculators enables students to produce many examples when exploring mathematical problems. ‘‘This supports the observation of patterns, and the making and justification of generalizations’’ (British Education Communication Agency, 2004).

According to the National Council of Teachers of Mathematics position statement regarding technology, appropriate use of technology allows more students access to mathematical concepts (NCTM, 2008). A motivating factor for increasing the accessibility of mathematics is that mathematics knowledge has become as an important part of critical citizenship (Adler, Ball, Krainer, lim& Novotna, 2005). Technology help students gain the skills that will be useful as citizens, students have the opportunity to use the same technology that is available outside the walls of their classrooms (Haapasalo, 2007) . Using the same technology that is available outside the classroom allows students to transfer their knowledge into the world as they move beyond formal education.

According to Schellenberg (2009), some teachers and school systems remain wary of integrating technology into mathematics education. The three most common reasons are curriculum scope (convincing teachers the benefits are worth the change), availability of technology (open computer labs, for example) and accessibility of the programs (technology that is easy enough to learn that the focus remains on mathematics) (Little ,2008) . Equipment failure can also be a major roadblock to the adoption of technology, as teachers will not commit to using something they cannot rely on in their daily teaching (Cuban, Kirkpatrick& Peck, 2001).

Schellenberg (2009) pointed out that the views of mathematics teachers greatly influence whether and how technology will be incorporated into the classroom. According to a recent study, middle-aged and more experienced teachers were more likely to integrate technology than their younger counterparts, despite having a more negative attitude regarding technology (Hung & Hsu, 2007). This suggests that familiarity with technology might not correlate to increased technology use in the classroom. A base level of technical skills is required, however, as a previous study notes that “effective teachers who use ICT are teachers who are confident with ICT ’’(Bramald ,Miller & Higgins ,2000) .

The technology used in mathematics teaching and learning can be categorized into two major types, virtual manipulatives and general software tools (Preiner, 2008) .A virtual manipulative can be defined as “an interactive , web-based visual representation of a dynamic object that presents opportunities for constructing mathematical knowledge ’’ (Moyer , Bolyard & Spikell, 2002) .Virtual manipulatives allow a student to interact with mathematical situation without any additional skills or training , though the student’s exploration is limited by the design of the virtual manipulative . By contrast, general software tools allow the student to explore any number of mathematical concepts, but require some training to use.

A variety of general software tools are used in mathematics, including dynamic geometry software (DGS) ,computer algebra systems (CAS) and spread sheets . Barzel (2007) defines general software tools as “tools that can be used for a wide set of tasks and be considered to be general purpose tools that are not useful for only a limited number of specific tasks -that is the character and as well as the most important benefit of general tools.’’ Dynamic Geometry Software (DGS) is the most easily adopted form of general software tools, as it was explicitly designed for classroom use (Ruthven, 2008). DGS is controlled primarily with the mouse, allowing the basic functionality to be easily learned. Using DGS , teachers and students are able to quickly and accurately explore geometrical figures , changing their dimensions while maintaining the mathematical relationships in the figure .DGS is a dynamic modeling of the traditional paper and pencil (blackboard and chalk) teaching environment through the drag mode .DGS has the ability to profoundly change the way we teach proof , one of the most crucial ideas in mathematics .DGS allows students to instantly create and test conjectures , allowing them the freedom to explore geometry and discover patterns .Although the power and flexibility of DGS is enticing , we must understand and acknowledge that changing the medium of teaching geometry will cause important changes in the way students construct meaning about geometry . The role of the teacher is shifted when DGS is utilized in the classroom, but the teacher's role remains critically important; the teacher's guidance is crucial as the student tries to construct meaning from the explorations they are involved in.

Another type of general software being used in mathematics education is a Computer Algebra Systems (CAS). A CAS can be defined as "a piece of software which is capable of working symbolically as well as numerically. In principle, it is a program which does on a computer the manipulation that has traditionally been done with pencil and paper ''(Lawson ,1997). It is important to note that CAS was created for use by practicing mathematicians not for mathematics education (Ruthven, 2008). This has caused slower adoption of CAS into the classroom, and teachers and researchers are still attempting to come to terms with the effects of using CAS in the classroom. Much of the discussion on CAS in the revolves around what portions of the curriculum students need to know how to do by hand , and what portions they can offload to a computer . The answers to these questions greatly influence what is taught and how it is assessed. Supporters of CAS in education emphasize the ability of students to access higher level concepts, without having to drudge through tedious algebraic manipulations (Atiyah, Monaghan & Pierce, 2004). Access to these higher level concepts allows students to leave contrived problems behind, giving them a chance to explore real world situations instead (Heid & Edwards, 2001).

GeoGebra is software that attempts to combine DGS, CAS and spreadsheets into one application. Incorporating technology into mathematics teaching and learning allows greater access to mathematical concepts. General mathematics software allows students to explore any number of mathematical situations, but require students to learn the software first. Dynamic Geometry software is quite easy to use, allowing students and teachers to test conjectures by exploring geometrical figures. Computer Algebra systems are able to perform much of the symbolic manipulations that students do by hand .Educators must determine which algorithms can be done by hand. Spreadsheets are particularly useful when teaching statistics, but can also be used to teach a wide variety of mathematical topics.

Crisan, Lerman and Winbourne (2007) highlighted several factors influencing mathematics teachers' integration of ICT into their lessons. Contextual factors such as the school context, departmental ethos and the availability of and accessibility to ICT facilities, key persons promoting the ICT use within the department, teacher ICT skills, ICT professional development and the presence of ICT within the mathematics scheme of work. Interesting in Crisan, Lerman and Winbourne's (2007) findings was how personal teacher factors influenced the use of ICT in the teaching of mathematics.

Law (2009) found that the most frequently adopted activities by mathematics teachers in her research study were 'exercise to practise skills or procedures', 'teacher lectures' and 'discovering mathematics concepts and principles'. Although Law (2009) reported a change in pedagogical approach by teachers when ICT was being used, the more conventional and traditional pedagogical approaches still prevailed, especially in some countries (e.g., Hong Kong, Singapore and Taiwan). Teachers in the abovementioned countries were reported to value a more traditionally oriented curriculum, as compared to curriculum goals that focused on lifelong learning and connectedness.

McAlister, Dunn and Quinn (2005) examined teachers' attitudes towards the use of computers in teaching mathematics in the primary school classroom. Positive attitudes of teachers towards the use of ICT in teaching and the availability of the necessary resources would facilitate the use of computers in teaching mathematics in the primary classroom. The computers could be used as a tool in supporting and enhancing students' learning as well as a tool for teaching.

The literature studies reviewed above suggest that the teaching of English and mathematics could adopt various approaches - learning *from* and *with* ICT, with or without production and with or without collaboration. In addition the literature also further suggests that the integration of ICT into the classroom depends on individual teachers as well as the schools' contextual factors. Teachers' beliefs have been viewed as a key area that needs to be addressed in the context of integration of ICT into classrooms (Gao, Wong, Choy & Wu, 2010; So & Kim 2009). Many other studies also reported that teachers' beliefs could affect the integration of ICT into the classroom (Chere-Masopha & Bennett, 2007; Garthwait & Weller, 2005; Hayes, 2007; Penuel, 2006; Sipilä, 2010; Tondeur, Cooper & Newhouse, 2010; Towndrow & Vaish, 2009). However, it is also important to note that "technology itself is not likely to improve ineffective teaching practices" (Tee & Lee, 2011).

It is important to reflect on current classroom practices when considering other strategies that would enrich mathematics achievement among students. The need to adopt ICT tools or resources in lesson delivery is hinged on the gap that it comes to fill. Use of technology in lesson delivery would probably consume more class time, thus this calls for teachers who know and believe in technology they choose to adopt as an effective way of enriching lesson delivery.

Thus the question to ponder about is whether technology use benefits learners in terms of learning achievement in relevant knowledge, skills and attitudes.

Effective ICT integrated lessons ought to fulfill the following:

- meet expected learning objectives
- students actively engaged in lesson activities catering for various abilities
- students' observable confidence levels
- application of learnt concepts

Some of the benefits of ICT integrated lessons are accelerated learning, ability to apply learnt concepts in other situations and enrichment of lesson activities. Research has revealed significant impact of technology on cognitive outcomes. Hillel, Kieran &Gurtner (1989); McCoy (1996); Simmons & Cope (1993) as cited in MSC Malaysia (Year) indicated that Logo programming, computer-assisted instruction (CAI), micro-worlds, algebra and geometry software were found effective in facilitating mathematics achievement. Accordingly, ICT integrated lessons improve quality of learning and achievement through a medium that illustrates concepts that would otherwise be abstract to explain traditionally in line with the findings of Selinger (2004).

In regard to retention of learnt concepts, students tend to recall mathematics skills long after using computer software than those taught traditionally through verbal instruction.

ICT integration by all standards should not replace the teacher; instead it should be a means to an end. ICT integration is about deliberate effort to use it as a teaching or learning resource to fulfill a teaching or learning gap. A teaching or learning gap is a state of inability to effectively convey a given concept due to its abstractness. Therefore, the point of ICT integration in any given lesson is determined by where the gap is experienced. This reasoning applies to the learning gap as well. Learning gaps that ICT integration seeks to fill include:

- concretization of otherwise abstract concepts
- access to ideas and information from diverse sources
- extension of ideas and information to enrich themselves and apply on other situations
- Transform ideas and information into new or different forms
- Share ideas and information across networks

Teachers therefore should be able to

- Select computer-based technologies according to their appropriateness for particular areas of learning
- Evaluate software in terms of the learning need and preferences of individual students or groups
- Use computer-based technologies to illustrate /demonstrate concepts, access information, individualized instruction
- Use desktop publishing/graphics/multimedia applications to prepare learning materials for students and teachers
- Store material electronically and modify it for different classes and students

- Use internet as a personal resource

GeoGebra is relatively new dynamic mathematics software that integrates the possibilities of dynamic geometry, computer algebra and calculus in one tool for teaching and learning mathematics. It affords opportunities for mathematical investigation encouraging interaction and collaborative learning, making mathematics open, practical, accessible, tangible and manageable to more pupils (Hohenwarter& Fuchs, 2004).

There are several studies on the integration of the IWB into a whole-class teaching and learning and classroom practices (Kennewell& Beauchamp, 2007; Lacina, 2009; and Hennessy, 2011) and other studies as well on the use of GeoGebra and related applications in Mathematics (Hohenwarter& Fuchs, 2004; Hohenwarter & Jones, 2007; Chrysanthou, 2008).

There have been very little works done on the potentials of the joint use of GeoGebra,Grapes and Graph in the teaching and learning of mathematics. The affordances of the use of GeoGebra and Grapes in promoting the idea of interactive teaching and learning of mathematics in the context of interactive technologies, within the whole-class activity setting and the clear expectation that this could enhance the implementation of such effective and efficient teaching and learning of mathematics that this study is designed to explore. For the effective and intelligent use of digital technologies in mathematics education, the school culture requires the gradual re-orientation of its practices to gain access to a new form of expressivity, multiple representational interactivity, and new habits of mind and to the new environment resulting from a serious presence of digital technologies (Hegedus& Moreno-Armella, 2009).

GeoGebra and the Interactive Whiteboard in Mathematics Education

Technology-based teaching and learning of mathematics has over the years expanded becoming more distributive, socio-constructivist and technologically enhanced in practice. In the efforts to teach mathematic better the use of Computer algebra systems (CAS) and dynamic mathematics software (DMS) has become common placed (Haapasalo& Silverberg, 2007).

Over the years Mathematics Geometry or Dynamic Mathematics software (DGS/DMS)(i.e. Cabri Geometry, Geometer's Sketchpad, Autograph, GeoGebra etc.) research have shown that the use of DGS in mathematics offers students new way to approach mathematics problems, create dynamic models of real situations, find approximate numerical solutions and gain experience with the use of data. These potentially engage learners in building autonomy and empowering them, enabling and allowing students to negotiate, lead and own their learning; thereby increasing their ability to take control of what they are learning and building up a peer support system (Doer & Pratt, 2008). The potentials of Cabri-Geometer in the process of constructing conjectures and proving under various dragging activities have been investigated (Olivero, 2002).

Computer algebra systems allow students higher order mathematical operations, quantitative and symbolic calculations, 2D and 3D graphical representations. Some of the well-known CAS tools; Derive, Mathematica, Maple and LiveMath (Simpson,Hoyles&Noss (2005) work with strings of symbols, besides the routine manipulations it has the potentialities to execute symbol manipulations in algebra, calculus, complex numbers and matrices. Its other advantage in mathematics education is the ability to facilitate and extend experimentation with mathematical symbols (Artigue, 2002). Research by Shaw et al. (1997) showed that students' use of CAS technology to develop long-lasting mathematical skills, frees up time and space to focus on understanding the problem and doing the mathematics. For Simpson, Hoyles&Noss (2004) CAS functions as an effective motivational, cognitive and social tool. Other studies of note are; Heid, 1988; on *Derive*-Monaghan, (1993, 2005), *Mathematica*- (Sangwin, 2003).

And more recently studies have been done on the joint use of CAS-DMS tool.

***Casyop*ee**- is a geometrical and symbolic learning environment an integrated CASDG

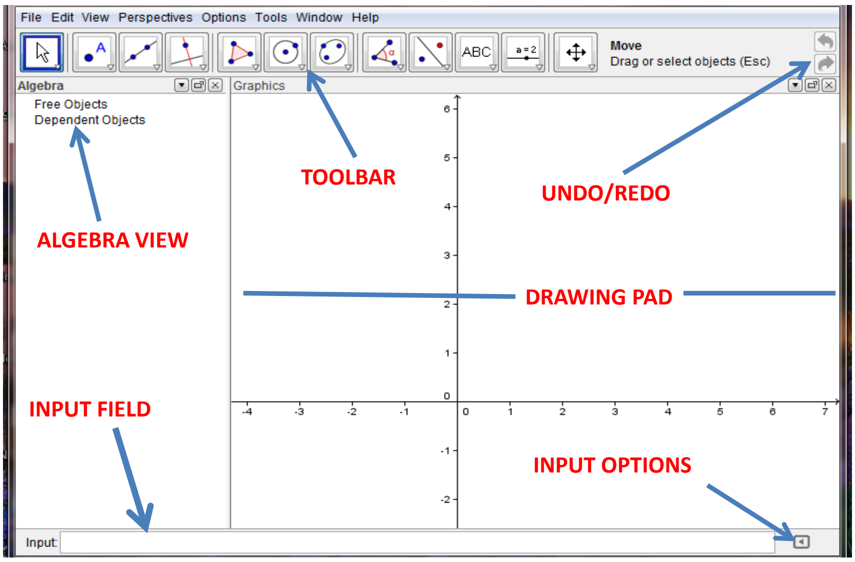
tool that allows explorations of visual and dynamic formats and mediates social interaction in co-construction of knowledge (Lagrange, 2005; Lagrange & Minh,2009). ***GeoGebra*** integrates the potential and emerging possibilities of the CASDMS interface (Sangwin, 2007).

GeoGebra: Dynamic Mathematics Software

GeoGebra is a freely available dynamic mathematics software (DMS) that affords dynamically linked multiple mathematical representations, computational utilities, documentation tool and a technical tool to support teaching and learning; as a psychological tool (instrument) it potentially enhances the teacher's instructional plans and strategies, and also a pedagogical tool that facilitates classroom practices in its many diverse forms (Hohenwarter& Jones, 2007; Bu, Mumba&Alghazo,2011). GeoGebra dynamically linked together: algebra, graphics, Spreadsheet,

Computer Algebra System (CAS) and all the benefits and potentials of Dynamic Geometrical Software systems (DGS). These harmonious mathematical connections and simultaneous display of two representational systems create a rich, blended embodiment of a dynamic, complex and unique pedagogical platform that could potentially impact on mathematics and science teaching. The evolving development in GeoGebra Touch allows adjustment of use with IWB; the GeoGebra Mobile affords use in modern web browsers and in mobile phones. This allows students and teachers irrespective of location the large pool of GeoGebra dynamic resources available virtually on all devices with a web browser (Hanc et al., 2011; Ancsin,Hohenwarter&Kovac, 2011). An Archive of online resources are available GeoGebra Wiki and GeoGebra Forum- which are free and available to all users as a collaborative platform and community of practice (Wenger, 1998; Lavicza ,2010).

GeoGebra



2.7.1 The Uniqueness of GeoGebra

The uniqueness of Geogebra is that it is free, multi-platform, open-source, no licence issue associated with its usage, accessible on PC, Mobile phones and adapted for use in the whole-class setting with an IWB, available in over 50 languages with a living

GeoGebraWiki and communities of practice in over 190 countries. With the ever expanding international community of developers and users, regularly updated, it is intellectually, collaboratively and economically promising and sustainable for empowering teachers for creating an engaging meaningful learning environment and supporting students in discovering alternative pathways to productive learning of mathematics (Hohenwarter, Jarvis &Lavicza, 2009; Lavicza et al., 2010; Lavicza& Papp-Varga, 2010).

Another notable uniqueness of GeoGebra is its affordance of bidirectional representation of every object: every input in the algebra window has a simultaneous and corresponding object in the geometry window and vice versa providing rich and reinforcing relations between geometry and algebra. The drag mode of GeoGebra allows free movement between windows and automatically adjusts to any change in the algebraic representation far beyond the possibilities of paper and pencil (Laborde, 2001; Chrysanthou, 2008). The two formal pillars of mathematics algebra and geometry are given equal weight and treated as equal partners (Atiyah, 2001; Sangwin, 2007).

GeoGebra is designed specifically for educational purposes and has the added advantage of enabling students to visualize mathematical concepts, foster rich and active student-centred learning by affording opportunities for mathematical experimentations, interactive explorations, conceptual and visual feedbacks, support guided discovery learning, produces flexible results, enable multi-lingual classroom and generate mathematically accurate diagrams for problem sheets and does very well what it sets to achieve (Bruner, 1961; Sangwin, 2007; Preiner, 2008*). Although GeoGebra has been designed for education in secondary schools, it certainly has uses* *in higher education for demonstrations in lectures or for students to use in exploring functions, graphs and so on* (Sangwin, 2007).

The GeoGebra construction protocol and navigation bar offers researchers and teachers a history of the step by step record of strategies and thought pattern of students' interaction with the software (Preiner, 2008). *"If a construction is too complex to do live in a lecture a construction steps tool allows you to step through a pre-prepared construction without having to actually do it live"* (Sangwin, 2007). The underlying design principle is to keep it short and simple thereby reducing the cognitive load for the benefit of a more efficient and effective software (Clark & Mayer, 2003; Hohenwarter, 2006).

Technology use in mathematics teaching helps students to easily acquire basic mathematical skills. Organized and well planned supports as well as enough practice would greatly help students to improve their skills particularly in exploring their potential in information technology to the maximum (Zulnaidi & Zamri,2017). Students need guidance in applying the latest technology to solve various mathematical problems (Oldknow & Taylor,2000). The computer is now widely used as a teaching aid in mathematics in order to enhance students' self-motivation and self-confidence (Sivin-Kachala & Bialo,2000). The use of computer in teaching and learning mathematics is actually a sophisticated method as opposed to conventional methods to produce a brilliant generation in the aspects of physical, emotional, spiritual and intellectual development (Norazah & Effandi, 2007). Various types of computer software are commonly used to help students be more responsible for their own learning through a more creative approach (Zamri & Zulnaidi, 2017).

Teachers should embrace the current changes and strive to realize the use of the latest technology in the classroom. Educators should try the hardest in making mathematics a very interesting subject in order to attract students' interest and at the same time to help them consciously focus on important mathematical concepts (Zamri & Zulnaidi, 2017). It is the teacher's responsibility to prepare students to focus on the future world which undoubtedly would depend on mathematics, science and technology (Furner & Marinas, 2007). Technology based learning provides symbols , formula , tables , graphs , numbers , equations and manipulative materials to link them with various real life ideas and those are indeed parts of conceptual and procedural knowledge (Post,1998). Technology application in teaching and learning mathematics helps students to better understand basic mathematical concepts and to experience intuition in solving certain mathematical problems (Rohani et al, 2009).

Teaching Mathematics with GeoGebra

The computer is a powerful and helpful tool in the teaching and learning mathematics and in particular in understanding the mathematical concepts, as it was noted by many authors (Hohenwarter &Jones,2007; Guyer ,2008). Created by Markus Hohenwarter in 2001,GeoGebra represents one such software program that was designed to combine geometry ,algebra , and calculus in a single ,dynamic environment. GeoGebra is a dynamic learning environment that enables its users to create mathematical objects and interact with them. GeoGebra users, mostly teachers or students, can use this environment to explain, to explore and to model mathematical concepts and the relationships between them, or mathematics in general (Hohenwater & Jones ,2007). In order to make the best use of GeoGebra , teachers must have a deep , integrated knowledge of the content to be taught , the students who are to learn it , and the affordances and constraints of GeoGebra in relation to both.

GeoGebra is an embodiment of the ease of use of interactive features of dynamic geometry software with the potentiality and functionality of a computer algebra system. It brings to bear therefore a wide range of learning opportunities and application possibilities in the teaching and learning of mathematics (Preiner, 2008). Hence, GeoGebra is a powerful interactive presentational and methodological tool that enables students see mathematical ideas as living, breathing and moving with its:

- Visualisation that is vividly dynamic and graphical
- Interactivity and immediacy of response and feedback
- Modelling and simulation of mathematical processes (Hanc et al., 2010).

From the student perspective, it affords deep engagement with mathematical modelling, problem solving explorations and collaborative open-ended questioning and the ownership of mathematical construction.

From a task perspective, with GeoGebra a new dimension emerges through exploration of alternatives strategies or pathways that problem-based, dialogic and makes mathematics task a collaborative discourse. From the teacher educator perspective GeoGebra helps to scaffold and accommodate the diverse needs of students, allow several entry points; as a tool for assessment through the construction protocol teacher can assess and follow students' process of thinking and act as a means for building a mathematics community of practice with shared pedagogical resources and tools. It as well deeply enriches and enhances the learning environment with its multiple representations, web friendly features and customizable tools that extends the scope of teaching and learning mathematics beyond the walls of the classroom and the traditional pencil and paper techniques (Lu, 2009; Bu, Mumba&Alghazo, 2011).

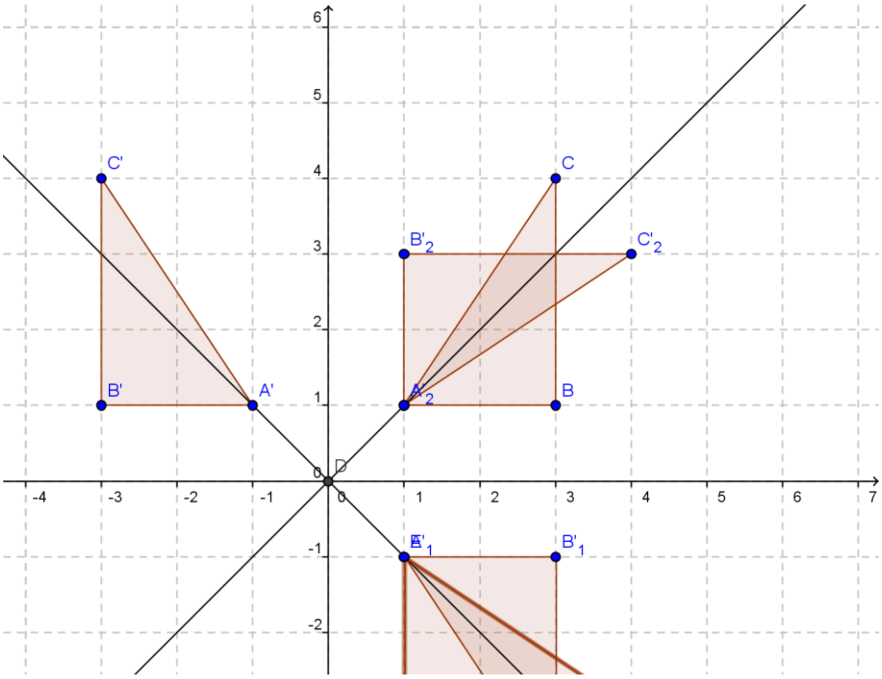


Figure 2. 2: GeoGebra view on reflection

Despite the potentials and enabling interactivity of GeoGebra for teaching and learning mathematics, teachers have not fully explored the capability to link algebra and geometry (Lu, 2009). Heid and Blume (2008) call for a bolder focus on research that enables and *"help teachers, curriculum developers and researchers to understand how students move between, connect, and reason from multiple representations*". In this effort the vital role of the mathematics teacher is central to all considerations (Clements, 2007).

Grapes

Grapes is graphing software developed at the Centre for Research on International Cooperation in Educational Development (CRICED), University of Tsukuba, Japan. The graphing software may support a way of mathematical reasoning not developed before, and which may help different students to learn in different ways.

The availability of easy-to-use graphing software highlights the role of the graphical representations of functions and relations. There may be intrinsic educational value in the traditional activities of substituting and calculating values in symbolic expressions in order to plot individual points in a Cartesian plane in order to obtain a graph. However, for many expressions, these “hand-made” procedures can be very time consuming and cumbersome, thus rendering them unusable for most educational purposes.

In contrast, the immediacy of obtaining a graph for a certain function or relation opens up new opportunities for many activities and issues to be learned. For example:

- Students may be able to model and study graphical representations of problems involving complicated algebraic expressions, impossible to obtain otherwise.

- Traditionally, the graph was an end point of many mathematical problems: on the basis of a given symbolic expression and by means of certain analytic tools (e.g. derivatives of a function) students are required to deduce the main characteristics of a graph, and proceeded to sketch it.

These sketches can be easily checked with a graphing software, but, the possibility to instantaneously obtain a graph may put into question such traditional problems altogether. Instead, graphing software may be used for reversing these problems; namely, given a graph can we find the symbolic expression which generated it? Once we conjecture a certain expression for a given graph, the graphing software serves as a means for checking our conjectured expression.

In the case that our conjecture is wrong or approximate, we can use the graphing software to revise, adjust and refine our proposals until we succeed. This process directs attention to the role of the coefficients in a symbolic expression, and provides a sense of how they influence the shape of a graph. Such a sense may be only phenomenological at first, but it may be further studied analytically.

Graphing software may help visualizing families of functions and relations, making more transparent the roles of parameters. Working with graphs bring to the fore the issue of scaling, for example, drawing attention to the fact that the parts of a graph observable in the display of the graphical window depends on the axes range, which one is free to stipulate. Sometimes one may think of a graph as linear only because its scale produces such illusion. Sometimes one may be surprised that the software is not producing any graph at all, and then realizing that it may be outside the range selected for the axes. And so on. Graphing software may produce unexpected results, which forces one to engage on interpretation, using all the knowledge at one’s disposal. Sometimes, surprising results are due to mathematical phenomena of which we may not be aware at first sight, in other occasions, they are the result of our wrong input, and yet other times they may be due to the limitations of the technology. In either case, unpacking the reasons for a surprise has learning potential, as it may require explanations based on checking and coordinating different representation, and making connections between different kinds of knowledge.

Graphs can serve as the basis for the solution to problems, traditionally solved by other means. Graphs can be operated upon (e.g. added, subtracted), can be translated and rotated. Graphs may be the source for symbolic insights. In sum, graphing software may support a way of mathematical reasoning not developed before, and which may help different students to learn in different ways.

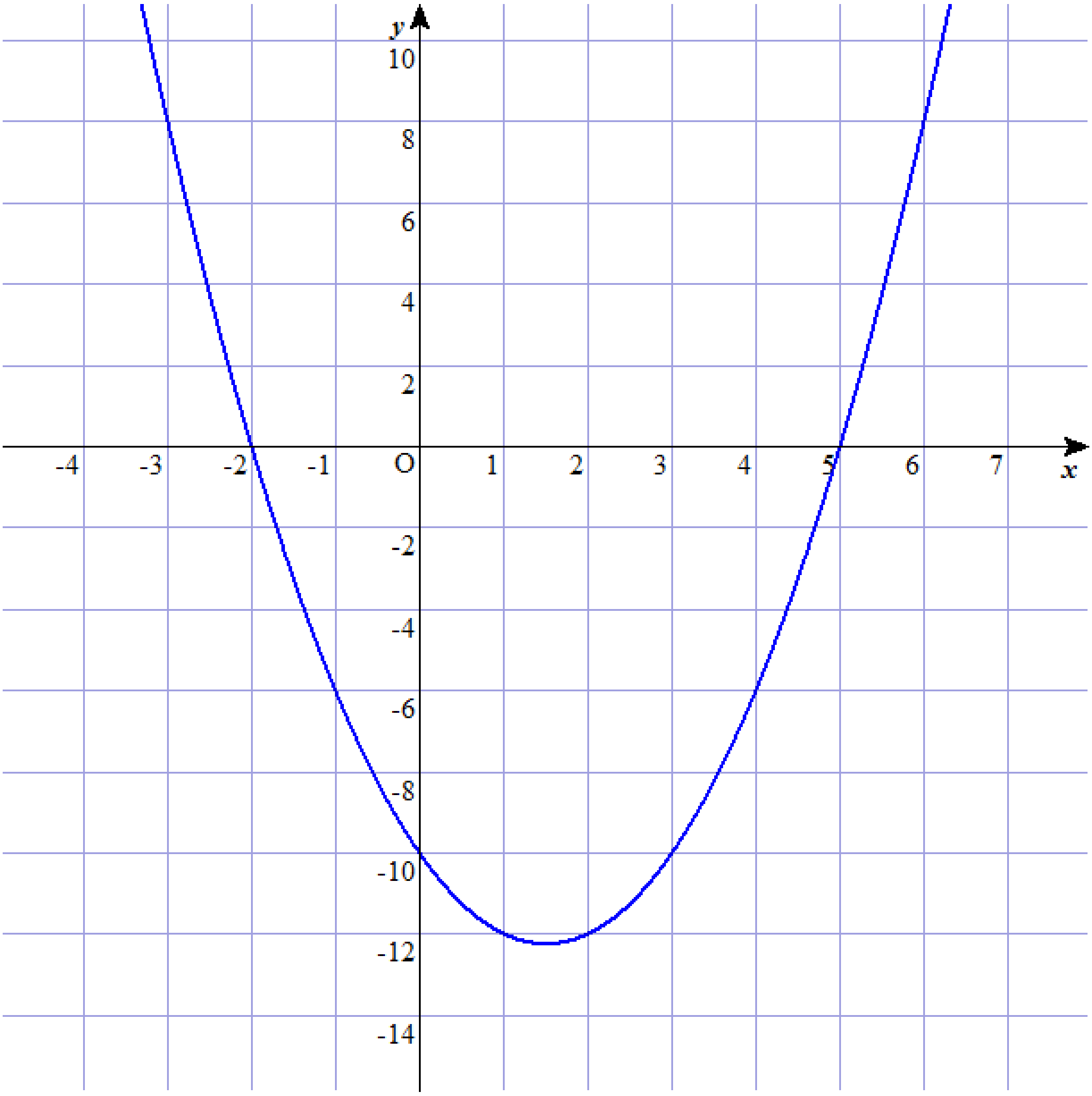


Figure 2.3: Grapes view on quadratic graphs

The brief descriptions above include only some of the educational possibilities afforded by graphing software:

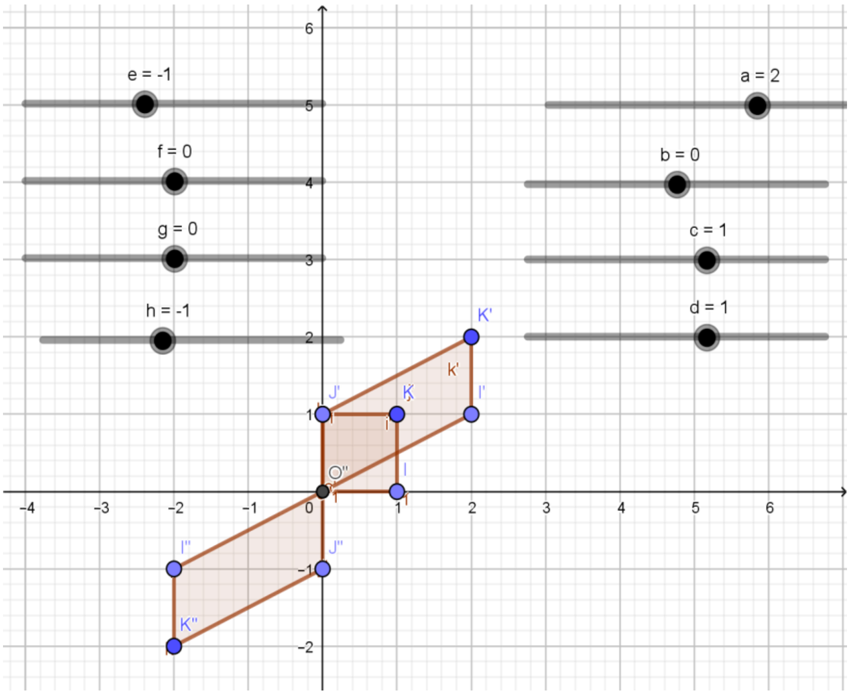


Figure 2. 4: GeoGebra view on successive transformations

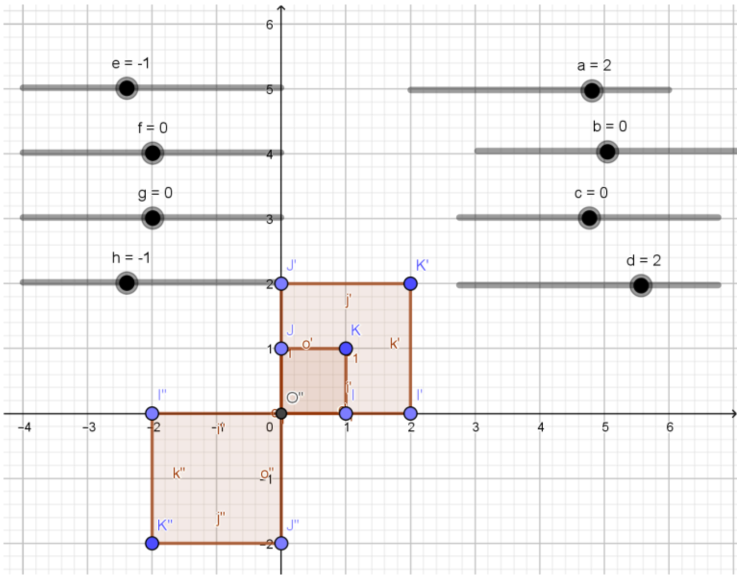


Figure 2.5: GeoGebra view on transformations.

According to Umameh(2012), the joint use of GeoGebra and Interactive white Board(IWB) offers new and extended opportunities for deep forms of creative and productive learner-learner and learners-teacher through GeoGebra levels of interactions. Preiner(2008) noted that the visualization of mathematical concepts and exploring mathematics in multimedia environments can foster their understanding in a new way. She found out that the use of GeoGebra was useful in helping students view mathematics less passively. Technology environments allow teachers to adopt their instruction and teaching methods more effectively to their students' needs.

In a research carried out in Malaysia by Zamri(2017), the findings showed a significant difference in procedural and conceptual knowledge of Mathematics Function topic between students who used the GeoGebra software and those taught using the conventional method. The research found out that GeoGebra software has positive effects and it does help to enhance students' conceptual and procedural knowledge in mathematics. Leong & Praveen (2017) found out that GeoGebra software can be used as an enabler in the teaching and learning of mathematics and more specifically of circles, as there was a significant increase in experimental students' conceptual understanding of circles as compared to the control group. GeoGebra proved to be an effective tool in enhancing mathematics teaching and learning, specifically in learning circles. Learners were able to experience hands on method of learning which had a positive effect in enabling them to understand the concepts better rather than being passive learners. The findings also showed that the use of GeoGebra software not only increased student scores, it was also observed that the software enabled realization of a vibrant classroom, where co-operative and collaborative principles of learning were evident.

Mercer etal(2010), found out that learners using Interactive White Board(IWB) tended to work for longer hours on the given tasks than groups in the class working with conventional resources. The IWB helped to create a suitable dialogic space for learners to pursue collaborative educational activities.

Dogan (2010) conducted an experimental design study using a pre-post test to evaluate the success of students learning using the GeoGebra software. The findings showed that computer based activities can efficiently be used in the learning process and the GeoGebra software encouraged higher order thinking skills. The findings also showed that GeoGebra had a positive effect in motivating students towards learning and retaining their knowledge for a longer period. Learners explored their learning beyond what was assigned by the teacher and were happy and engaged in the lesson using GeoGebra software.

Bakar , Ayub , Luan and Tarzimi(2002) compared GeoGebra to a software program created by them on two groups of Malaysian secondary school students and found that students using the GeoGebra software to study the transformation topic achieved better results than students using the created software.

Herceg and Herceg (2010) conducted a study on two groups of students. The study tested how to incorporate computer based learning to reduce the working process of numerical integration. The results of this study showed that the GeoGebra experimental group gained more knowledge and skills than the control group. The study also suggested that GeoGebra use is helpful for students who face difficulty in solving mathematical problems since they do not have to spend much time solving by hand.

Mollakuqe, Rexhepi and Iseni (2021) conducted a research Incorporating GeoGebra into Teaching Circle properties at High School level and its comparison with the Classical Method of Teaching. The results showed that using GeoGebra in teaching facilitates, accelerates and make geometry more tangible. During the explanation process, there is an increased interest and active participation of the students in the classroom through questions and discussion. The findings showed that when geometry is explained with GeoGebra, the lessons become very concrete. The use of GeoGebra software enabled all the learners to do the right thing in construction. With the use of GeoGebra in construction all the learners, without exception, noticed the exact construction work. The research also found out that learners were very much willing to learn geometry through GeoGebra software. Critical thinking, understanding and interest were much higher when working with this software compared to not using any software. Classic geometric tools are suitable for teaching and learning but the probability of error is very high. Uncertainty, lagging during construction, giving up on lessons, along with the idea that learning is difficult, is some of the characteristics of the learners especially below average and intermediate students. The research also showed that exploring GeoGebra attracts more students to learn mathematics. The presentation of the circle properties to the learners was found out to be very clear and made them very curious.

Mailizar and Fan (2021) conducted a research on Secondary School Mathematics Teachers' instructional practices in the Integration of Mathematics Analysis Software (MAS) in the teaching of mathematics at upper secondary schools in Indonesia. The findings of this study showed that to a large extent, the participants failed to take advantage of pedagogical opportunities offered by Mathematics Analysis Software as most of them still used traditional method to approach mathematics topics. One of the possible reasons of this unfavourable state is that Indonesian secondary mathematics teachers had lack of ICT as well as lack of knowledge of the integration of the technology in the classroom. Such knowledge is necessary to be acquired by the teachers in order to be able to integrate technology in ways that bring real world experience into the classroom as well as provide scaffolding to facilitate students' learning in complex cognitive tasks. As a cognitive tool, MAS should be able to facilitate the knowledge construction process. The finding of this study suggested that one of the important steps that teachers need to do in order to be able to fully capitalize MAS in their teaching is to design rich mathematical tasks which will lead to a change in teachers' instructional practice at classroom and subject levels. Technology-rich mathematical tasks address high order thinking skills and utilize technology to simulate, represent and model mathematical contents.

Ince-Muslu and Erduran (2021) conducted a study to identify the main factors that affected the process of technology integration in mathematics education in secondary schools in Turkey. Based on the findings of the study, the factors that affected the process of technology integration in mathematics education were examined as teacher-driven and non teacher-driven factors. The teacher-related factors were also grouped as personal and professional factors. The personal factors were specified as voluntariness, interest in technology , the convenience of known , curiosity , language factor , self-confidence , openness to innovation , perception of technology use , self-awareness , technological knowledge technological predisposition. On the other hand, the professional factors included perspective on mathematics teaching, educational background, concerns related to the classroom management, subject-specific technological knowledge, awareness of technology, planning, the purpose of using technology and technological materials. Furthermore , the non-teacher related factors were specified as expectation of the student , readiness of the student , support provided by the administrator , expectations of the administrator , availability of an individual responsible for technology , economic status , physical conditions , mathematics curriculum and mathematics curriculum approach. The ‘‘mathematics curriculum’’ provided insights about which teachers should use technology and relevant guidelines to use technology. The ‘‘mathematics curriculum approach’’ is based on the constructivist understanding and is focused on the competencies and skills included in the curriculum. The results of the study aimed at contributing to the process of planning and designing of technology integration in mathematics education.

Markovits and Patkin (2021) conducted a study to explore in-service pre-school teachers’ attitudes and beliefs about geometry and its teaching and to investigate their knowledge of shapes and solids in Israeli pre-school teachers. The results illustrated that many teachers lacked knowledge of shapes and solids. This was also manifested in cases where such knowledge related to the naming of shapes and solids, an integral component of the activities in which teachers are meant to involve their pre-school children. Lack of geometric knowledge was found among pre-school teachers in research studies conducted in different countries (eg Inan &Dogan-Temur,2010; Ulysoy,2019;Clement & Sarama,2011). Shapes and solids constitute a central area of activity in which pre-school children engage. Basic knowledge about shapes and solids implies the ability to distinguish between examples and non-examples, manifested by the ability to correctly name shapes and solids. Pre-school teachers found it difficult to name less familiar polygons. They also encountered difficulties in naming polygons that should be familiar and are part of the children's mathematics curriculum. The findings also suggested that the majority of the pre-school teachers did not ground their explanations about shapes in their properties but mainly in their appearance. Relying on the appearance of the shape rather than on its properties is one of the developmental stages of young children's comprehension with geometry and this was found among some of the pre-school teachers as well.

The kinds of attitudes towards and beliefs about mathematics which pre-school teachers hold are probably connected to their experience as students in mathematics classes in school and to their experience with the courses and programs they have studied as prospective pre-school teachers and as in-service teachers, and to their experiences while engaging in mathematics with young children. School, and especially high school, plays an important role in shaping teachers' attitudes towards and beliefs about geometry. Most of the pre-school teachers maintain that accurate mathematical language should be applied when pre-school children aged 3-6 deal with shapes and solids.

- Wassie and Zergaw(2019) conducted a research on some of the Potential affordance , challenges and limitations of using GeoGebra in Mathematics Education in Ethiopia. The study found out that GeoGebra plays a vital role in visualizing and understanding the effects of varying parameters and the effects of rigid and non-rigid body transformations. The existence of dynamic math's software, GeoGebra, is an opportunity for researchers and teachers to augment the dynamic characteristic of many real world phenomena. The study also found out that students became more responsible for their own learning and actively engaged more often in class. Students' involvement in lessons, their collaboration and their reasoning skills are improved while using GeoGebra. The study found out that among many others, the accessibility of resources e.g. computers, awareness of stake holders, pedagogical knowledge to integrate GeoGebra, student class ratio and the technology fluency of the users are some of the challenges to deliver effective GeoGebra integrated mathematics education. Getting the resources is neither the end goal nor a guarantee for securing the objectives of the lesson. GeoGebra supplemented lessons requires belief of its users, a proper plan as well as the careful implementation of sessions. While delivering GeoGebra integrated lessons, care must be given in deciding the role of the teacher, the choice of the lesson, and the design of the activities. In addition, before implementing a GeoGebra integrated lesson, the study found out that teachers should make sure of:
- The technological fluency of their students
- The support GeoGebra might bring to instructional goals. and
- The need to secure a backup plan in the class for possible system failure or electricity interruption which is common in developing countries.

Dikovic (2009) conducted a research on the applications of GeoGebra into teaching some topics of mathematics at the college level in Serbia. The aim of the research was to try to check, on the basis of the scores the students obtained on a test, if there was a positive effect of using GeoGebra applets in the differential calculus teaching. The test in question consisted of ten simple tasks, chosen in order to check the elementary knowledge of students in differential calculus: what is the ‘‘accumulation point’’ of a sequence, computing some basic limits of the functions, computing left-hand and right-hand limit of the functions, understanding the ∆y of the function on an interval, understanding the instantaneous rate of change of a function at a point, geometrical interpretation of a derivative, etc. The findings showed that the use of applets created with the help of GeoGebra and used in differential calculus had a positive effect on the understanding and knowledge of the students. The findings further showed that GeoGebra can be a powerful tool for visualization and stimulation of the key notions of differential calculus (the slope of the tangent line, connection between slope of the tangent line and graph of the gradient function, continuity / discontinuity of a function, connection between differentiability and continuity etc). The findings further showed that GeoGebra has many possibilities to help students get an intuitive feeling and to visualize adequate mathematical processes. The use of this software tools allows students to explore a wider range of function types and provides students to make the connections between symbolic and visual representations.

2.8 competency-based curriculum (CBC)

Competencies are a collection of trainable skills, knowledge, abilities, behaviour, attitude, aptitude, confidence, experience, talent and proficiency (Simon priest, 2014). Competency based learning refers to systems of instruction , assessment , grading and academic reporting that are based on students demonstrating that they have learned the knowledge and skills they are expected to learn as they progress through their education (Simon Priest,2014). Competency Based Learning emphasizes more of application of knowledge and skills through creativity, innovation and problem solving. Competency based curriculum is designed to emphasize the importance of developing skills and knowledge (competencies) and also applying those competencies to real life situations. In CBC, the teacher facilitates learners to construct their own knowledge and skills through exposure to challenging situations and experiences.

From 7-4-2-3 system in 1963 to 8-4-4 system in 1985,overtime the system became academic and examination oriented and therefore there was a need to change into the new system of 2-6-6-3 as from 2017. In response to the constitution of the Kenya 2010 and to achieve Kenya Vision 2030, there was need to transform the education system towards developing three components:

(a) **Competencies**

Kenya's economy is rapidly changing and therefore there is need to prepare learners for new possibilities. The 21st century demands citizens who are multiskilled. The new system is therefore designed to produce a child with relevant competencies to thrive in a rapidly changing world.

(b**) Character**

The new system need to mould learners to acquire values that support peace and national unity. Value based education and parental involvement are core pillars in the new curriculum. The new curriculum (CBC), seeks to produce a child who has good character.

(c) **Creativity**

The 21st century is a society in which knowledge and well thought out ideas are key source of economic growth. The school system needs to develop Kenyans who are able to creatively solve problems.

Competency Based Curriculum (CBC) focus on the four core skills of communication and collaboration; critical thinking and problem solving; creativity and imagination; and citizenship. All subjects are linked to these four core skills.

According to Njagi and Kihumba (2019), the primary focus of CBC is to equip learners with skills, competencies and knowledge which will enable to thrive in the 21st century environment. The new curriculum is a differentiated and innovative way of imparting in learners life-long skills and experiences that are more focused on the individual learner and not the school system or even syllabi. At the end, it is anticipated that the curriculum will promote love for learning or what has come to be known as learning to learn.

The CBC also stands out for de-emphasizing the exams oriented system, which has over the years eroded the essence of learning as a process of helping individuals gain life skills. The CBC seeks to make all learning contextually relevant for all learners and contribute to their holistic growth and development in order to make constructive contributions to the society.

According to Njagi and Kihumba (2019), all the teachers are required to adopt new ideologies in the curriculum and implement them in their teaching. They noted that CBC is neither prescriptive nor restrictive. It does not focus on the syllabus but lays more attention to realization of learning outcomes. It is largely left to the teacher to be innovative and use designs that are appropriate in achieving the desired outcomes in the context of specific learning or teaching environment.

The new competency based curriculum which will replace 8-4-4 system is intended to make learning more relevant and more independent, confident, co-operative and inspired learners. The new curriculum is also meant to promote love for learning and produce empowered citizens. The new curriculum will be designed to ensure it provides opportunities to identify the potential that every learner brings to school and nurture this potential through learning pathways and tracks that will be provided at senior secondary school. The mission will ensure that no child is labeled a failure at the end of basic education.

The competency based approach to basic education allows learners to connect within and between subject areas through a focus on competencies. The CBC, which is based on KICD and the Basic Education Framework, seeks to achieve seven core competencies:

- Communication and collaboration
- Self-efficacy
- Critical thinking and problem solving
- Creativity and imagination
- Citizenship
- Digital literacy
- Learning to learn.

The structure of the new curriculum entails: Early years education (pre-primary and lower primary); Middle school education (upper primary and lower secondary);

Senior school (Science, Technology, Engineering and Mathematics (STEM); Social Sciences and Arts and Sports Sciences). The introduction of the Competency Based Curriculum (CBC) is intended to eradicate wastage of potential in learners by ensuring that every child's ability is identified, harnessed and channeled appropriately.

According to Njagi and Kihumba(2019), the following are the key features of the new curriculum:

(a) **Orientation**

The competency Based Curriculum is a learner centred curriculum. The teacher is just a facilitator.

(b) **Teaching Methodology**

The new curriculum will be practical oriented and will involve using inquiry based learning. The 21st century skills and approaches such as collaboration, problem solving and imagination will be used. It is going to be a curriculum to help learners to demonstrate what they can do.

(c) **Evaluation**

The new curriculum requires every learner to be built a profile.

(d) **Talent identification and Management**

The new curriculum requires identification and nurturing of talent in every learner.

(e) **Learning**

Learners are required to demonstrate what they know. The emphasis is on the practical work.

The use of GeoGebra and Grapes in teaching of Mathematics is in agreement with the new curriculum which emphasizes on practical work. Use of Grapes and GeoGebra requires communication and collaboration, critical thinking and problem solving skills, and creativity and imagination. These are features which are highly emphasized in the new curriculum. The traditional methods employed in the teaching of the previous curricula (7-4-2-3 and 8-4-4) forced the learners to learn Mathematics by memorization ending up with falling success and imposing a feeling of being unsuccessful in learning mathematics. The nature of Mathematics requires high level of mental processes such as critical thinking, reasoning, imagination and considering many different features with related facts. The use of pencil drawn shapes on paper or board is not enough in the teaching and learning of mathematics. According to constructivist approach to learning, mathematics courses need to be addressed with different emphases which make them enjoyable, understandable and constructible to the learners. It is accepted that computer and software use in primary education is promising and may improve mathematics education remarkably, if it is directed to teaching and learning process. Geometric constructions using GeoGebra software acquire dynamic properties with the computer so that learners can make observations as well as the imagination. The process of dragging, transforming, rotating, enlarging, translating and reflecting can easily be done with the use of GeoGebra instead of using pencil and paper or board. The use of GeoGebra and Grapes softwares make the learning of abstract concepts easier. The use of GeoGebra and Grapes is more effective than the traditional approach to learning, especially in transformation geometry, polygons, prisms and pyramids.

2.9 Unesco's Ict Framework

UNESCO's framework (2011) emphasizes that it is not enough for teachers to have ICT competencies and be able to teach them to their students. Teachers need to be able to help the students become collaborative, problem-solving, creative learners through using ICT so they will be effective citizens and members of the workforce. The framework is arranged in three different approaches to teaching. The first is technology literacy, enabling students to use ICT in order to learn more efficiently. The second is knowledge deepening, enabling students to acquire in-depth knowledge of their school subjects and apply it to complex, real world problems. The third is knowledge creation, enabling students, citizens and workforce they become, to create the new knowledge required for more harmonious, fulfilling and prosperous societies.

The framework argues that teachers need to use teaching methods which are appropriate for evolving knowledge societies. Students need to be enabled not only to acquire an in-depth knowledge of their school subjects but also to understand how they themselves can generate new knowledge, using ICT as a tool. The use of new technologies in education implies new teacher roles, new pedagogies and new approaches to teacher education. The successful integration of ICT into the classroom will depend on the ability of teachers to structure the learning environment in new ways, to merge new technology with new pedagogy, to develop socially active classrooms, encouraging co-operative interaction, collaborative learning and group work. According to UNESCO (2011), the teaching skills of the future will include the ability to develop innovative ways of using technology to enhance the learning environment, and to encourage technology literacy, knowledge deepening and knowledge creation. Teacher professional learning will be a crucial component of this educational improvement.

The UNESCO International Commission on Education for the 21st century views learning throughout life and participation in the society of life as key to meeting the challenges posed by a rapidly changing world. The commission emphasizes four pillars of learning: ‘learning to live together’, ‘learning to know’, learning to do’ and ‘learning to be’. The policy goal of the technology literacy approach is to enable learners, citizens and the work force to use ICT to support social development and improve economic productivity. Corresponding changes in the curriculum entailed by this approach might include improving basic literacy skills through technology and adding the development of ICT skills into relevant curriculum contexts. Changes in pedagogical practice involve the use of various ICT tools and digital content as part of whole class, group and individual student activities.

According to UNESCO (2011), the aim of knowledge deepening approach is to increase the ability of students, citizens and the work force to add value to society and the economy by applying the knowledge gained in school subjects to solve complex, high-priority problems encountered in real world situations of work, societies and in life generally. This approach often requires changes in the curriculum that emphasizes depth of understanding over coverage of content and assessment that emphasize the application of understanding to real world problems. The pedagogy associated with this approach includes collaborative problem- and project –based learning in which students explore a subject deeply and bring their knowledge to bear on complex, every day questions, issues and problems. Teaching is student-centred and the teacher’s role is to structure tasks, guide student’s understanding and to support students as they tackle collaborative projects. Lessons and classroom structure are more dynamic, with students working in groups for extended periods of time. In guiding students’ understanding of key concepts , teachers will employ open-ended

ICT tools that are specific to their subject area, such as visualization in science , data analysis tools in mathematics and role play simulations in social studies.

According to UNESCO (2011), the aim of knowledge creation approach is to increase productivity by creating students, citizens and a workforce that is continually engaged in, and benefits from knowledge creation, innovation and life-long learning. With this approach, the curriculum goes beyond a focus on knowledge of school subjects to explicitly include the knowledge society skills that are needed to create new knowledge. These are skills such as problem solving, communication, collaboration, experimentation, critical thinking and creative expression. These are skills that can be used throughout a life time to participate in a learning society. The role of teachers is to overtly model these processes, structure situations in which students apply these skills, and assist students in their skill acquisition. Teachers build a learning community in the classroom in which students are continuously engaged in developing their own and each other's learning skills. Teachers can then be seen as model learners and knowledge producers who are constantly engaged in educational experimentation and innovation in collaboration with their colleagues and outside experts to produce new knowledge about learning and teaching practice.

Teachers who are competent in the knowledge creation approach will be able to design ICT based learning resources and environments, use ICT to support the development of knowledge creation and the critical thinking skills of students, support students' continuous, reflective learning, and create knowledge communities for students and colleagues. They will also be able to play a leading role with colleagues in creating and implementing a vision of their school as a community based on innovation and continuous learning, enriched by ICT. The use of Grapes and

GeoGebra in the teaching of mathematics are in agreement with the UNESCO's ICT policy framework which emphasizes the use of ICT in knowledge deepening approach so as to increase the ability of students, citizens and the work force to add value to society and the economy by applying the knowledge gained in school subjects to solve complex, high-priority problems encountered in real world situations of work, societies and in life generally. The use of Grapes and GeoGebra encourages collaborative problem- and project –based learning in which students explore a subject deeply and bring their knowledge to bear on complex, every day questions, issues and problems.

According to UNESCO (2021), successful integration of ICT into teaching and learning requires rethinking the role of teachers in planning and applying ICT to enhance and transform learning. The education system needs to regularly update and reform teacher preparation and professional development, ensuring that all teachers can harness technology for quality teaching and learning. The UNESCO ICT competency Framework for teachers (ICT-CFT) seeks to help countries develop comprehensive national teacher ICT competency policies and standards and integrate these in overarching ICT in education plans. Teacher training is critical component of integrating ICT in education and the Ministry of Education, Science and Technology is mandated to develop a skilled and innovative manpower in Kenya and works towards the integration of ICT at all levels of learning. Teachers also need to embrace change with the new paradigm shift in teaching and learning brought about by the demand of ICT tools.

2.10 National Ict Policy in Kenya

After several years of effort, Kenya promulgated a National ICT policy in January 2006 that aims to improve the livelihoods of Kenyans by ensuring the availability of accessible, reliable and affordable ICT services (National ICT policy, 2006). The national policy has several sections, including information technology, broadcasting, telecommunications and postal services. The section on information technology sets out the objectives and strategies pertaining to ICT and education. The relevant objective in this section states that government will encourage the use of ICT in schools, colleges, universities and other educational institutions in the country so as to improve the quality of teaching and learning. The relevant strategies under the heading ‘‘E-learning ’’ are to:

- Promote the development of e-learning resources.
- Facilitate public-private partnerships to mobilize resources in order to support e-learning initiatives.
- Promote the development of an integrated e-learning curriculum to support ICT in education.
- Promote distance education and virtual institutions, particularly in higher education and training.
- Promote the establishment of a national ICT centre of excellence.
- Provide affordable infrastructure to facilitate dissemination of knowledge and skill through e-learning platforms.

- Promote the development of content to address the educational needs of primary, secondary and tertiary institutions.
- Create awareness of the opportunities offered by ICT as an educational tool to the educational sector.
- Facilitate sharing of e-learning resources between institutions.
- Exploit e-learning opportunities to offer Kenyan education programmes for export
- Integrate e-learning resources with other existing resources.

The ministry of education developed a Kenya Education Sector Support Program (KESSP) in 2005 that featured ICT as one of the priority areas with the aim of mainstreaming ICTs into the teaching and learning process. The National ICT policy embedded this content as a national priority and provided the impetus for the ministry to develop its sector on ICT in Education. The ministry moved quickly and in June 2006, introduced the National ICT policy for Education and Training. This document, referred to as the ICT policy for the education sector, consists of the following components, each with its own statement of strategic objectives and expected outcomes:

- ICT in education policy
- Digital equipment
- Connectivity and network infrastructure
- Access and equity

- Technical support and maintenance
- Harnessing emerging technologies
- Digital content
- Integration of ICT in education
- Training (capacity-building and professional development)
- Research and development

The Ministry of Education was given the mandate to lead the monitoring and evaluation of the strategy's implementation, guided by overall government policies on education and ICT, specific education strategic documents for implementing its mandate, and global goals such as Education for All (EFA) and the Millennium Development Goals (MDGs).

The ministry's policy framework indicates that there are a number of challenges concerning access to and use of ICT in Kenya, including high levels of poverty, limited rural electrification, and frequent power disruptions. Most secondary schools have some computer equipment; however this could consist of one computer in the office of the school head. Very few secondary schools have sufficient ICT tools for teachers and students. Even in schools that have computers, the student-computer ratio is 150:1. Most of the schools with ICT infrastructure have acquired it through initiatives supported by the parents, the government, NGOs, or other development agencies and the private sector, including the NEPAD e-schools program. Attempts to set up basic ICT infrastructure in primary schools are almost negligible.

The core problem is that Kenya lacks adequate connectivity and network infrastructure. Although a small number of schools have direct access to high speed connectivity through an internet service provider, generally there is limited penetration of the national physical telecommunication infrastructure into rural and low income areas. As a solution to these access problems, the ministry hopes to leverage the e-government initiative of networking public institutions countrywide to facilitate connectivity for the educational sector.

Infrastructure can also be organizational in nature. There are three organizations of critical importance in the context of ICT development in Kenyan schools. One of these, the Kenya ICT Trust Fund, facilitates mobilization of resources to provide ICT to schools and communities and acts with its members as coordinating body for sharing information about priorities and developments. The second component of the education system infrastructure is the Kenya Institute of Curriculum Development (KICD), which has a mandate to:

- Prepare syllabuses , publish and print materials
- Develop digital curriculum content
- Provide teacher in-service training
- Develop and transmit programmes via mass media to support educational development
- Prepare distance learning materials
- Conduct research on educational matters.

The third component is the Non-Governmental organizations Network Initiative for Computers in Education (NICE), an umbrella agency whose members are non-governmental organizations involved in the introduction and use of ICTs in schools. NICE provides a coordinating and rationalizing function and , through its membership in the Kenya ICT Trust Fund , ensures that the work and needs of its members are known and considered in the Fund's decision making processes.

The National Information, Communications and Technology (ICT) policy of 2019 was designed to realize the potential of the digital economy by creating an enabling environment for all citizens and stakeholders. A review of the 2006 policy was necessitated by the rapid changes and developments in the ICT sector, evolving global trends and fast changing public needs. The review of 2006 ICT policy was inspired by the need to align the policy with the new constitutional dispensation in Kenya and vision 2030. The 2019 ICT policy was a product of an all inclusive participatory and consultative process and was guided by the following principles: putting ICT at the centre of the national economic agenda, improving access to ICT especially broadband, efficient public service delivery and maintaining an open government.

2.11 Gender differences in mathematics achievement.

Mathematics is a very important subject not only because of the types of skills and knowledge that learners acquire from learning the subject but also because of its use in the learning of other subjects of the curriculum. It is for this reason that mathematics is made compulsory for all learners in Kenyan secondary schools. Gender equity is an important issue in mathematics education.

There is a general misconception and belief that mathematics is a male domain. Girls should overcome the myth that mathematics and sciences are masculine subjects.

There is need to remove gender insensitive materials in the curriculum and teaching methodologies. Teachers should not only expect boys to do wonderfully well in mathematics and sciences while they expect girls to be just average or below. Girls should not be considered to be inferior in doing mathematics. The basic idea behind the gender issue is equity. The teacher should give equal opportunities to both boys and girls. At no time should the teacher be seen to be promoting one sex as opposed to the other. No one sex is superior to the other. According to Ajum (2015), recent research has revealed that the gender differences in mathematics education in many countries seem to be narrowing. Some studies have shown that as students reach higher grades, males tend to show elevated levels of mathematics achievement (Campbell, Goldberg & Stemler, 2000).

According to Ajai and Imoko (2015), their study showed that female students outperformed their male counterparts in mathematics achievements though the difference was not statistically significant. They argued that the reason for equal performance of male and female students may be connected with the fact that both see themselves as equals and capable of competing and collaborating in classroom activities. They pointed out that both sexes are capable of competing and collaborating in classroom activities.

Ajai and Imoko(2015) pointed out that there is need to give boys and girls exactly the same opportunities and challenges in mathematics. Male and female students need to compete, collaborate and gain from one another in mathematics teaching and learning. They recommended that teacher professional development programs should make more concerted efforts to advise teachers about the ways in which to approach the teaching of mathematics so as to avoid disadvantaging particular groups of girls or boys. They also pointed out that mathematics teaching and evaluation should be gender bias free. This way, boys and girls will tend to see themselves as equals capable of competing and collaborating in classroom activities. They also recommended that male and female teachers should work jointly with boys and girls and adopt a more socially just and inclusive approach to creating equal opportunities for all students.

According to the research conducted by Kaiser and Zhu (2022), boys performed better than girls in overall mathematics achievement but the difference was insignificant. On average, a Shanghai boy would achieve significantly higher marks than a girl in programme for International student Assessment 2012 mathematics test.

Research has shown that gender differences in mathematics performance are diminishing (Frost,Hyde & Fennema,1994; Hyde, Fennema & Lamon,1990). Piere, Moran and Lutkus (2005) found out that the gap has been narrowing in the United States of America. Research in Australia indicated that the gender differences in mathematics achievement are reducing and shifting (Forgasz, Leder & Vale, 2000).

According to Vale (2009), many studies conducted between 2000 and 2004 in Australia showed significant differences in mathematics achievement between male and female students though males were more likely to obtain higher mean scores.

Feminists researchers have tried to make meaning of the experiences of girls and boys in mathematics classrooms and to interpret male-female power relations (Jungwirth,1991; Waiden & Walkerdine,1985). Their findings revealed that girls are often marginalized and given subordinate status in the mathematics class. The findings suggest that perceptions of teachers are that girls’ performances in mathematics are dependent on rote learning, hard work and perseverance rather than natural talent, flexibility and risk taking which are the learning styles of the boys. The research conducted by Offoe and Kwamina (2015) in Ghana found out that there was no statistically significant difference in mathematics achievement between male and female students from the experimental group. This is an important finding in the sense that male students are generally perceived to do better in mathematics than female students. This result shows that performance assessment tests are not gender biased and also contradict the assertion that boys perform better in mathematics than girls with particular reference to early high school level in Ghana. The findings showed that performance assessment driven instruction encouraged the student to own the process of solving given problem. The student is engaged in a process of constructing individual interpretation of their experiences.

2.12 Importance of Geometry in Mathematics.

According to Jones (2002), the study of geometry contributes to helping students develop the skills of visualization, critical thinking, intuition, perspective, problem-solving, conjecturing, deductive reasoning, logical argument and proof. Geometric representations can be used to help students make sense of other areas of mathematics: fractions and multiplication in arithmetic, the relationships between the graphs of functions (of both two and three variables), and graphical representations of data in statistics. Spatial reasoning is important in other curriculum areas as well as mathematics: science, geography, art, design and technology. Working with practical equipment can also help develop fine motor skills.

Geometry provides a culturally and historically rich context within which to do mathematics. There are many interesting, sometimes surprising or counter-intuitive results in geometry that can stimulate students to want to know more and to understand why. Presenting geometry in a way that stimulates curiosity and encourages exploration can enhance student's learning and their attitudes towards mathematics. By encouraging students to discuss problems in geometry, articulate their ideas and develop clearly structured arguments to support their intuitions can lead to enhanced communication skills and recognition of the importance of proof. Geometry is a rich source of opportunities for developing notions of proof. While more is said about this in a later section, it is worth emphasizing that visual images, particularly those, which can be manipulated on the computer screen, invite students to observe and conjecture generalizations. Proving conjectures requires students to understand how the observed images are related to one another and are linked to fundamental 'building blocks'. In dynamic geometry software understanding observed images means working with points, circles, and parallel and perpendicular lines. In the programming language Logo, it involves understanding the way in which the 'turtle' moves.

We live on a solid planet in a 3D world and, as much of our experience is through visual stimulus, this means that the ability to interpret visual information is fundamental to human existence. To develop an understanding of how spatial phenomena are related and to apply that understanding with confidence to solve problems and make sense of novel situations has to be part of the educational experience of all students. Geometry offers a rich way of developing visualization skills. Visualization allows students a way of exploring mathematical and other problems without the need to produce accurate diagrams or use symbolic representations. Manipulating images in the head can inspire confidence and develop intuitive understanding of spatial situations.

There can be a tendency to teach geometry by informing students of the properties associated with plane or solid shapes, requiring them to learn the properties and then to complete exercises which show that they have learned the facts. Such an approach can mean that little attempt is made to encourage students to make logical connections and explain their reasoning. Whilst it is important that students have a good knowledge of geometrical facts, if they are to develop their spatial thinking and geometrical intuition, a variety of approaches are beneficial. For example, some facts can be introduced informally, others developed deductively or found through exploration.

To teach geometry effectively to students of any age or ability, it is important to ensure that students understand the concepts they are learning and the steps that are involved in particular processes rather than the students solely learning rules. More effective teaching approaches encourage students to recognize connections between different ways of representing geometric ideas and between geometry and other areas of mathematics. The evidence suggests that this is likely to help students to retain knowledge and skills and enable them to approach new geometrical problems with some confidence.

When planning approaches to teaching and learning geometry, it is important to ensure that the provision in the early years of secondary school encourages students to develop an enthusiasm for the subject by providing opportunities to investigate spatial ideas and solve real life problems. There is also a need to ensure that there is a good understanding of the basic concepts and language of geometry in order to provide foundations for future work and to enable students to consider geometrical problems and communicate ideas. Students should be encouraged to use descriptions, demonstrations and justifications in order to develop the reasoning skills and confidence needed to underpin the development of an ability to follow and construct geometrical proofs.

It is useful to consider geometry as a practical subject and provide opportunities for students to use a range of resources to explore and investigate properties of shapes and geometrical facts. Particular consideration should be given to ways in which the ICT resources, which are increasingly available in schools, can be used to enhance the teaching and learning of geometry. The use of dynamic geometry enables the teacher or individual students to generate and manipulate geometrical diagrams quickly and explore relationships using a range of examples.

Geometry is the part of the mathematics curriculum where it is possible to have the most fun. It is visual, intuitive, creative, and demanding. New developments in computing technology mean that the 21st century will be one where spatial thinking and visualization are vital. Geometry is where those all important skills are nurtured. Engage with geometry yourself and get your pupils thinking geometrically.

2.13 Critical review of the related Literature.

Hismanoglu (2012) conducted a study on teacher's perceptions of ICT integration in Turkey. The study found out that ICT presents a powerful tool for learning environment for learners in the classroom. The study recommended that since teachers are the main characters to employ ICT in educational contexts, they should be trained in how ICT can be integrated into the teaching process. Higher education institutions should pay a special attention in revising and updating the curricula, equipment and educational materials on a permanent basis in the faculties of education. Pre-service teachers with negative ICT perceptions cannot transfer their ICT skills to their students and stimulate them to deploy ICT when the start teaching.

The study found out that most higher education institutions cannot provide pre-service teachers with positive technological experiences. As to distance higher education in Turkey, it is to be noted that ICT can create a better teaching and learning environment in schools as long as prospective teachers are trained well through a curriculum rescued from traditional behaviourist approach domination and the curricula, equipment and educational materials are designed with a more internationally accepted and fast growing educational model based on practicing and experiencing.

Ololube (2006) conducted a study on the impact and uses of Information and Communication Technology (ICT) in Nigeria and the issues that underlie the integration of ICT in teacher education programs in Nigeria. The study found out that achievements in the ICT penetration and usage in Nigeria teacher education programs is dependent on the recognition of the importance of ICT application to education for sustainable development by the federal and state government by making useful policies and providing enough funds to the institutions themselves on the other hand. An effort towards creating an enabling environment for teacher education programs to strive towards producing highly qualified ICT literate teachers that would assist in making the integration and usage of ICT in secondary schools a success. The designing and implementing successful ICT enabled teacher education program is the key to fundamental, wide ranging educational reforms. The teacher education institutions in Nigeria should either assume a leadership role in the transformation of education or be left behind in the swirl of rapid technological changes.

Accordingly, for Nigerian education to reap the full benefits of ICTs in learning, it is essential that pre-service and in-service teachers are able to effectively use these tools for learning. Teacher education institutions and programs must provide the leadership for pre-service and in-service teachers and model the new pedagogies and tools for learning through effective strategic plan (Ololube, 2006). Leadership in higher education should be visionary about conceiving a desired future state, which includes the picturing of where and what the teacher education program should be in the future, without being constrained by such factors as funding and resources , and then walking backward to develop action plan to get to where they want to get to.

Integration of ICT into education is a procedure in which instructional technologies such as computers and software are applied regularly to support both teaching and learning across levels and subject matter (Leng, 2006). In Singapore, the affluent nature of our society ensures that the average household has at least one desktop computer in the home with internet access. Of those that do not, nonetheless they have access to computers in school and a variety of other publicly accessible locations such as cyber cafes. The ministry of education in Singapore has recognized the importance of equipping our students with technological skills that will allow smooth transition into the workplace of the future. The use of technology is in accordance with the movement towards student-centred instruction and increased motivation of learners where the teacher’s role is that of a facilitator and students are active participants. Technology implementation in the curriculum not only motivates learning but also improves student performance on a school-wide scale (Leng,2006).

Keong (2005) conducted a study in Malaysia to identify the barriers preventing the integration and adoption of information and communication technology in teaching mathematics. Six major barriers were identified: lack of time in the school schedule for projects involving ICT, insufficient teacher training opportunities for ICT projects, lack of knowledge about ways to integrate ICT to enhance the curriculum, difficulty in integrating and using different ICT tools in a single lesson and unavailability of resources at home for the students to access the necessary educational materials. The use of ICT in teaching mathematics can make the teaching process more effective as well as enhance the students' capabilities in understanding basic concepts.

Agyei and Voogt (2011) conducted a study to explore the feasibility of ICT use in Mathematics teaching at senior high school levels in Ghana. Preliminary results showed that mathematics teachers in Ghana do not integrate ICT in their mathematics instruction. Among the major perceived barriers identified were lack of knowledge about ways to integrate ICT in lesson and lack of training opportunities for ICT integration knowledge acquisition. The results of the study showed that schools lacked common mathematical software used in teaching mathematics. The most frequently used strategy for teaching as reported was the chalk and talk approach in which teachers did most of the talking and intellectual work, while students were passive recipients of the information provided. These teachers also have been taught in the same manner and for most of them effectively integrating ICT in their instruction is a complex innovation which requires them to change their routines of teaching. The pre-service teachers reported that most instructors at the teacher education programme were mainly dependent on lecture based instruction. The programme also did not include courses where teachers were taught how to integrate ICT in their lessons. This means that the pre-service teachers' experience to integrate ICT in teaching is limited making the programme fall short of the practical approach.

Although the curriculum requires mathematics teachers to use ICT in instruction, some teachers alleged that the current status of the curriculum presented serious threats to possibilities of teaching to integrate ICT in the classroom. Both in-service and pre-service teachers expressed the need for mathematics teachers to integrate ICT in their lessons. The study found out that there is need for a professional development scenario that will assist pre-service and in-service teachers to develop skills on ways to integrate ICT in their teaching process (Agyei &Voogt,2011).

According to Alqahtani and Powell (2016), understanding geometry is important in itself and for understanding other areas of mathematics. It contributes to logical and deductive reasoning about spatial objects and relationships. Geometry provides visual representations alongside the analytical representation of a mathematical concept. Dynamic geometry environments (DGE) are tools that learners can appropriate through an instrumentation process. In DGE, the usage schemes include knowledge about the software use and its functionalities. The second level of utilization schemes for a DGE includes knowledge of geometry and dependencies. When learners appropriate DGE as an instrument, they will be able to use it to demonstrate geometrical concepts and solve geometrical problems. This appropriation may result in knowledge of how to use dynamic geometry software as well as knowledge of geometry.

According to Hudson and Porter (2010), today's students are expected to learn about and use digital technology in mathematics to prepare them for their future, the workforce and the challenges of everyday life. International studies show that secondary mathematics teachers are still not effectively integrating computer technology in their classroom. Hudson and Porter (2010) conducted a study to determine the extent to which mathematics teachers in government high schools in New South Wales, Australia has integrated computer technology into their teaching. The findings of the study indicate that the strongest predictors that are positively associated with computer use are training on EXCEL and the need for ongoing support for the inclusion of technology in mathematics teaching.

Mathematics Education in the public secondary schools in New South Wales, Australia has been experiencing reforms directed towards the integration of technology courses dating back to the late 1990's. There is evidence that the mandated policy of computer-based technologies in the mathematics key learning area of the New South Wales Department of Education has not been fully embraced by schools in New South Wales (Hudson and Porter, 2010). Despite the mandate that accompanies this policy document that computer technology be integrated in the range of courses in the secondary mathematics key learning areas, there is evidence to suggest that computers are not widely integrated into Australian secondary mathematics classrooms. Similarly, for teachers in the USA, where despite teachers' increasing knowledge of and familiarity with technology and there being infrastructure to support it, many mathematics teachers are still not effectively integrating technology into their teaching (Foley and Ojeda, 2007). The international evidence suggests that one reason for the teachers not embracing technology is the fear that it might replace them (Li, 2007). Others attribute the ineffective integration of technology to the lack of adequate knowledge about when and how computers could be used in mathematics instruction, and lack of sufficient training (Jamieson-Proctor and Finger, 2008).

One of the barriers that mathematics teachers identified in failing to adopt the use of computers in the classroom are the lack of professional development in technology. To address this issue, several authors prescribed different types of professional development in the use of technology. This can be in the form of formal training in technology courses (Swan and Dixon, 2006), training of teachers in the use of software packages (Toumasis, 2006), instructional strategies (Sorkin etal, 2004) and lesson planning integrating technology in mathematics (Hardy, 2004).

In 2013, the Teachers Service Commission (TSC) developed a harmonized curriculum for integration of ICT in teaching and learning for the purpose of the rollout of the National Laptops Project in Kenya. This curriculum was developed out of a felt need to equip learners with modern ICT skills which is in line with one of the flagship projects in Kenya Vision 2030. Integration of information, communications and technology in the learning and teaching situations is also well covered in various policy frameworks and specifically in sessional paper number 14 of 2012 that states in part : ‘‘The government recognizes that an ICT literate workforce is the foundation on which Kenya can acquire the status of a knowledge economy by 2030’’. Against this background, the government shall make education the natural platform for equipping the nation with ICT skills in order to create dynamic and sustainable economic growth. The ministry of education has continued to supply ICT equipment, content and training of teachers on ICT. Additionally, an interactive e-learning aims at mainstreaming ICT as a tool for teaching and learning. ICT is a major vehicle for teaching and learning from the earliest years. It is at a very young age that learners begin to acquire digital skills which they increasingly use to explore and exploit the world of information and to craft that into knowledge. ICT facilitates the opportunity for more student-centred teaching and more peer teaching. It also provides greater opportunity for teacher-to-teacher, and student-to-student communication and collaboration and access to the World Wide Web and the suggested teaching /learning resources contained therein.

The way teachers and learners interact with the curriculum in schools has been forced to change because of the dramatic developments ushered in by technology. Internet and social media have in one way or the other affected the dynamics of learning and teaching and it is important that teachers master the situations created by the developments. Added to this challenge is the anticipated introduction of laptops in the primary schools through the government programme.

Primary schools teacher capacity building is key to successful implementation of this program. It is for this reason that in accordance with TSC Act 2012, Teachers Service Commission has embarked on capacity building of teachers and education managers to effectively lead in the utilization of ICT tools in education. It is expected that the training will cascade down to the rest of the teachers in all schools for ease of adaptation and innovation in the classroom, for all teachers that handle children in schools. Microsoft partners in learning offers a range of professional development programs to bridge the gap between technology skills and innovative teaching. It reaches beyond traditional software training to provide a scaffold that helps educators of all skill levels on their learning journey. Partners in learning give educators the knowledge they need to impart 21st century skills to their students and deliver exceptional student outcomes.

The Microsoft Teaching with Technology curriculum helps educators move beyond learning technology tools to develop a deeper understanding of how technology integration can enhance the teaching and learning experience, give their students 21st

century skills , and save time. Teaching with technology includes a self-assessment to identify learning gaps , e-learning content to help fill those gaps, summative assessments and a range of learning activities and tutorials to help extend the learning and to encourage educators to apply their new knowledge in the classroom with their students.

Teaching with technology helps build both the skills and the ability to apply those skills to perform a particular job or task. This curriculum guide has been developed to assist the education implementers to integrate ICTs in primary education. The guide outlines the competencies, skills and attitudes to be developed in preparation for integrating ICTs in schools. The curriculum guide is organized in three parts namely; Education Leaders training, ICTs in Education and ICT integration in teaching and learning. It is envisaged that at the end of the training, all the trainees will adapt contemporary technology and apply it in their day to day suggested teaching/learning activities. Mollakuqe etal (2021) conducted a research Incorporating GeoGebra into Teaching Circle properties at High School level and its comparison with the Classical Method of Teaching. The results showed that using GeoGebra in teaching facilitates, accelerates and make geometry more tangible. During the explanation process, there is an increased interest and active participation of the students in the classroom through questions and discussion. The findings showed that when geometry is explained with GeoGebra, the lessons become very concrete. This study is on the joint use of Grapes and GeoGebra in teaching the area of Geometry and particularly the graph work. The aim is to find out whether the findings on the use of Grapes and GeoGebra are the same as those of using GeoGebra to teach circles.

From the literature that has been reviewed, it can be seen that not much studies have been done in the Kenya on the role of Grapes and GeoGebra in the teaching of mathematics in Kenyan secondary schools. Most of the studies on this area have been conducted internationally in countries such as Malaysia, Singapore, United Kingdom, Israel, Austrialia, Japan, and Turkey. At the regional level some studies on the use of GeoGebra in teaching of Mathematics have been carried out in Ghana and Nigeria. This study was carried out to find out if the findings of the researches carried out at the international level are applicable to the Kenyan situation. At the same time, most of the researches that have been conducted have been focusing on the use of GeoGebra only in teaching certain topics of the mathematics curriculum. Very few studies have been conducted on the application of the Grapes software. This study considered the joint application of Grapes and GeoGebra in teaching graph work.

2.12 Summary of the Chapter

ICTs in education are not transformative on their own. Transformation requires teachers who can use technology to improve student learning. The professional development of teacher educators in the area of ICT integration is essential. Unless teacher educators model effective use of technology in their own classes, it will not be possible to prepare a new generation of teachers who effectively use the new tools for teaching and learning.

From the literature that has been reviewed, it is evident that much of the studies of the impact of ICT integration on the teaching and learning process in Kenyan secondary schools have not been addressed at the local level. Many studies have looked at the issue of ICT integration at international level and regional level. The Kenya Government together with the donors has spent a lot of resources in ICT in all sectors of the economy and particularly the education sector. Many teachers of mathematics and sciences have undergone SMASSE INSET on how to integrate the use of technology in the teaching and learning process.ICT centres in all the Districts in Kenya have been established and funded through the Economic Stimulus Fund (ESF). Secondary school teachers in those centres have been trained on how to integrate ICT in the teaching of all the subjects in the curriculum. It is therefore quite timely that my research study investigated the role of GeoGebra and Grapes in the teaching and learning of mathematics. Most of the researches that have been done in Kenya are general in nature on the issue of ICT integration in teaching and learning process.

CHAPTER THREE: RESEARCH DESIGN AND METHODOLOGY

3.1 Introduction

This chapter presents the research design and methodology that was used in the study to answer the research questions. The chapter discusses the methodology, research design, target population, sample and sampling techniques, research instruments, validity and reliability of the research instruments, data collection procedures, data analysis, ethical considerations and summary of the chapter.

3.2 Research Design and Methodology

According to Maree (2016), research is ultimately about understanding the world, and your understanding is informed by how you view the world, what you think understanding is and what you see as the purpose of understanding. According to Crotty (1998), methods are the techniques or procedures used to gather and analyse data related to some research question or hypothesis whereas methodology is the strategy, plan of action, process or design lying behind the choice and use of particular methods and linking the choice and use of methods to the desired outcomes. According to Hesse-Biber and Leavy (as quoted by Maree, 2016), methods are the tools that researchers use to collect data. These tools enable us to gather data about social reality from individuals, groups, artefacts and texts in any medium. The research method or methods for a particular project may include interviewing, observation, or the collection of textual or visual data. It is generally accepted that it is essential to ensure a tight fit between the purpose or research question and the method (Maree, 2016). Methodology describes the overall approach to research design (Mingers, 2001; Serafeimidis& Smithson, 2000; Benbasat & Zmud, 1999). It is a plan of action that links methods to outcomes..

According to Berg (as quoted by Maree, 2016), the choice of methods are indicative of how we see the world and thus of our ontological and epistemological position. According to Hesse-Biber and Leavy (as quoted by Maree, 2016), methodology is the bridge that brings our philosophical standpoint (on ontology and epistemology) and method (perspective and tool) together. They emphasize that it is important to remember that the researcher travels his/her bridge throughout the research process and therefore claim that our methodology serves as a strategic, but malleable guide. Essentially, research methodology includes the procedures by which researchers go about their work of collecting data, analyzing, describing, and explaining phenomena. According to Sandelowski (as quoted by Maree, 2016), the words ‘‘method’’ and ‘‘methodology’’ entail some understanding of the world and how to know it, variously referred to as theory, philosophy, or paradigm. Although they are used interchangeably, method/methodology connotes some theoretical/philosophical orientation to inquiry (Maree, 2016).

According to Cohen et al. (2001), a research design is used to describe the procedures for conducting a study, and its purpose is to help find appropriate answers to research questions. Mc Millan and Schumacher (2001) describe a mode of inquiry as a collection of research practices. Mode of inquiry informs research design, for example how the research is set up, what happens to the respondents and what methods of data collection are used (McMillan & Schumacher, 2001). Research design is a plan or proposal to conduct research, involves the intersection of philosophy, strategies of inquiry and specific methods. To reiterate, in planning a study, researchers need to think through the philosophical worldview, and the specific methods or procedures of research that translate the approach into practice (Creswell, 2014).

According to Kothari (2004), a research design is the arrangement of conditions for collection and analysis of data in a manner that aims to combine relevance to the research purpose with economy in procedure. The research design is the conceptual structure within which research is conducted; it constitutes the blueprint for the collection, measurement and analysis of data. As such the design includes an outline of what the researcher will do from writing the hypothesis and its operational implications to the final analysis of data. Research design stands for advance planning of the methods to be adopted for collecting the relevant data and the techniques to be used in their analysis, keeping in view the objective of the research and the availability of staff, time and money. Preparation of the research design should be done with great care as any error in it may upset the entire research. Research design, in fact, has a great bearing on the reliability of the results arrived at and as such constitutes the firm foundation of the entire edifice of the research work. A research design helps the researcher to organize his/her ideas in a form whereby it will be possible for him/her to look for flaws and inadequacies (Kothari, 2004).

According to Maree (2016), a research design is a plan or strategy that moves from the underlying philosophical assumptions to specifying the selection of participants, the data gathering methods to be used and the data analysis to be done. The choice of research design is based on researchers’ ontological and epistemological perspective, research skills and research practices, and influences the way in which they collect data. Currently, there is a very wide range of research designs from which researchers may select one that is congruent with their research question and philosophical assumptions as well as most appropriate for generating the kind of data required to answer the research questions posed (Maree, 2016).

This study adopted quantitative research methods .According to Creswell (2014), quantitative research is a means for testing objective theories by examining the relationships among variables. These variables, in turn, can be measured, typically on instruments, so that numbered data can be analyzed using statistical procedures. Those who engage in this form of inquiry have assumptions about testing theories deductively, building in protections against bias, controlling for alternative explanations, and being able to generalize and replicate the findings. According to Maree (2016), quantitative research is a process that is systematic and objective in its ways of using numerical data from only a selected subgroup of a universe (or population) to generalize the findings to the universe that is being studied. The three most important elements in this definition are objectivity, numerical data and generalisability. This study was quantitative in nature and involved collecting of numerical data which was used to test the hypotheses and make some conclusions.

According to Maree (2016), quantitative research is a process that is systematic and objective in its ways of using numerical data from only a selected subgroup of a universe (or population) to generalize the findings to the universe that is being studied. The three most important elements in this definition are: objectivity, numerical data and generalisability.

Whereas ontological assumptions concern the nature of reality, epistemology relates to how things can be known -how truths or facts or physical laws, if they do exist, can be discovered and disclosed (Maree, 2016). Ritchie and Lewis (2003) claim that the epistemology is concerned with ways of knowing and learning about the social world, and focuses about questions such as: how can we know about reality, and what is the basis of our knowledge? There are three main issues around which there is debate in social research. The first debate concerns the relationship between the researcher and the researched. Some believe that, in the social world, people are affected by the process of being studied and that the relationship between the researcher and the researched is interactive. In this case, the researcher cannot be objective and cannot produce an objective or ‘‘privileged’’ account. Findings are either mediated through the researcher, or they can be negotiated and agreed between the researcher and research participants (Ritchie & Lewis, 2003).

The second debate relates to the objectivity of knowledge. From an epistemological perspective the question arises whether knowledge can be viewed as objectively knowable or, in contrast, only subjectively knowable (Maree, 2016).Burrell and Morgan (1979), and Guba and Lincoln (1989) agree that in social inquiry, subjective knowledge produces a subjective relationship between elements of the inquiry. We can therefore conclude that knowledge of ‘‘what is’’ is always subjective as it is perceived and described through the observations made subjectively by a human observer.

The third epistemological debate centres on the question whether the findings of research are generalisable or not. Parallel to this is the argument of the transferability of findings. In other words, we may ask whether the findings of research can have universal application and thus be generalized to all contexts, or whether the findings can only be applied to specific cultural and historical sites (Maree, 2016). According to Maree (2016), positivists argue that the scientific method produces precise, verifiable, systematic and theoretical answers to the research question. They also suggest that the use of scientific method provides answers that are neutral and technical and can thus be universalized and generalized to all historical and cultural contexts. Contrary to this, qualitative researchers argue that precise, systematic and theoretical answers to complex human problems are not possible. They assert that every cultural and historical situation is different and unique, and requires analyses of that which is uniquely defined, in particular contexts in which it is embedded. Because of the specific social, political, economic and cultural experiences underpinning each study, the findings cannot be generalized; they do however bring us greater clarity on how people make meaning of phenomena in a specific context, thus aiding greater understanding of the human condition. According to Lincoln & Guba et al (as quoted in Maree, 2016), in qualitative research, the concepts credibility, dependability and transferability have been used to describe various aspects of trustworthiness.

Although philosophical ideas remain largely hidden in research (Slife &Williams, 1995), they still influence the practice of research and need to be identified. The term worldview is ‘‘a basic set of beliefs that guide action’’ (Guba, 1970). Others have called them paradigms (Lincoln & Guba, 2000; Mertens, 1998); epistemologies and ontologies (Croty, 1998), or broadly conceived research methodologies (Neuman, 2000). According to Creswell (2014), worldview is a general orientation about the world and the nature of research that a researcher holds. These worldviews are shaped by the discipline area of the student, the beliefs of advisers and faculty in a student's area and past research experiences. The types of beliefs held by individual researchers will often lead to embracing a qualitative, quantitative or mixed methods approach in their research.

This study was guided by the post positivist worldview. According to Creswell (2014), the postpositivist assumptions have represented the traditional form of research, and these assumptions hold true more for quantitative research than qualitative research. This worldview is sometimes called scientific method or doing science research. It is also called positivist/postpositivist research, empirical science and postpositivism. This last term is called postpositivism because it represents the thinking after positivism , challenging the traditional notion of the absolute truth of knowledge (Philips & Burbules ,2000) and recognizing that we cannot be ‘‘positive’’ about our claims of knowledge when studying the behavior and actions of humans. The postpositivist tradition comes from 19th century writers, such as Comte, Mill, Durkheim, Newton and Locke (Smith, 1983), and it has been most recently articulated by writers such as Philips and Burbules (2000).

Postpositivists hold a deterministic philosophy in which causes probably determine effects or outcomes. Thus, the problems studied by postpositivists reflect the need to identify and assess the causes that influence outcomes, such found in experiments. It is also reductionistic in that the intent is to reduce the ideas into small, discrete set of ideas to test, such as the variables that comprise hypotheses and research questions. The knowledge that develops through a postpositivist lens is based on careful observation and measurement of the objective reality that exists ‘‘out there ’’ in the world. Thus, developing numeric measures of observations and studying the behavior of individuals becomes paramount for a postpositivist .Finally, there are laws or theories that govern the world, and these need to be tested or verified and refined so that we can understand the world. Thus, in the scientific world, the accepted approach to research by postpositivists, an individual begins with a theory, and then makes necessary revisions before additional tests are made (Creswell, 2014).

The objectivist epistemology was used in this study. Objectivist epistemology holds that meaning and therefore meaningful reality exists as such apart from the operation of any consciousness (Crotty, 1998). In this study, the use of Grapes and GeoGebra was used to teach the area of Geometry which has been perceived to be abstract and challenging to most candidates as has been seen in KCSE reports. Objectivists' research is normally associated with quantitative methods of research which was used in this study. The ontological underpinning of this study is realism. Realism is an ontological notion asserting that realities exist outside the mind and is often taken to imply objectivism which is an epistemological notion asserting that meaning exists in objects independently of any consciousness(Crotty, 1998).

3.3 Research Design

This study adopted Experimental research design. In an experiment, researcher may identify a sample and generalize to a population; however, the basic intent of an experimental design is to test the impact of a treatment (or an intervention) on an outcome, controlling for all other factors that might influence that outcome. As one form of control, researchers randomly assign individuals to groups. When one group receives a treatment and the other group does not, the experimenter can isolate whether it is the treatment and not other factors that influence the outcome (Creswell, 2011). The experimental method is a research plan conducted to determine the influence or impacts of a manipulation (Zulnaidi & Zamri, 2017). In this research , the effects of GeoGebra and Grapes were used to determine the achievement of students in mathematics on the area of Geometry.

Experimental designs have been developed to answer a specific kind of research question, namely the cause and effect question: Does a specific treatment have any effect on some dependent measure (dependent variable)? (Maree, 2016). The following three characteristics distinguish an experimental design from other designs:

- Manipulation takes place –some of the participants receive some kind of treatment.
- There is some control –some participants participate as a control group by not receiving the treatment .The rationale behind this strategy is that it is not known if the treatment has a beneficial, a harmful or no effect on the participants (West & Spring, 2012).
- Randomization is used to assign the participants to different groups.

In the Solomon four group experimental designs, it can be determined whether the pre-test and / or the intervention have an effect on the outcomes of the study. The comparison of post-test measures of groups 1 and 2 is the critical analysis to see whether there is a treatment effect. The comparison of post-test measures of groups 1 and 3 serves as a basis to see whether the pre-test in group 1 has any effect on top of the treatments. Group 4 provides some more controls –its post-test outcomes should be similar to group 2 but different from groups 1 and 3(Maree, 2016).

According to Creswell (2014), experimental research seeks to determine if a specific treatment influences an outcome. This impact is assessed by providing a specific treatment to one group and withholding it from another and then determining how both groups scored on an outcome. Experiments include true experiments, with the random assignment of subjects to treatment conditions, and quasi-experiments that use nonrandomized designs (Keppel, 1991).

A classic example of an experimental of an experimental design and the one that is probably most commonly used is the **pretest-posttest** design with a control group. In this design all the participants, in other words both the experimental and the control groups, are first being measured (assessed) on the dependent variable (pretest). Thereafter, the experimental group receives the ‘‘new’’ treatment or intervention (the impact of which the researcher is trying to determine), while the control group either receives no treatment or an alternative form of treatment (Maree, 2016).

According to Ravilochanan (2009), the experimental research studies are mainly focused on finding out the cause and effect relationship of the phenomenon under study .An experiment is a test or trial or an act of operation for the purpose of discovering something unknown or of testing a principle, supposition, etc. It is a process in which one or more variables are manipulated under conditions that permit the collection of data that show the effects of any such variables in a unconfused fashion.

Solomon Four-Group Design is a special case of 2×2 factorial design, this procedure involves the random assignment of participants to four groups .Pre-tests and treatments are varied for the four groups. All groups receive a post-test.

Table 3. 1: Solomon Four-Group Design

Group	Pre-test	Treatment	Post-test
1. Pre-tested Experimental Group = E (R)	O_1	X	O_2
2. Pre-tested Control Group = C (R)	O_3		O_4
3. Unpre-tested Experimental Group = UE (R)		X	O_5
4. Unpre-tested Control Group = UC (R)			O_6

Source: Adapted from Maree (2016).

NB:

- X represents an exposure of a group to an experimental variable or event, the effects of which are to be measured.
- O represents an observation or measurement recorded on an instrument.
- X's and O's in a given row are applied to the same specific persons.
- The left- to -right dimension indicates the temporal order of procedures in the experiment.
- The symbol R indicates random assignment.

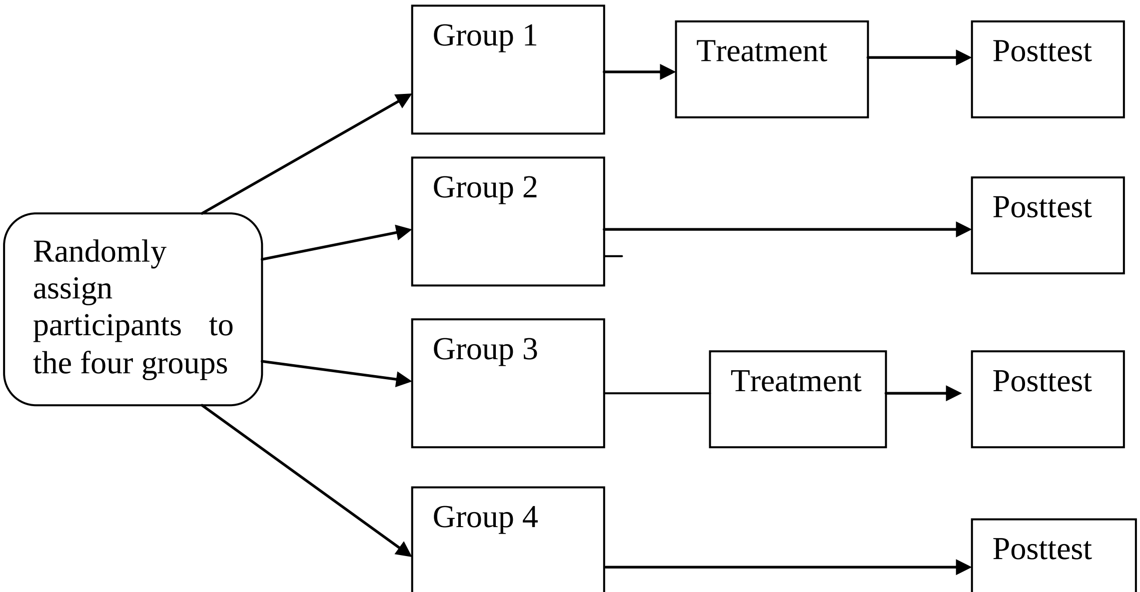


Figure 3.1: Solomon's four-group design

In the absence of randomization, the possibility always exists that some critical difference, not reflected in the pretest, is operating to contaminate the posttest data. For example, if the experimental group consists of volunteers, they may be more highly motivated, or if they happen to have a different experience background that affects how they interact with the experimental treatment - such factors rather than X by itself, may account for the differences. The advantage of randomization is that any differences that appear in the posttest should be the result of the experimental variable rather than possible difference between the two groups to start with. This is the classical type of experimental design and has good internal validity. The external validity or generalizability of the study is limited by the possible effect of pre-testing. The Solomon Four-Group Design accounts for this. This design overcomes the external validity weakness in the design caused when pre-testing affect the subjects in such a way that they become sensitized to the experimental variable and they respond differently than the unpre-tested subjects.

Both the experimental and the control groups are first being measured on the dependent variable (pretest). Thereafter the experimental group receives the new treatment or the intervention (the impact of which the researcher is trying to determine) , while the control group receive an alternative form of treatment . Both groups are subsequently measured on the dependent variable again (posttest). The answer to the question whether the new treatment had an effect is obtained when comparing the two groups on the posttest results. Randomization ensures that the two groups are equivalent on statistical grounds, while the pretest may be used as a check to see whether the experimental and the control groups are actually equivalent on the dependent variable. The control and the experimental group received the instructions covering the same concepts of the graph work. The only differences between the two groups were the manner in which the information was presented to the learners.

Solomon Four Group experimental design was described by Solomon in 1949. Since it is a four-group design, only four groups are included and only one experimental treatment is used , the effects of which are determined by comparison of the posttest scores of the experimental and control groups. Since there is only one experimental treatment, no subscript appears on X. Groups 1 and 3 are experimental groups , Groups 2 and 4 are control groups (indicated by the absence of X) (Wiersma, 2000).

The advantage of Solomon four-group design is that it enables the researcher to check on possible effects of pretesting, since some groups are pretested and others are not. It is possible that pretesting affects the posttest score or that pretesting interacts with the experimental treatment. That is, the effect of the experimental treatment is not the same in pretested and non-pretested groups. Since pretesting is not the rule in actual classroom, this is often an important consideration for validity (Wiersma, 2000).

According to James (1996), at least 15 subjects in each group in an experiment are sufficient in a sample. Also according to Gay (1992), the minimum number of subjects believed to be acceptable for a study depends upon the type of research involved. For descriptive research, a sample of 10% of the population is considered minimum .For smaller populations, 20% may be required. For correlational studies, at least 30 subjects are needed to establish the existence or nonexistence of a relationship. For causal-comparative studies and many experimental studies, a minimum of 30 subjects per group is generally recommended. Experimental studies with tight experimental controls may be valid with as few as 15 subjects per group. Some authorities believe that 30 subjects per group is generally recommended.

To ensure that all the students from the selected schools benefit from the experimental treatment, the switching replication design was applied. When the circumstances are right for this design, it addresses one of the major problems in experimental designs: the need to deny the program to some participants through random assignment (James, 1996). In the repetition of the treatment, the two groups switch roles; the original control group becomes the treatment group in phase two, whereas the original treatment acts as a control. By the end of the study, all the participants have received the treatment. The switching replication design ensures that everyone will eventually benefit from the program. In experimental studies, investigators need to collect data so that all participants, not only an experimental group, benefit from the treatments. This may require providing some treatment to all groups or staging the treatment so that ultimately all groups receive the beneficial treatment (Creswell, 2014).

According to Creswell (2014), there are several threats to validity that will raise questions about an experimenter's ability to conclude that the intervention affects the outcome and not some other factor. Experimental researchers need to identify potential threats to the internal validity of their experiments and design them so that these threats will not likely arise or are minimized. There are two types of threats to validity: internal threats and external threats. Internal validity threats are experimental procedures, treatments, or experiences of the participants that threaten the researcher's ability to draw correct inferences from the data about the population in an experiment.

There are those involving participants (i.e. history , maturation , regression , selection , and mortality) ,those related to use of an experimental treatment that the researcher manipulates (i.e. diffusion , compensatory and resentful demoralization , and compensatory rivalry) , and those involving procedures used in the experiment (i.e. testing and instruments).

Potential threats to external validity also must be identified and designs created to minimize these threats. External validity threats arise when experimenters draw incorrect inferences from the sample data to other persons, other settings, and past or future situations (Creswell, 2011). These threats arise because of the characteristics of individuals selected for the sample, the uniqueness of the setting, and the timing of the experiment. For example, threats to external validity arise when the researcher generalizes beyond the groups in the experiment to other racial or social groups not under study, to settings not studied, or to past or future situations. Other threats are the threats to statistical conclusion validity that arise when experimenters draw inaccurate inferences from the data because of inadequate statistical power or the violation of statistical assumptions.

According to Mugenda & Mugenda (2003) Solomon four- group design is used to achieve three purposes:

i) To assess the effect of treatment

ii) To assess the effect of a pretest

iii) To assess the interaction between pre-test and treatment conditions.

In the above designs, two factors are varied-pretest and treatment.

(1) To investigate if the pretest had effect, compare groups 1 and 3 or group 2 and 4.

(2) If the pretest had an effect on the experimental group, this should result in pretest treatment interaction. To investigate this, the difference in the results of the post-test between groups 1 and 3 should be more than the difference between groups 2 and 4. This is because the pretest has an effect on the experimental group and not the control group.

The pretest results were carried out and the results showed that there was not any significant difference between the experimental group and the control group at the beginning of the experimental research. The experimental group was subjected to the lessons arranged with Grapes and GeoGebra software in computer assisted teaching method while the control group was subjected to the lessons using the traditional approach. A computer assisted material was developed by the researcher for the experimental group.

Grapes and GeoGebra software was introduced before carrying out activities on graph work using the two software. A two weeks course which contains Grapes and GeoGebra activities was planned for the experimental groups. The control groups were taught the same content using the traditional approach. The Grapes and GeoGebra prepared activities aimed to make the teaching of graph work more dynamic, concrete and visual. In all the mathematics sessions, the Grapes and GeoGebra prepared activities were shared with the students both with visual and dynamic features. The exercises on graph work from students' mathematics textbooks were also done using dynamic software to supplement what was given by the researcher. The achievements of the experimental and the control groups were then compared after the intervention.

3.4 Target Population

The study was conducted in Bomet County. Form IV Secondary school students formed the target population. They were chosen for the study because there are many topics in Form IV that requires a lot of graphical work. Therefore the use of Grapes and GeoGebra software was handy in teaching graphical work.

The rationale for the selection of Bomet County will be guided by the fact that the performance in mathematics at KCSE level is not very impressive. It therefore forms the basis for a fertile ground for research on how the performance in mathematics can be improved.

3.5 Sampling technique and sample size.

Stratified random sampling was used to select the respondents. In this method, the population is divided into different strata (Segments). The items in each segment are homogeneous. Bomet County has got 5 sub counties namely Bomet East, Bomet Central, Chebalungu, Sotik and Konoin. Only four sub counties were picked at random. Schools in each sub county are stratified as per the performance in national examinations and gender. A school is picked at random from the homogenous strata. A total of 120 subjects randomly selected from four schools which are homogeneous were included in the research. The 120 subjects are assigned randomly to the four groups. Each group will comprise of 30 subjects. This design in its four-group form includes two control and two experimental groups, but the experimental groups receive the same experimental treatment. Only one of each of the two types is pretested and all four groups are posttested at the conclusion of the experimental period. The assignment of subjects to all groups is random. Two of the groups receive the treatment and two do not .Furthermore, two of the groups receive a pretest and two do not. Within each treatment condition, one group is pretested and the other is not. By explicitly including testing as a factor in the design, it is possible to assess experimentally whether testing threat is operating. According to Creswell (2011), there is need to control the variables that might influence the outcome in the experimental design. Procedures to place control into experiments involve using covariates (e.g. pre-test scores) as moderating variables and controlling for their effects statistically, selecting homogeneous samples, or blocking the participants into subgroups or categories and analyzing the impact of each subgroup on the outcome (Creswell, 2008).

According to Maree (2016), minimum of 15 respondents per group are required when comparing groups. Thirty respondents per group were used in this study.

3.6 Research Instruments

Quantitative data collection techniques were used in the study. The main data collection instruments will include the following:

(a) Students' pre-test mathematics questions

(b) Students' post-test mathematics questions

(c) Students' attitude questionnaire on the use of Grapes and GeoGebra softwares

3.7 Research Variables

The independent variables were the traditional methods of teaching mathematics and the teaching of mathematics using Grapes and Geogebra. The dependent variables were the outcomes on the post test scores.

3.8 Validity and Reliability of the Research Instruments

3.8.1 Validity

According to Maree (2016), the validity of an instrument refers to the extent to which it measures what it is suppose to measure.

Validity refers to the "correctness, soundness of results or conclusion reached in a study" (Kothari, 2008:73; Pelto & Pelto 1978:33. cited in Scrimshaw, 1990: 88). The extent to which the results of a research study can be interpreted accurately and with confidence defines internal validity. The extent to which research results are generalizable to population and/or conditions defines external validity (Wiersma, 2000). In other words, research instruments are valid if they measure what they purport to measure, that is, fulfilling the function for which they are being used.

In this study, validity was considered in four types: face validity, content validity, criterion or predictive validity and construct validity. Face validity refers to the extent to which an instrument ‘‘looks’’ valid. In other words, does the instrument appear to measure what it is supposed to measure? This type of validity cannot be quantified or tested, but any instrument should be scrutinized by experts in the field to ensure a high degree of face validity (Maree, 2016). According to Maree (2016), content validity refers to the extent to which the instrument covers the complete content of the particular construct that it is set out to measure. Content validity is the extent to which the sample items on the instrument provides adequate coverage in the topic under study. To ensure the content validity of an instrument, the researcher usually presents a provisional version to experts in the field for their comments before finalizing the instrument (Maree, 2016).This was done to ensure that the worksheet covered all the relevant areas on Geometry and graphical work.

According to Maree (2016), criterion validity is probably the ultimate test as to whether an instrument measures what it is supposed to measure. To be able to measure the degree of criterion validity of an instrument, scores on an existing instrument (the criterion) which is known to measure the same construct should be available for the sample of respondents. The correlation between the instrument and criterion is an indication of the criterion validity of the instrument. A high correlation indicates a high degree of validity and a low correlation indicates a low degree of validity. Criterion validity also refers to the extent to which the scores on a measuring instrument are related to an independent external variables believed to measure directly the behavior or characteristics in question. The instrument must be relevant, reliable and free from bias for it to be criterion valid.

The content related validity of the instruments was determined by giving the questionnaire to my supervisors, colleagues in class and other experts to carefully and critically examine and assess the relevance of the items to the objectives of the study. In the process of data collection, triangulation of information from different research methods, techniques and sources was done. In this research study, the research procedures ensured that the various data collection methods were used correctly.

According to Maree (2016), construct validity is needed for standardization and has to do with how well the construct(s) covered by the instrument is/are measured by different groups of related items. Construct validity of an instrument should first be examined and shown to be present before it can be said to be standardized instrument. Statistical techniques which can be used are factor analysis and item analysis. Item and factor analysis are two statistical techniques that are commonly used in the process of standardizing an instrument. Factor analysis is used to examine the construct validity of the instrument while item analysis is used to look individually at the items to identify ‘‘bad’’ items that need to be removed or replaced (Maree,2016).

3.8.2 Reliability

When we speak of reliability of an instrument we mean that if the same instrument is used at different times or administered to different respondents from the same population, the findings should be the same. In other words, reliability is the extent to which a measuring instrument is repeatable and consistent (Maree, 2016). It is easy to understand why an instrument should be reliable-what would be the use of an instrument if it gives one score today and a different one tomorrow?

Reliability refers to the degree of consistency or whether it can be relied upon to produce the same results when they are used by someone else (Scrimshaw, 1990:89). Reliability is the extent to which a test or procedure produces similar results under constant conditions on all occasions (Yin, 1994). The goal of reliability is to minimize the errors and biases in a study. The objective is to ensure that, if a later investigator followed exactly the same procedures, the same findings and conclusions would result. The basic difference between reliability and internal validity is that reliability deals with the data collection process to ensure consistency of results, while internal validity focuses more on the way such results support conclusions (Then, 1996).

According to Maree(2016), there are a number of different types of reliability. They are

- Test –retest reliability
- Equivalent form reliability
- Split-half or split-halves reliability
- Internal reliability

Test-retest reliability

This type of reliability of an instrument is determined by administering the instrument to the same respondents on two or more occasions. The first set of scores is then compared with the second set by calculating a correlation coefficient. Such a coefficient will take on a value close to zero if the instrument has low reliability, and close to one if it has a high reliability. One problem with this method is the ‘‘memory effect’’-if the time lapse between the two occasions is too short, the respondents may remember their responses on the first occasion and then simply respond in the same way. This will then result in an artificially high reliability.

Equivalent form reliability

A measure of this type of reliability is obtained by administering the instrument and then, on a second occasion, administering an equivalent instrument – measuring the same construct to the same respondents. Comparing the two sets of scores by means of a correlation coefficient gives the degree of this type of reliability of the instrument. Since a different instrument is used on the second occasion, the possibility of the memory effect problem is eliminated.

Split-half or split-halves reliability

To obtain a measure of this type of reliability, the items that make up the instrument are divided into two, forming two separate instruments. To divide the items, three methods are commonly used:

- The even-numbered items form one instrument and the odd-numbered items the other.
- The items are randomly assigned to the two instruments.
- The first half of the items form one instrument and the second half the other.

The scores on these two separate ‘‘half instruments’’ are then compared by means of a correlation coefficient.

Internal reliability

This type of reliability is also called internal consistency. When a number of items are formulated to measure a certain construct, there should be a high degree of similarity among them since they are supposed to measure one common construct. A measure of this degree of similarity is an indication of the internal consistency (or reliability) of the instrument.

The coefficient that is used to measure the internal reliability of an instrument is called Cronbach's alpha coefficient and is based on the inter-item correlations. If the items are strongly correlated with each other, their internal consistency is high and the alpha coefficient will be close to one. If on the other hand, the items are poorly formulated and do not correlate strongly, the alpha coefficient will be close to zero.

Guidelines for the interpretation of Cronbach's alpha coefficient have been suggested and the following seem generally accepted by researchers:

- 0.90-high reliability
- 0.80-moderate reliability
- 0.70-low reliability

Depending on what an instrument has to be used for, different degrees of internal reliability are required. Reliability estimates of 0.80 are regarded as acceptable in most applications while lower than 0.60 are regarded as unacceptable.

3.9 Piloting of the research instruments

The questionnaires were pilot tested in selected two schools in Kericho County. Following the pre-test, the questionnaires were adjusted to improve clarity and relevance for some questions as well as the flow and sequencing of questions. The main purpose of the pilot was to determine the students' difficulties in understanding the tasks used in the worksheets so as to make the necessary corrections for the main study.

The pilot studies that were carried out examined the instruments for clarity and ambiguity of items, appropriateness of procedures of instrument administration, validity and reliability. The consistency of the instruments in measuring what they intend to measure were established by using the test-retest reliability coefficient, where the two sets of data obtained from the same group of respondents at different times during the piloting of the questionnaires were correlated using Pearson product moment correlation. The correlation coefficients between the scores of the responses from the questionnaire administered on the two different occasions were used to calculate the reliability coefficient using the Pearson product moment correlation coefficient formula. The reliability coefficient for two sets of the students' questionnaire was 0.70 and 0.72 respectively. According to Kerlinger (1973) and Koul (1984), a positive correlation coefficient, r of 0.5 and above is a strong one and hence the research instruments were deemed reliable.

3.10 Data collection procedures

The data for this study was collected in two phases. The first phase involved a reconnaissance visit to the study area to familiarize with the research area and obtaining relevant information for refining the research study. The researcher interacted with the potential respondents and sought for some information related with the area of study. The research problem was clarified further and focus was made on critical themes to be addressed by questionnaires. Survey questionnaires were developed and pre-tested.

The second phase involved establishing rapport with relevant authorities, obtaining research clearance and selecting the respondents. The experimental groups and the control groups were selected from the target population.

3.11 Data Analysis

Quantitative data analysis techniques were used. Quantitative data was used to put figures on what existed and what was representative and provide a context for the cases. Quantitative data was processed by editing, coding and analyzed using the SPSS. For descriptive statistics, percentages, frequencies and means were used to explain proportions. Inferential statistics such as Anova, t-test and regression analysis were used to understand relationships between different variables.

The interpretation of the data was guided by the theoretical framework which guides the critical understanding and analysis of the responses from the respondents in order to make inferences and draw conclusions.

3.12 Ethical Consideration Issues.

What is being studied, purpose of the study, who are involved in the study, the methods to be taken in the collection and analysis of data and the usefulness of the findings to the school were all to be communicated to the respondents. The ethical issues were highly emphasized in order to protect the rights, privacy and confidentiality of the respondents.

The respondents' consent to participate in the research was voluntary, free from any coercion or promises of benefits likely to result from participation. The respondents were assured of confidentiality and anonymity in all phases of the research.

The researcher respected the privacy of respondents and ensured that the information collected was only used for the purpose of research. Only numbers were used instead of the real names of the respondents involved in order to protect the individual's identity.

It is ethically unacceptable to deny one group of the participants treatment altogether. The control group should receive some kind of treatment. In this research, the experimental groups were taught using Grapes and GeoGebra whereas the control groups were taught using the traditional teaching skills in Mathematics. To ensure that all the students from the selected schools benefit from the experimental treatment, the switching replication design was applied. When the circumstances are right for this design, it addresses one of the major problems in experimental designs: the need to deny the program to some participants through random assignment (James, 1996). In the repetition of the treatment, the two groups switch roles; the original control group becomes the treatment group in phase two, whereas the original treatment acts as a control. The results of the phase two of the switching replication were not collected but the process was done to ensure that by the end of the study, all the participants had received the treatment. The switching replication design ensures that everyone will eventually benefit from the program. In experimental studies, investigators need to collect data so that all participants, not only an experimental group, benefit from the treatments. This may require providing some treatment to all groups or staging the treatment so that ultimately all groups receive the beneficial treatment (Creswell, 2014).

Before undertaking the research, the researcher got a letter of introduction from the School of Education which was then be used to seek for the research permit from the National Council for Science and Technology (NCST).

3.13 Summary of the chapter

In this chapter, the research design and methodology, the target population, sampling and sampling techniques, data collection instruments, validity and reliability of the research instruments, data collection procedures, data analysis and ethical considerations were presented. In the next chapters, data will be presented, interpreted, discussed and conclusions and recommendations made.

CHAPTER FOUR: DATA ANALYSIS, PRESENTATION AND DISCUSSION OF RESULTS

4.1 Introduction

Data analysis refers to examining what has been collected in a survey or experiment and making deductions and inferences. It involves uncovering underlying structures; extracting important variables, detecting any anomalies and testing any underlying assumptions. It involves scrutinizing the acquired information and making inference (Kombo and Tromp, 2006).

The main purpose of this study was to investigate the role which Geogebra and Grapes can play in the teaching and learning of Mathematics in Kenyan secondary schools. Data collected was analyzed to get the overall picture on the use of Grapes and GeoGebra in the teaching and learning of mathematics. Specifically data was analyzed to determine:

(1) The effectiveness of using Grapes and Geogebra on students' learning of graphs as compared to the traditional approach.

(2) Whether the use of Geogebra and Grapes can improve the performance in mathematics for both boys and girls.

(3) Whether the teaching method influence the performance of students in mathematics.

(4) Students' perceptions on the use of Grapes and Geogebra in the teaching and learning of graphical work.

As stated in chapter three, the main research instruments were students' pre-test mathematics questions, students' post-test mathematics questions and students' attitude questionnaire on the use of Grapes and GeoGebra software. Four research hypotheses were tested. The independent variables were the traditional methods of teaching mathematics and the teaching of mathematics using Grapes and Geogebra. The dependent variables were the outcomes on the post test scores. Both descriptive and inferential statistics were used to analyze the data. For descriptive statistics, frequencies, means and standard deviation were used while for the inferential statistics, the analysis of variance (ANOVA) ,t-test and regression analysis were used to test the hypotheses at alpha, ά= 0.05 level of significance and appropriate degrees of freedom.

4.2 The effectiveness of using Grapes and GeoGebra on students' learning of graphs as compared to the traditional approach.

Before the introduction of the two different teaching methods, two groups of students were pretested. This was done to find out if the experimental and the control group had the same academic ability before the start of the experimental period. Thereafter all the four groups were subjected to two different teaching methods. Upon the completion of the instructional course, all the four groups of students took the same posttest. The control and experimental group received instruction covering the same concepts of graph work. The only differences between the groups were the manner in which the information was presented or explored. The experimental groups were taught graph work using Grapes and GeoGebra whereas the control groups were taught using the traditional method of pencil and paper or the board.

Table 4. 1: Results of the independent t-test on the pre-tests of experimental and control groups

Group	N	Mean	SD	t-value	Sig(2-tailed)
Experimental Group	30	49.43	5.969	0.292	0.771
Control Group	30	48.97	6.387		

Both the experimental and the control groups were first measured on the dependent variable (pretest). Pretesting was done to ensure the two groups are of the same academic ability before being subjected to the two different teaching methods, namely the use of Grapes and GeoGebra and the traditional teaching method.

From the table 4.1 above, it can be seen that the pre-test scores for the experimental group is 49.43 whereas that of the control group is 48.97. The mean for the pre-test scores for the experimental group are slightly higher than that of the control group. The mean score difference between the two groups was 0.46.

To determine whether any significant differences existed between the mean of the pre-test scores of both the control and the experimental groups, an independent sample t-test was done. The p-value was 0.771>0.05 indicating that the difference in the mean scores of the two groups was not significant. This implies that the two groups were homogenous. This result illustrated that both the students in the control and the experimental group were similar in their academic abilities before the treatment was administered. Before the introduction of the two teaching methods, the level of achievements among the students did not significantly differ between the experimental and the control group.

The two groups of the students had the same academic ability before they were introduced to the two different teaching methods. One group was the experimental and was taught using Grapes and GeoGebra whereas the control group was taught using the traditional method.

Table 4. 2: Results of the independent samples t-test on the pre-tested post-tested experimental group

Group	N	Mean	SD	t-value	Sig(2-tailed)
Pre- tested experimental Group	30	49.43	5.969	-15.836	0.000
Post- tested experimental Group	30	80.40	8.892		

At the end of the research period, the students who studied under the experimental group had significantly improved on their mathematical achievement to the point where this achievement revealed a significant difference in achievements between the experimental and the control group.

From the table above, it is seen that there is statistically meaningful difference between the students' success points of the experimental group on pre-experimental process and the score on post-experimental process ($t=-15.836$, p- value$=0.000<0.05$). The origin of the difference is seen that students were successful on post-experimental processes (mean =80.40), than the pre-experimental processes (mean=49.43). This finding can be interpreted that the lessons in which Geogebra and Grapes softwares were used had a meaningful effect on students' learning of the experimental group. There is therefore a significant difference between pre-tested experimental group and post-tested experimental group.

Table 4.3: Results of the independent sample t-test on pre-test and post-test of control group

Group	N	Mean	SD	t-value	Sig(2-tailed)
Pre-test Group	30	48.97	6.387	-4.719	0.000
Post-test Group	30	56.57	6.084		

From the table above, it can be seen that the mean for the pre-test group was 48.97 whereas the mean for the post-test group was 56.57. This implies that the traditional method resulted in improved scores. On further analysis using independent t-test it was found out that there is statistically meaningful difference between the pre-test scores and the post-test scores of the control group (t=-4.717 ,p-value =0.000<0.05). This finding can be interpreted that the lessons which were studied in traditional approach had a meaningful effect on students' learning of the content on graph work.

Table 4.4: Results of the independent t-test on the post-test of pretested experimental and control groups

Group	N	Mean	SD	t-value	Sig(2-tailed)
Experimental Group	30	80.40	8.892	12.116	0.000
Control Group	30	56.57	6.084		

From the above table ,the results of the independent t-test of the two groups showed that there was a significant difference between the mean performance score of the control group (mean =56.57 ,sd=6.084) compared to the experimental group (mean =80.40 ,p-value =0.000<0.05). The difference between the mean of the two post-test scores is 23.83 points. This finding indicated that students who had learned graphical work using Grapes and GeoGebra were significantly better in their achievement compared to those who underwent the traditional approach. This indicated that there was a significant improvement in the scores of the experimental group as compared to the control group. From these results, it can be seen that students gained from both approaches but the students in the experimental group appear to have a higher mean score compared to the control group.

Table 4.5: Results of the independent sample t-test of the post-tested only experimental and control groups

Group	N	Mean	SD	t-value	Sig(2-tailed)
Experimental Group	30	72.80	6.338	11.57	0.000
Control Group	30	55.23	5.380		

From the table above, it can be seen that the mean for the post-test only experimental group was 72.80 whereas that of post-test only control group was 55.23. The students in the experimental group performed much better than the control group on post- test scores. On further analysis using independent sample t-test, the p-value =0.000<0.05. This means there is a significant difference between post-tested experimental group scores and post-tested control group scores. In this case there was no pre-test carried out and therefore pre-testing is not a factor in this case. The difference in scores cannot be attributed to pre-testing but is only due to the teaching method employed. The findings showed that teaching using Grapes and GeoGebra is more effective than using the traditional method of teaching.

Table 4.6: Test scores for the different teaching methods

Teaching Method	Mean	N	Std. Deviation
Traditional Method	55.90	60	5.51449
Teaching Using Grapes and GeoGebra	76.60	60	8.49853

From the table 4.6 above, it can be seen when the traditional method was used, the mean was 55.90. This seems to suggest that the teaching method used had an effect on the post test scores. There was a marked improvement on the scores of the students when the topic on graph work was taught using the conventional method. When the students were taught using grapes and GeoGebra, the mean of the post test scores was 76.60. This showed that the use of GeoGebra and Grapes was more superior as compared to the use of the traditional method because it resulted on higher scores.

Mathematical achievement among the students corresponded to the teaching method used. Students who studied under the experimental group performed much better than the students who studied under the traditional teaching approach. Improvement in mathematical achievement was distinctly greater among students who studied using Grapes and GeoGebra than the level of mathematical achievement among students who studied under the traditional teaching approach .The use of GeoGebra and Grapes yield better scores as compared to the traditional method. This seems to suggest that the use of Grapes and GeoGebra resulted on better understanding of the concepts of graph work as compared to the use of some concepts which appear to be abstract to the learners. Further analysis was done using the t-test to find out if the difference on the two teaching methods is statistically significant.

The use of Grapes and GeoGebra in the teaching and learning of mathematics ease the learning process by providing visualization that is simple to use and equipped with rich content. Students who were taught using Grapes and GeoGebra tend to comprehend the concepts more than students who learn geometry using the traditional approach.

Table 4.7: Results of the independent samples t-test on the use of Grapes and GeoGebra versus the use of traditional approach

Teaching Method	N	Mean	SD	t-value	Sig(2-tailed)
Traditional method	60	55.90	5.733	-15.56	0.000
Teaching using Grapes and GeoGebra	60	76.60	8.561		

The mean for the control group is 55.90 whereas the mean for the experimental group is 76.60. The mean for the experimental group is higher than that of the control group. On further analysis using t-test the p-value is $0.000<0.05$. This therefore means that there is a significant difference between teaching using the traditional method and teaching using Grapes and GeoGebra. Teaching using Grapes and GeoGebra is more effective than using the traditional method.

Traditional method of teaching force students to learn mathematics by memorization which ends up with a feeling of failure. Traditional methods of teaching make the learners to be unsuccessful in most cases owing to the abstract nature of mathematics. Mathematics requires high level mental processes such as critical thinking, reasoning, imagination and considering many different features with related facts. Along with the constructivist approach, mathematics teaching needs to be addressed with different emphasis which makes the teaching and learning of mathematics more enjoyable, understandable and constructible in terms of students' learning. It is not just enough to use only pencil drawn shapes on paper or board. Use of Grapes and GeoGebra provides meaningful learning experiences for teaching and learning of mathematics.

Use of Grapes and GeoGebra is a powerful tool as compared to traditional / conventional method of teaching mathematics. Teaching mathematics using Grapes and GeoGebra helps in maintaining and arousing students' interest and excitement. The experimental group encouraged more engaging problems and fostered mathematical discussion on a deeper level than the traditional approach that was used. Students taught with Grapes and GeoGebra showed more improvement than those taught with traditional approach. Teaching of mathematics should incorporate more hands on activities. Use of Grapes and GeoGebra guide the learners to a deeper understanding of the mathematics concepts on graph work. The two softwares offer a richer and deeper approach to the mathematical concepts covered in graphical work. They increase the students' interest, confidence and engagement in mathematics.

Learners can easily conceptualize the concepts on geometry when they are taught using Grapes and GeoGebra as compared to when they are taught using the traditional approach. The use of Grapes and GeoGebra improves the academic achievements of the students because of appealing to more senses as compared to the traditional method of using paper and pencil to do graph work. The interactive nature of Grapes and GeoGebra increases the students' attention towards mathematics lessons which in most cases consist of abstract concepts which are predominantly found in mathematics and difficult to visualize when the traditional method is used to teach.

The use of Grapes and GeoGebra in teaching and learning of mathematics assist the learners to develop problem solving and thinking skills. This will enable the learners to construct their own learning in mathematics. It also enables the learners to discover and explore as they use Grapes and GeoGebra in doing exercises on graph work. The two softwares have positive effect on retaining knowledge and help to construct and develop further knowledge in mathematics.

The findings of this study are consistent with the findings of Tamam and Dasari (2021) who found out that student' skills and responses were improved after learning geometry by using GeoGebra. There was a significant improvement of students' mathematical skills after learning using GeoGebra, students developed a positive attitude towards mathematics and improved their mathematical problem solving skills. GeoGebra also guided students to better understand geometry concepts compared to learning without using GeoGebra. The use of GeoGebra software is an innovative way of teaching and learning of mathematics by integrating technology. The findings of this study are also consistent with the findings of Mollakuqe etal (2021) who conducted a research Incorporating GeoGebra into Teaching Circle properties at High

School level and its comparison with the Classical Method of Teaching. The results showed that using GeoGebra in teaching facilitates, accelerates and make geometry more tangible. During the explanation process, there is an increased interest and active participation of the students in the classroom through questions and discussion. The findings showed that when geometry is explained with GeoGebra, the lessons become very concrete.

4.3 The use of Geogebra and Grapes and the performance in mathematics for both boys and girls.

GeoGebra and Grapes softwares were used to determine if there was any significant difference in achievement for both boys and girls. The findings are as shown in the table below:

Table 4.8: Results of post test of the experimental group for males and females.

Group	N	Mean	SD
Males	30	76.40	6.46773
Females	30	73.20	4.85148

From the table above, it can be seen that the mean for males is 76.40 whereas the mean for females is 73.20. The mean for the boys is slightly higher than that of the girls. It seems the performance of boys is slightly higher than that of the girls.

Table 4.9: One way ANOVA for the experimental group as per Gender

Posttest

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	102.400	1	102.400	3.133	.085
Within Groups	1242.000	58	32.684		
Total	1344.400	59			

On further analysis using one way ANOVA it can be seen that the p-value $=0.085>0.05$. This therefore shows that there was no significant difference between the scores of boys and girls in achievement involving graph work after learning using Grapes and GeoGebra. The students in the two genders have similar academic ability scores when they are taught using GeoGebra. The findings showed that the improvement in mathematical achievement among the boys was not significantly greater than the improvement in mathematical achievement among the girls. Use of GeoGebra and Grapes allow boys and girls to learn mathematics at the same level and the result of this is a gain for both genders with no bias. Boys and girls are born with equal mathematical intellectual potential and the slight differences in mathematical achievement could be environmental or cultural. All mathematics teachers should give female students equal opportunities in the classroom so that their confidence in the subject is instilled and nurtured.

The findings of this study are in agreement with the findings of Offoe and Kwamina (2015) who found out that there was no statistically significant difference in the mathematics achievement between male and female students from the experimental group. The result shows that performance assessment tests are not gender biased and also contradict the assertion that boys perfom better in mathematics than girls with particular reference to early high school level in Ghana. This is an important finding in the sense that male students are generally perceived to do better in mathematics than female students. The teaching and learning of mathematics in this study provided an equal platform for both sexes in terms of mathematics learning and achievement.

The findings of this study are contrary to what Klein (2008) found out. In his study, he found out that the improvement in mathematical achievement among the girls was significantly greater than the improvement in mathematical achievement among the boys. The findings of this study seems to be in agreement with the findings of Kaiser and Zhu (2022) who found out that boys performed better than girls in mathematics achievement even though the difference was not statistically significant. The findings of this study also seems to be on contrary to the finding of Ajai and Imoko(2015) who found out that female students outperformed their male counterparts in mathematics achievement even though the difference was not statistically significant.

The findings of this study are also contrary with the findings of Koller, Baumert and Schnabel (2001) who found out that gender differences in mathematics achievement favoured males more than the females. The findings of the research conducted by Mukiri (2016) are in agreement with the findings of this research. She found out that the use of GeoGebra allows boys and girls to learn mathematics at the same level and the result of this is a gain for both genders with no bias. The findings of this research are also consistent with the findings of the research conducted by Chebet (2016) who found out that both boys and girls have equal ability to do mathematics. Teachers should therefore give equal opportunity to both sexes when handling mathematics without gender related bias.

4.4 To find out whether the teaching method influence the performance of students in mathematics.

To determine whether the teaching method is a factor in determining a student score, regression analysis was used and the results are as shown in the tables below.

Table 4. 10: Model Summary of coefficient of determination

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate
1	.865[a]	.749	.742	6.69484

a. Predictors: (Constant), Gender, Teaching Method, Groups of Students

Table 4. 11: ANOVA table for the predictors of regression equation

Model		Sum of Squares	df	Mean Square	F	Sig.
1	Regression	15475.368	3	5158.456	115.090	.000[b]
	Residual	5199.223	116	44.821		
	Total	20674.592	119			

a. Dependent Variable: Test scores

b. Predictors: (Constant), Gender, Teaching Method, Groups of Students

Table 4. 12: Regression Coefficients[a]

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.
		B	Std. Error	Beta		
1	(Constant)	37.473	2.453		15.277	.000
	Groups of Students	-2.080	.404	-.271	-5.152	.000
	Teaching Method	14.860	.807	.924	18.404	.000
	Gender	-.037	1.287	-.001	-.028	.977

a. Dependent Variable: Test scores

The squared multiple correlations are reported frequently as an index of the overall strength of a prediction equation. After fitting a regression equation, the most natural questions to ask are:

(a) "How effective is the regression equation at predicting the criterion?" and

(b) "How precisely has this effectiveness been determined?"

Regression analysis is a statistical technique for measuring relationship between a dependent variable and one or more independent variables. Regression analysis requires a single quantitative dependent variable and one or more independent quantitative variables (Maree,2016) . A mathematical expression is derived that represents the relationship and this can then be used in prediction. It can be used to predict a student's score based on the teaching method. Multiple regression analysis was used to predict a student's score based on gender, teaching method and group of students as in Solomon Four Group Experimental design. The multiple regression equation is as shown below:

$SC=a+b_1G+b_2M+b_3Gs+\mu$, where:

SC=Scores, G=Gender, M=Teaching method, Gs=Group of students, μ=error term and b_1-b_3 are the regression coefficients of the selected independent variables. The regression coefficients b_1,b_2,b_3 tell us about the direction(positive or negative) and the magnitude (the value) of the partial effect of each independent variable on the dependent variable.

A multiple regression equation uses variables that are known to individually predict the criterion to make a more accurate prediction. Since a combination of variables usually results in a more accurate prediction than any one variable, prediction studies often result in a prediction equation referred to a multiple regression equation.

From the tables above the multiple regression equation obtained after the analysis is as follows:

$SC=37.655-2.242Gs+15.832M-0.002G$.

From the table 4.10 above ,R^2 , which is called the coefficient of determination is a summary statistic which tells us how well the prediction line fits the data. R^2=0.749, explains 74.9% of the total variation observed in the dependent variable .The 74.9% of the scores can be explained by the explanatory variables specified in the regression equation. Thus 25.1% of the total variation in the dependent variable (scores) remains unexplained by the regression equation. The balance of variation is attributed to omitted variables and stochastic variables.

The p-value =0.000<0.05 implies that the fitted regression equation is valid to draw inferences .As expected , the teaching method has a direct effect on the score of a student since the coefficient is positive and it is statistically significant at 5% level of significance (p-value=0.000<0.05). Thus the teaching method is a major determinant of the score of the student.

As expected, gender has no influence on the score of a student. It has a negative sign of coefficient. The p-value =0.998>0.05 implies that gender is not statistically significant at 5% level of significance.

4.5 Students' perceptions on the use of Grapes and Geogebra in the teaching and learning of graphical work.

Table 4. 13: Students' attitude towards the use of Grapes and GeoGebra

ITEM No.	STATEMENT	N	Mean
1	I was excited about using GeoGebra and Grapes softwares.	60	4.4667
2	I learnt a lot using Grapes and GeoGebra.	60	4.4167
3	I felt confident using the GeoGebra and Grapes software.	60	3.1667
4	I was very engaged in the learning process with the use of Grapes and GeoGebra.	60	4.5000
5	I benefited a lot through the teacher-learner interaction while using Grapes and GeoGebra.	60	4.4500

6	I was able to visualize and answer the questions after each activity with the use of Grapes and GeoGebra.	60	4.5000
7	I was able to think creatively and critically in the discussion and during the question and answer sessions.	60	4.5167
8	I enjoyed learning mathematics much more using Grapes and GeoGebra softwares.	60	4.5333
9	I was able to form better connections between previous learning and new learning with the use of Grapes and GeoGebra.	60	4.5333
10	The use of Grapes and GeoGebra encourages discovery learning in mathematics.	60	4.4333
11	The use of GeoGebra and Grapes motivated me to develop a positive attitude towards mathematics.	60	4.5000
12	The use of Grapes and GeoGebra enabled me to understand abstract concepts in mathematics.	60	4.6000

Table 4. 14: Attitudes of students by gender on the use of Grapes and GeoGebra in teaching and learning of mathematics.

Item No.	Statement	Gender	N	Mean
1	I was excited about using GeoGebra and Grapes softwares.	Male Female	30 30	4.4333 4.5000
2	I learnt a lot using Grapes and GeoGebra.	Male Female	30 30	4.3667 4.4667
3	I felt confident using the GeoGebra and Grapes software.	Male Female	30 30	3.2667 3.0667
4	I was very engaged in the learning process with the use of Grapes and GeoGebra.	Male Female	30 30	4.6000 4.4000
5	I benefited a lot through the teacher-learner interaction while using Grapes and GeoGebra.	Male Female	30 30	4.5000 4.4000
6	I was able to visualize and answer the questions after each activity with the use of Grapes and GeoGebra.	Male Female	30 30	4.5667 4.4333
7	I was able to think creatively and critically in the discussion and during the question and answer session.	Male Female	30 30	4.6333 4.4000
8	I enjoyed learning mathematics much more using Grapes and GeoGebra softwares.	Male Female	30 30	4.6000 4.4667
9	I was able to form better connections between previous learning and new learning with the use of Grapes and GeoGebra.	Male Female	30 30	4.6333 4.4333
10	The use of Grapes and GeoGebra encourages discovery learning in mathematics.	Male Female	30 30	4.4333 4.4333
11	The use of GeoGebra and Grapes motivated me to develop a positive attitude towards mathematics.	Male Female	30 30	4.5000 4.5000
12	The use of Grapes and GeoGebra enabled me to understand abstract concepts in mathematics.	Male Female	30 30	4.7000 4.5000

From the results in the table above, it can be seen that all the items in the table were rated highly by both the boys and the girls. Both boys and girls generally gave positive feedback towards the use of Grapes and GeoGebra softwares in doing graph work. Since the softwares were new to the students, some of them rated the item on the confidence in using Grapes and GeoGebra at 3.2667 for boys and 3.0667 for girls.

It is hoped that with a lot of practice and exposure to the softwares, the students' confidence will improve a lot. The use of the Grapes and GeoGebra motivated the students to have a positive attitude towards the subject (the rating was 4.500 for both boys and girls). With the use of Grapes and GeoGebra , the students were able to think creatively and critically in the discussion and during the question and answer session(the rating for boys and girls was 4.6333 and 4.4000 respectively).

The findings in the table also show that the use of Grapes and GeoGebra encourages discovery learning in mathematics. This is one of the strategies that is encouraged in the teaching and learning of mathematics. Learners gain a lot when they discover certain things in mathematics on their own. Another thing that students gave was on use of Grapes and GeoGebra in learning some of the abstract concepts in mathematics. The use of the two softwares demystify some of the concepts that have traditionally been taught using the conventionally method. The use of Grapes and GeoGebra makes the learning of some of the difficult and abstract concepts to appear easier and simpler.

Students loved the use of Grapes and GeoGebra because it makes the teaching and learning of mathematics tangible. GeoGebra makes a link between Geometry and Algebra in an entirely new, visual way. Students can finally see, touch and experience mathematics .These findings are consistent with the findings by Ogwel (2009) who found out that the use of GeoGebra is advantageous rather than the use of existing media or other teaching methods in Geometry. The use of Geogebra and Grapes enable learners to develop higher order thinking skills (analysis, synthesis and evaluation). The use of Geogebra and Grapes affords generality of concepts and reveal mathematical structures with speed and efficiency, unlike paper and pencil scenarios. The use of Grapes and GeoGebra has the potential to create and arouse curiosity and interest in the teaching and learning of mathematics. The use of GeoGebra and Grapes is one of the innovative ways of teaching mathematics supported by technology. Many students showed a high interest in learning using Grapes and GeoGebra softwares since they promote their understanding of the taught concepts. The use of Grapes and GeoGebra in teaching and learning also results in teacher-students interaction during the lesson.

According to Pound and Lee (2015), teachers need to use imaginative approaches in order to make learning more interesting and effective. The use of Grapes and GeoGebra arouse the curiosity and interest of the learners. Creative teaching and learning have been associated with innovation, originality, ownership and control. In order to teach creatively, teachers should use all their creative skills to plan and provide imaginative and stimulating activities, experiences and resources. Creative teaching also involves promoting the creativity of children in order to develop their understanding. This may be through encouraging them to question or challenge what has been presented to them, to imagine other possibilities, to make connections with other ideas or areas of learning and to present their ideas in ways that promote critical reflection.

The use of Grapes and GeoGebra has the power to engage the learners fully in the teaching and learning of mathematics. Creative teaching and learning concerns the use of creative arts to symbolize, support and represent mathematical ideas. Teaching mathematics creatively involves gaining an understanding of the creative nature of mathematics. By teaching creatively, teachers can support learners in becoming creative thinkers. The use of Grapes and GeoGebra makes the teaching of mathematics not boring and dry compared to the traditional method. Research into the nature of geniuses (Howe,1999) has famously demonstrated the way in which engagement is key to mastery .This is in line with the use of Grapes and GeoGebra which make the learners to be fully engaged throughout the lesson and are able to master some concepts which seems otherwise abstract when taught using the traditional method . The use of Grapes and GeoGebra in teaching and learning of mathematics will make the learners to become good at mathematics because it makes the subject to be interesting and lively since the learners would want to spend time doing it.

The use of Grapes and GeoGebra help the learners to develop good problem solving skills. Problem solving is at the heart of mathematics and at the heart of human creativity. Problem finding and solving should be built into mathematics from the beginning, as they are what humans do well. The use of ICT in teaching and learning of mathematics assist in bridging the gap between concrete mathematics and the abstract concepts. Abstract nature of mathematics has made teachers of mathematics to look for approaches and strategies that emphasize real and concrete experiences. The use of Grapes and GeoGebra will bridge this gap since learners need every day experiences on which to base their ideas. Making mathematics real involves much more than just focusing on the mathematics we use in our everyday lives. It involves encouraging the use of imagination and a host of opportunities for symbolic representation.

Grapes and GeoGebra make use of a range of opportunities in order to develop mathematical understanding. They support abstract transformation unlike the use of traditional method which makes the teaching of mathematics to be very difficult and boring.

The use of Grapes and GeoGebra in the teaching and learning of mathematics has a wealth of innovative ideas and enrich mathematics teaching.

According to Dale's cone of experience (1969), learning experiences at the bottom of the cone tend to hold student attention longer and involve active student participation. Active learning would include those activities that charge our brains and capacities to remember what we are experiencing. At the bottom are hands on experiences. Experiences at the bottom of the cone are appropriate than those at the top. This is consistent with the use of Grapes and GeoGebra in teaching and learning of mathematics. Grapes and GeoGebra have a way of motivating and arresting the attention of the learners for a longer period of time and also involve active participation of the learners. Learner's curiosity and consciousness get increased. It provides a sound environment for realistic and enjoyable teaching and learning atmosphere. Experiences at the top of the cone are mainly those that involve the traditional method of teaching .Learners are not fully engaged in the learning process but are just considered to be passive recipients of knowledge. Traditional teaching method mainly involves rote learning.

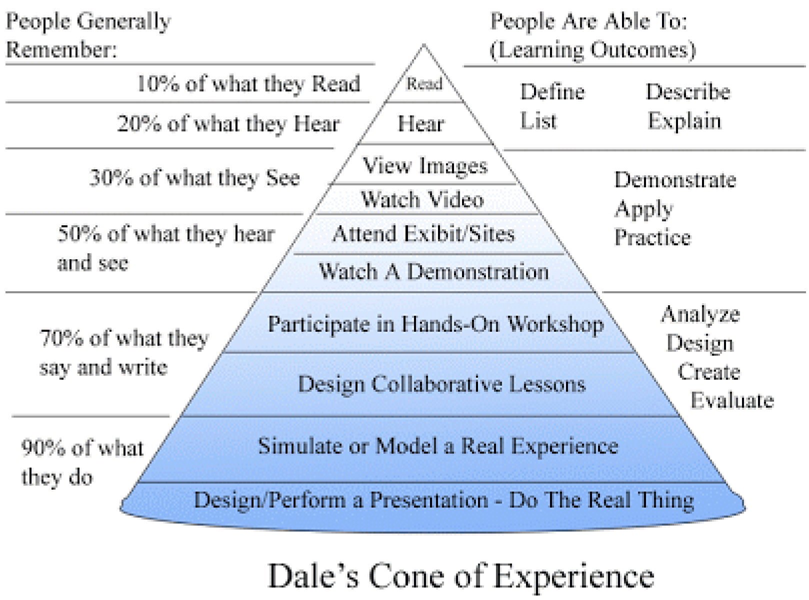


Figure 4. 1: Dale's Cone of Experience

The organizing principle of the Cone was a progression from most concrete experiences (at the bottom of the cone) to most abstract (at the top). The figure above shows what students will be able to do at each level of the Cone (the learning outcomes they will be able to achieve) relative to the type of activity they are doing (reading, hearing, viewing images, etc.). The numerical figures on the left side of the image, what people will generally remember indicate that practical, hands-on experience in a real-life context will allow students to remember best what they do.

Dale's cone of experience encourages involving the learner in the learning process and effective teaching which want the teacher to do the facilitation while the learner expresses themselves in line. This is true with the use of Grapes and GeoGebra in teaching and learning of mathematics .The teacher is just a guide and a facilitator in the learning process.

Dale's cone of Experience provides teaching and learning models that allows teachers to understand how to increase the retention rate of learners by involving the learner.

This means that while the learner participate and get involved in the learning process by expression, they awaken the sensory organs. The more sensory channels possible in interacting with a resource, the better chance that many students can learn from it. The use of Grapes and GeoGebra involve a lot of sensory organs and this assist in the retention of the concepts learnt and that is why students who were taught using Grapes and GeoGebra performed much better than the ones taught using the traditional method.

According to Training Needs Assessment (TNA) carried out by CEMASTEA (CEMASTEA, 2015), the findings showed that the teaching and learning of mathematics and sciences was still teacher centred. This teacher centredness led to lack of interest among learners during the teaching and learning process. Inquiry based learning (IBL) was identified as one way of addressing this concern. According to TNA (CEMASTEA, 2017), there exists a gap between learners' beliefs, misconceptions, cultural practices and the reality. Teachers rarely use learners' experiences and scenarios .Inquiry Based Learning generates excitement in students and triggers curiosity. The students become more inquisitive and are able to answer their own questions. These findings are in agreement with the use of Grapes and GeoGebra which arouse interest and the curiosity of the learners.IBL is mainly student centred and the teacher just play the role of being a facilitator. Inquiry Based Learning method of teaching is widely accepted as a method of teaching that places students' questions, ideas and observations at the centre of the learning experience. According to CEMASTEA (2018), IBL create a culture in the classroom that allows students to engage in inquiry activities. Through IBL, learners are engaged in authentic investigations in which they identify problems, propose solutions, make predictions, design procedures, collect and organize data and draw conclusions. Based on this argument, it seems that raising questions and working towards looking for solutions to the questions are important components of teaching that embrace Inquiry Based Learning. Besides raising questions, other components of IBL includes data collection, data analysis and drawing of conclusions.

The use of Grapes and GeoGebra make the teaching and learning process to be more engaging. When the learners are engaged and interested, meaningful learning will take place. Teachers should be conversant with the use of the new technology if they are to be effective in their teaching. They should emphasize the use of technology, digital media and the integration of 21st century skills.

Teachers should be in a position to produce good teaching materials and very innovative teaching ideas to engage the students fully in the classrooms. In the early 1990’s teachers had the monopoly of knowledge and they were the ones who could come to class to deliver that knowledge so that the students could acquire that knowledge. Today, knowledge is no longer a monopoly of teachers because students can get knowledge from myriad of sources and hence the role of the teachers today is facilitation. They guide the students where they can get the right knowledge and information.

The use of technology in teaching and learning contributes significantly in class instruction. When learners are exposed to the use of the new technology, they are exploring –something that engages the students a lot. The use of Grapes and GeoGebra in teaching engages the learners and thus creates some intrinsic motivation to learn. Teachers are expected to scan the globe for best practices in the teaching and learning of mathematics. Ongoing professional development is one of the key factors to ensure that there is success in the educational sector. Schools can form professional learning groups so that they can share the best practices and critique lessons with colleagues in their own school and with others around the world. By so doing, they will discover new ways of teaching mathematics.

Teachers should find new ways of connecting with the learners so that meaningful learning can take place. Since the teaching and learning process is dynamic, teachers need to be adaptive in their teaching. Teaching cannot be stagnant. They cannot teach the same way they were taught some years ago. They have to be adaptive in their teaching methods and strategies so that the learners are fully engaged for real learning to take place.

4.6 Summary of the chapter

In this chapter, data analysis, presentation and discussion of the results were presented. In the next chapter, summary of findings, conclusions, recommendations and suggestion for further research will be presented.

CHAPTER FIVE: SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

5.1 Introduction

This chapter will revisit the research objectives and hypotheses outlined in chapter one, discuss each one of them and draw conclusion. The main purpose of this study was to investigate the role which Geogebra and Grapes can play in the teaching and learning of Mathematics in Kenyan secondary schools. Data collected was analyzed to get the overall picture on the use of Grapes and GeoGebra in the teaching and learning of mathematics. The main research instruments were students' pre-test mathematics questions, students' post-test mathematics questions and students' attitude questionnaire on the use of Grapes and GeoGebra software. Four research hypotheses were tested. The independent variables were the traditional methods of teaching mathematics and the teaching of mathematics using Grapes and Geogebra. The dependent variables were the outcomes on the post test scores.

5.2 Summary of the main findings

5.2.1 The effectiveness of using Grapes and Geogebra on students' learning of graphs as compared to the traditional approach.

The first objective was: **To determine the effectiveness of using Grapes and Geogebra on students' learning of graphs as compared to the traditional approach.**

The findings indicated that students who had learned graphical work using Grapes and GeoGebra were significantly better in their achievement compared to those who underwent the traditional approach. The findings further indicated that there was a significant improvement in the scores of the experimental group as compared to the control group. From these results, it can be seen that students gained from both approaches but the students in the experimental group appear to have a higher mean score compared to the control group. The students in the experimental group had superior scores compared to their counterparts who were taught using the conventional method. This therefore suggests that teaching using Grapes and GeoGebra is more effective than using the traditional method. Teaching using Grapes and GeoGebra places the student at the centre of the learning process. It attempts to address the individual differences among the learners according to their level of mathematical achievements. According to Kashti etal(1997) and Yishraeli(2008) (as cited in Biashara ,2015) the characteristics of traditional method is frontal, students receive information unilaterally and without using means of concrete and creative illustration , change of class location for group activity or any reciprocal type of activity.

The first objective also involved testing of the hypothesis $HO_{2:}$ **There is no significant difference between the use of Grapes and Geogebra and the traditional approach in teaching graphical work.**

On further analysis ,the results of the independent t-test of the two groups showed that there was a significant difference between the mean performance score of the control group (mean =56.57 ,sd=6.084) compared to the experimental group (mean =80.40 ,p-value =0.000<0.05). The difference between the mean of the two post-test scores is 23.83 points. This finding indicated that students who had learned graphical work using Grapes and GeoGebra were significantly better in their achievement compared to those who underwent the traditional approach. This indicated that there was a significant improvement in the scores of the experimental group as compared to the control group. From these results, it can be seen that students gained from both approaches but the students in the experimental group appear to have a higher mean score compared to the control group. Therefore the null hypothesis was rejected and the conclusion is “there is a significant difference in achievement scores between the uses of Grapes and GeoGebra and the traditional approach in teaching graphical work.”

5.2.2 The use of Geogebra and Grapes and the performance in mathematics for both boys and girls.

The second objective was: **To establish whether the use of Geogebra and Grapes can improve the performance mathematics for both boys and girls.**

The use of Grapes and GeoGebra improved the performance of both boys and girls. However, the finding seems to suggest that the use of GeoGebra and Grapes improve the performance of boys more than that of the girls. The findings of the study show the mean for males is 61.69 whereas the mean for females is 59.44. The mean for the boys seems to be slightly higher than that of the girls. The difference between the two means is 2.25.

The second objective also involved testing of the hypothesis HO_3: **There is no significant difference between the scores of boys and girls when they are taught using Grapes and Geogebra**

On further analysis using the independent sample t-test to find out if there is any significant difference between the scores of boys and girls, the p-value $=0.269>0.05$. The null hypothesis was therefore accepted. This therefore shows that there is no significant difference between the scores of boys and girls. The students in the two genders have similar academic ability scores. The use of Grapes and GeoGebra improve the performance of both boys and girls in a similar way. The findings of this study are contrary to what Klein (2008) found out. In his study, he found out that the improvement in mathematical achievement among the girls was significantly greater than the improvement in mathematical achievement among the boys. Boys and girls are born with equal mathematical intellectual potential and the gaps that exist between the two groups are just environmental or cultural.

5.2.3 The teaching method and the performance of students in mathematics.

The third objective was: **To determine whether the teaching method influence the performance of students in mathematics.**

The findings showed the mean for the control group is 55.90 whereas the mean for the experimental group is 76.60. The mean for the experimental group is higher than that of the control group. This seems to suggest that the teaching method is a determining factor in the achievement of a student's score in teaching graph work. Those who were taught using Grapes and GeoGebra seemed to have performed much better than those who were taught using the conventional method of using paper and pencil.

The third objective also involved the testing of the hypothesis HO_4: **There is no significant difference between the teaching method and the performance of students in mathematics**.

On further analysis using t-test the p-value is $0.000<0.05$. This therefore means that there is a significant difference between teaching using the traditional method and teaching using Grapes and GeoGebra. Teaching using Grapes and GeoGebra is more effective than using the traditional method. The null hypothesis was therefore rejected and the alternative hypothesis is accepted that there is a significant difference between the teaching method and the performance of students in graph work. The students' mathematical achievement level in both the experimental and the control group showed that there are statistically significant differences between the two groups on the post test achievement. The experimental group performed much better than the group that was taught using the traditional / conventional method. The GeoGebra and Grapes mathematical softwares significantly increased students' achievement in mathematics. Uses of Grapes and GeoGebra in teaching assist the learners to develop problem-solving and thinking skills in mathematics. The uses of ICT integration in the teaching of mathematics enable the learners to construct their own learning. It also enable the learners to discover and explore as they use Grapes and GeoGebra in doing graph work. The two softwares have positive effect on retaining knowledge and this helps in construction and development of further knowledge in mathematics.

5.2.4 Students' perceptions on the use of Grapes and GeoGebra in the teaching and learning of graphical work.

The fourth objective was: **To determine students' perceptions on the use of Grapes and Geogebra in the teaching and learning of graphical work**.

The use of the Grapes and GeoGebra motivated the students to have a positive attitude towards the subject (the rating was 4.500 for both boys and girls). With the use of Grapes and GeoGebra, the students were able to think creatively and critically in the discussion and during the question and answer session (the rating for boys and girls was 4.6333 and 4.4000 respectively).

The findings also showed that the use of Grapes and GeoGebra encourages discovery learning in mathematics. This is one of the strategies that is encouraged in the teaching and learning of mathematics. Learners gain a lot when they discover certain things in mathematics on their own. Another thing that students gave was on use of Grapes and GeoGebra in learning some of the abstract concepts in mathematics. The use of the two softwares demystify some of the concepts that have traditionally been taught using the conventionally method. The use of Grapes and GeoGebra makes the learning of some of the difficult and abstract concepts to appear easier and simpler.

Students loved the use of Grapes and GeoGebra because it makes the teaching and learning of mathematics tangible. GeoGebra makes a link between Geometry and Algebra in an entirely new, visual way. Students can finally see, touch and experience mathematics .These findings are consistent with the findings by Ogwel (2009) who found out that the use of GeoGebra is advantageous rather than the use of existing media or other teaching methods in Geometry. The use of Geogebra and Grapes enable learners to develop higher order thinking skills (analysis, synthesis and evaluation. Grapes and GeoGebra assist the learners in achieving the principles of constructivist learning while doing the graphical work. Constructivist teaching is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction rather than passively receiving information. Learners are the makers of meaning and knowledge. Constructivist teaching fosters critical thinking and creates motivated and independent learners. A constructivist teacher and classroom differ from a traditional classroom in a number of ways: the learners are interactive and student-centered; and the teacher facilitates a process of learning in which students are encouraged to be responsible and autonomous.

5.3 Conclusion

The study found out that Grapes and GeoGebra softwares have proven to be very effective tools in enhancing mathematics teaching and learning of graph work as compared to the traditional method of using paper and pencil. Students were able to experience a hands on and minds on method of learning which had a positive effect in enabling them to understand concepts on graph work better rather than just being passive recipients of the teaching and learning process. At the same time Grapes and GeoGebra gave the students and the teacher an opportunity to work together collaboratively in exploring and visualizing new concepts. Grapes and GeoGebra are effective tools in assisting the students to develop discovery learning in mathematics. Grapes and GeoGebra also assist the learners in achieving the principles of constructivist learning while doing the graphical work. Constructivist teaching is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction rather than passively receiving information. The study also found out that the use of Grapes and GeoGebra is not gender biased since it improved the performance of both boys and girls in a similar way. Boys and girls need to compete, collaborate and gain from one another in mathematics teaching and learning. The teacher should give equal opportunities to both boys and girls. At no time should the teacher be seen to be promoting one sex as opposed to the other. No one sex is superior to the other.

5.4 Recommendations

From the research findings of the experimental research that was conducted, the following are recommended:

1. Teachers should utilize the teaching and learning of mathematics using Grapes and GeoGebra in secondary schools as this study found out that this approach contributes to a better understanding and academic achievement in mathematics as compared to the traditional approach.

2. The ministry of education should come in strongly to assist schools in the provision of computer hardware, software and training for all the teachers on the ICT integration .ICT infusion and integration requires that teachers should have the basic skills on ICT.

3. Schools should establish ICT centres where teachers can handle the teaching of mathematics better by use of the new technology such as Grapes and GeoGebra. ICT provides teachers with a range of new tools and materials to facilitate learning and also present teachers with the potential to develop new teaching methods. The pedagogical rationale for promoting ICT in schools is concerned with the use of ICT in the teaching and learning process.

4. Teachers should move away from the traditional methods and embrace the use of the new technology in the teaching and learning of mathematics. Use of new technology makes the teaching and learning to be easier .Learners can easily grasp some concepts which are considered difficult and abstract when Grapes and GeoGebra areused in the teaching and learning of mathematics. At the same time the use of the new technology arouse the interest and curiosity of the learners. Teachers should endeavour to integrate ICT more in their planning and preparation for the teaching of mathematics.

5. Learners should be fully involved and engaged in the teaching and learning of mathematics so that the concepts which are considered to be abstract are demystified. Teaching and learning of mathematics becomes effective when the learners are actively involved. This is only possible when mathematics teachers are creative in teaching the subject.

6. The teaching and learning of mathematics should involve a lot of practical activities which engage the learners throughout the lesson .This will make the learners to develop a lot of problem solving skills and critical thinking skills which are required in mathematics.

7. There is need for an increased emphasis on the application of ICT in the teaching and learning in teacher education at the pre-service, induction and continuing professional development stages. Teacher education at the university level should provide student teachers with the skills necessary to effectively use ICT in their teaching and inculcate in them a culture of using ICT in their daily work of teaching mathematics. A major focus of such initiative should be how ICT may be integrated and infused fully in the teaching and learning of mathematics.

8. Schools and teachers should regularly review the use of ICT in their work. They should strive to ensure greater integration of ICT within the teaching and learning activities in classrooms during mathematics lessons. Teachers should exploit the use of ICT so as to develop a wide range of higher order thinking skills of problem-solving such as synthesis, analysis and evaluation.

9. Principals should encourage and facilitate suitable ICT training for mathematics teachers. Schools should liaise with relevant support services from institutions such as CEMASTEA and should endeavour to establish mechanisms to facilitate the sharing of best practices for the teaching and learning of mathematics among the members of staff.

10. Schools should endeavour to provide all their students with the basic skills in ICT. This is because for a student growing up in a culture of the new technology, ICT provides new and more exciting and relevant learning opportunities.

11. Professional development opportunities in ICT play a big role in the development of ICT in schools. Teachers should also be given a lot of technical support when it comes to ICT integration in the teaching and learning of mathematics since technical support and maintenance of ICT infrastructure is a significant hindrance to the development of ICT in schools.

12. Mathematics teachers should be encouraged to use Grapes and GeoGebra in teaching graph work as opposed to paper and pencil. This is because the use of these two softwares enhances students' understanding on graph work.

5.5 Summary of the chapter

In this chapter, the role which Geogebra and Grapes can play in the teaching and learning of Mathematics in Kenyan secondary schools was discussed. The findings indicated that students who had learned graphical work using Grapes and GeoGebra were significantly better in their achievement compared to those who underwent the traditional approach. Those who were taught using Grapes and GeoGebra seemed to have performed much better than those who were taught using the conventional method of using paper and pencil. The use of Grapes and GeoGebra resulted on the improved performance for both boys and girls. The findings also showed that the use of Grapes and GeoGebra encourages discovery learning in mathematics. This is one of the strategies that is encouraged in the teaching and learning of mathematics. Learners gain a lot when they discover certain things in mathematics on their own. Teaching of graph work in mathematics using Grapes and GeoGebra also assist the learners in achieving the principles of constructivist learning while doing the graphical work. Constructivist teaching is based on the belief that learning occurs as learners are actively involved in a process of meaning and knowledge construction rather than passively receiving information.

5.6 Suggestions for Further Research

This study could not exhaust all about the role of Grapes and GeoGebra in the teaching and learning of mathematics. More research is recommended to supplement data from this study. The following are areas that need further research:

1) Since the present study was limited to secondary schools in Bomet county, similar studies could be carried out in other counties. This present study might be a pointer in such direction.
2) Further research need to be conducted into the possibility of using Grapes and GeoGebra in the teaching and learning of other areas of mathematics other than Geometry and Algebra.
3) More research needs to be done so as to come up with how the use of Grapes and GeoGebra can be used to teach other topics of the secondary school mathematics syllabus.
4) Further research should also be done conclusively to ascertain whether the use of Grapes and GeoGebra actually have an effect on other mathematical

concepts and on different levels of students. The current study was mainly carried out on some selected secondary schools which were homogenous.

5) Not all the organizational variables related to the mathematics academic achievement of the students were considered. The study considered mainly the teaching method as the major factor determining students' success in the learning of mathematics. Further study needs to be carried out to determine other variables that contribute to the students' academic achievement in the teaching and learning of mathematics.

6) The study mainly employed the quantitative research methodology. Mixed methogs approach can be used to replicate this study. There is also the need to collect some qualitative data in order to better understand the reasons underlying those results. Supporting studies based on quantitative data with qualitative data is considered to be very useful to understand the reality of the results acquired in a study. The qualitative research method should also be employed, based on interviews and observations, to enable a more in-depth and comprehensive view for the examination of variables, teaching methods and students' mathematical achievement. Therefore, it is suggested to conduct studies by using mixed-methods approaches to better understand the social reality underlying the results in a study.

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APPENDICES

APPENDIX I: PRE-TEST EXAMINATIONS

ANSWER ALL THE QUESTIONS IN THE SPACES PROVIDED

1. Draw the graph of $y = 2x^2 + x - 2$ for $-3 \leq x \leq 3$ and use it to solve the equations: (10 marks)

   a) $2x^2 + x - 2 = 5$

   b) $2x^2 + x - 5 = 0$

   c) $2x^2 + 2x - 3 = 0$

2. Given the equation of a quadratic curve $y = x^2 + 5x - 3$

   (a) (i) Complete the table below for the function $y = x^2 + 5x - 3$ for $-6 \leq x \leq 1$ (2mks)

x	-6	-5	-4	-3	-2	-1	0	1
y		-3	-7		-9		-3	3

(ii) Draw the graph of $y = x^2 + 5x - 3$ for $-6 \leq x \leq 1$ (3mks)

(b) (i) State the equation of the line of symmetry for the graph. (1mk)

(ii) Use the graph you have drawn to solve the equations;

$x^2 + 5x - 3 = 0$ (1mk)

$x^2 + 4x - 2 = 0$ (2mks)

$x^2 + 5x - 3 = -3$ (2mks)

4. (a) Draw the graph of $y = x^2 + 4x + 1$ for $-4 \leq x \leq 2$. (Show the table of values)

   (b) On the same axis, draw line $y = 3x + 2$.

   (c) Use the graph to solve the equations

   (i) $x^2 + 4x + 1 = 0$

   (ii) $x^2 + x - 1 = 0$

5. On the grid provided draw the graph of $y = x^3 - 3x^2 - 9x + 2$ for $-3 \leq x \leq 5$ (5mks)

   Use your graph to solve:

   i. $x^3 - 3x^2 - 9x + 2 = 0$ (2 mark)

   ii. $x^3 - 3x^2 - 6x + 8 = 0$ (3 marks

6. (a) Complete the table for the function: $y = 2x^2 + 3x + 1$

x	- 4	-3	-2	-1	0	1	2	3
$2x^2$		18			0			18
3x + 1		-7			0			10
Y		11			1	6		

(b) Use the table in **(a)** above to draw the graph: -

$y = 2x^2 + 3x + 1$ for $-4 \leq x \leq 3$

(c) Use the graph in **(b)** to solve the equation:-

(i) $2x^2 + 4x – 3 = 0$

(ii) $x^2 + \underline{3}x + 2 = 3$

7. a) Draw the graph of $y = 2\boldsymbol{x}^2 + x – 2$ given the range $-3 \leq \boldsymbol{x} \leq 2$

b) Use your graph above to solve

i) $2\boldsymbol{x}^2 + \boldsymbol{x} – 2 =0$

ii) $2\boldsymbol{x}^2 + \boldsymbol{x} – 3 =0$

iii) $2\boldsymbol{x}^2 + \boldsymbol{x}-5 =0$

8. a) Complete the table below for the function $\mathbf{y = -x^3 + 2x^2 – 4x + 2}$.

X	**-3**	**-2**	**-1**	**0**	**1**	**2**	**3**	**4**
$-x^3$	27	8		0		-8		
$2x^2$	18	8	2	0				
-4x		8		0				-16
2	2	2	2	2	2	2	2	2
Y		26		2		-6		-46

b) On the grid provided below draw the graph of

$\mathbf{-x^3 + 2x^2 – 4x + 2}$ for $\mathbf{-3 \leq x \leq 4}$.

c) Use the graph to solve the equation $\mathbf{-x^3 + 2x^2 – 4x + 2 = 0}$.

d) By drawing a suitable line on the graph solve the equation.

$\mathbf{–x^3 + 2x^2 – 5x + 3 = 0.}$

9. (a) Copy and complete the table below for $y =2\sin (x +15)^o$ and $y =\cos(2x -30)^o$ for $0^o \leq x \leq 360^o$

X	0	30	60	90	120	150	180	210	240	270	300
y =2sin(x+15)											
y= cos(2x-30)											

(b) On the same axis draw the graphs:

$y = 2\sin (x + 15)$ and $y = \cos(2x -30)$ for $0^o \leq x \leq 360^o$

(c) Use your graph to:

(i) State the amplitudes of the functions

$y = 2\sin(x + 15)$ and $y = \cos(2x - 30)$

(ii) Solve the equation $2\sin(x+15) - \cos(2x - 30) = 0$

10. a) On the grid provided. Plot the points A(2, -1) B (0, -3) C(2, -4) and D (4, -2) and join them to form a quadrilateral ABCD. What is the name of this quadrilateral?

b) The points A^1 (1, 2) B^1 (3, 0) C^1 (4, 2) and D^1 (2, 4) are the images of ABC and D under a certain transformation T_1. On the same grid draw quadrilateral $A^1B^1C^1D^1$ and describe transformation T_1 fully.

c) The points A^{11}(-2, -4) B^{11}(-6, 0) C^{11}(-8, -4) and D^{11}(-4, -8) are the images of $A^1B^1C^1D^1$ under transformation T_2. On the same grid draw quadrilateral $A^{11}B^{11}C^{11}D^{11}$ and describe the transformation T_2 fully.

d) On the same grid draw quadrilateral A^{111} B^{111} C^{111} D^{111}, the image of A^{11} B^{11} C^{11} D^{11} under a reflection in the x-axis. State the co-ordinates of A^{111} B^{111} C^{111} D^{111}.

APPENDIX II: POST-TEST EXAMINATIONS

ANSWER ALL THE QUESTIONS IN THE SPACES PROVIDED

1. Plot a graph of $y = 2x^2 + 3x - 5$, $-4 \le x \le 2$ by completing the table below.

x	-4	-3	-2	-1	0	1	2
$2x^2$		-18			0		
3x	-12			-3			6
-5							
y			-3			0	

Use your graph to solve

(i) $2x^2 + 3x - 5 = 0$

(ii) $2x^2 + 6x - 2 = 0$

2. (a) Draw the graph of $y = 2x^2 - x - 3$ for $-3 \le x \le 3$ (5 marks)

(b) Using a suitable line solve

$2x^2 - 3x - 50 = 0$ (5 marks)

3. (a) Fill in the table below for the function **$y = -6 + x + 4x^2 + x^3$ for $-4 \le x \le 2$**

x	-4	-3	-2	-1	0	1	2
-6	-6	-6	-6	-6	-6	-6	-6
x	-4	-3	-2	-1	0	1	2
$4x^2$			16			4	
x^3							
y							

(b) Using the grid provided draw the graph for

$y = -6 + x + 4x^2 + x^3$ for $-4 \le x \le 2$

(c) (i) Use the graph to solve the equations:-

(i) $x^3 + 4x^2 + x - 4 = 0$

(ii) $-6 + x + 4x^2 + x^3 = 0$

(iii) $-2 + 4x^2 + x^3 = 0$

4. (a) Complete the table below for the equation :- $y = x^2 + 3x - 6$ for $-6 \le x \le 4$

X	-6	-5	-4	-3	-2	-1	0	1	2	3	4
Y	12			-6			-6				22

(b) Using a scale 1cm to represent 2 units in both axes.

Draw the graph of $y = x^2 + 3x - 6$

(c) Use your graph to solve:-

(i) $X^2 + 3X = 6$

(ii) $X^2 + 3X - 2 = 0$

5. (a) Complete the table below for the function $y = 2x^2 + 4x - 3$

x	-4	-3	-2	-1	0	1	2
$2x^2$	32		8	2	0		
4x – 3			-11		-3		5
y			-3			3	13

(b) Draw the graph of the function $y = 2x^2 + 4x - 3$ and use your graph to estimate the roots of the equation $2x^2 + 4x - 3 = 0$.

(c) In order to solve graphically the equation $2x^2 + x - 5 = 0$, a straight line must be drawn to intersect the curve $y = 2x^2 + 4x - 3$. Determine the equation of this line, draw it and hence obtain the roots of the equation $2x^2 + x - 5 = 0$ to 1 decimal place.

6. Complete the table below for the functions y = cos x and y = 2 cos (x +30°) for 0° ≤ X ≤ 360°

X	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
Cos X	1	0.87	0.5		-0.5	0.87	-1.0		0.5	0		0.87	1
2 cos (x+ 30°)	1.73		0	-1.0		-2.0	-1.73	-1.0		1	1.73	2.00	1.73

a) On the same axis, draw the graphs of y = cosx and y = 2 cos (x + 30°) for 0°≤ X≤ 360°

b) i) State the amplitude of the graph y = cos x°

ii) State the period of the graph y = 2cos (x + 30°)

c) Use your graph to solve $\cos x^0 = 2\cos(x + 30°)$

7. On the grid provided, draw triangle PQR with P(2,3), Q(1,2) and R(4,1). On the same axes draw triangle $P^{11}Q^{11}R^{11}$ with vertices P^{11}(-2,3), Q^{11}(-1,2) and R^{11}(-4,1). (2mks)

(a) Describe fully a single transformation which will map triangle PQR onto triangle $P^{11}Q^{11}R^{11}$. (1mk)

(b) On the same plane, draw triangle $P^1Q^1R^1$ the image of triangle PQR under reflection in the line y = -x. (2mks)

(c) Describe fully a single transformation which maps triangle $P^1Q^1R^1$ onto triangle$P^{11}Q^{11}R^{11}$. (2mks)

(d) Draw triangle $P^{111}Q^{111}R^{111}$ such that it can be mapped onto triangle PQR by a position quarter about (0, 0) (2mks)

(e) State all pairs of triangles that are oppositely congruent. (1mk)

8. The points A (2, 6), B (1, 1), C (2, 3) and D (4,0) are the vertices of quadrilateral ABCD.

(a) On graph paper plot the points A, B, C, and D and join them to form quadrilateral ABCD.

(b) The points A, B, C and D are the images of A^1, B^1, C^1 and D^1 respectively under an enlargement centre the origin and scale factor -2. On the same grid draw the image quadrilateral A^1 B^1 C^1 D^1.

(c) The points A^{11} B^{11} C^{11} and D^{11} are the images of ABCD respectively under reflection in the x – axis. On the same grid, locate the pints A^{11} B^{11} C^{11} and D^{11} and draw the second image quadrilateral A^{11} B^{11} C^{11} D^{11}.

(d) Quadrilateral A^{111} B^{111} C^{111} D^{111} is the image of ABCD under a certain transformation T.

9. Complete the table below for the functions

$$y = \cos x \text{ and } y = 2\cos(x + 30^0) \text{ for } 0^0 \le x \le 360^0$$

x	0°	30°	60°	90°	120°	150°	180°	210°	240°	270°	300°	330°	360°
Cos *x*	1	0.87	0.5		-0.5	-0.87	-1.0		0.5	0		0.87	1
2 cos (*x* +30°)	1.73		0	-1.0		-2.0	-1.73	-1.0		1	1.73	2.00	1.73

(a) On the same axis, draw the graphs of y= cos x and y= 2cos(x - 30) for O<x < 360°.

(b) (i) State the amplitude of the graph y = cos x^o.

(ii) State the period of the graph y = 2 cos (x + 30°).

c) Use your graph to solve Cos x = 2cos(x+30°)

10. a) Complete the table below for the functions y = cos $(2x + 45)^o$ and y = -sin (x + 30^o)for - $180^o \leq x \leq 180^o$.

	-180	-150	-120	-90	-60	-30	0	30	60	90	120	150	180
y=Cos(2x + 45^o)	0.71		-0.97	-0.71			0.71		-0.97			0.97	
y = -sin(x + 30^o)	0.5	0.87			0.5			-0.87		-0.87			0.5

b) On the same axis, draw the graphs of y = cos $(2x + 45)^o$ and y = -sin $(x + 30)^o$

c) Use the graphs drawn in (b) above to solve the equation.

$$\text{Cos } (2x + 45)^o + \sin(x + 30)^o = 0$$

APPENDIX III: STUDENTS' ATTITUDES ON THE USE OF GRAPES AND GEOGEBRA AND GRAPES TO LEARN MATHEMATICS.

GENDER: MALE ☐

FEMALE ☐

Dear student

This is a questionnaire whose aim is to get information about the use of Geogebra and Grapes in the teaching and learning of mathematics in secondary schools. This information will strictly be kept confidential. You are required to respond by ticking (√) the numerical value on the score for each item which best describes your feeling about the attitudes towards the use of Geogebra and Grapes in teaching and learning of mathematics in the classroom and participation in class. There are no right or wrong answers.

Note:

Do not tick more than one numerical value for each item in the scale.

KEY:

5-**S**trongly **A**gree (SA)

4-**A**gree (A),

3 –**U**ndecided (U)

2-**D**isagree (D),

1-**S**trongly **D**isagree (SD)

ITEM	STATEMENT	SA	A	U	D	SD
1	I was excited about using GeoGebra and Grapes softwares					
2	I learnt a lot using Grapes and GeoGebra .					
3	I felt confident using the GeoGebra and Grapes software					
4	I was very engaged in the learning process with the use of Grapes and GeoGebra					
5	I benefited a lot through the teacher-learner interaction while using Grapes and GeoGebra					
6	I was able to visualize and answer the questions after each activity with the use of Grapes and GeoGebra					
7	I was able to think creatively and critically in the discussion and during the question and answer session					
8	I enjoyed learning mathematics much more using Grapes and GeoGebra softwares					
9	I was able to form better connections between previous learning and new learning with the use of Grapes and GeoGebra					
10	The use of Grapes and GeoGebra encourages discovery learning in mathematics.					
11	The use of GeoGebra and Grapes motivated me to develop a positive attitude towards mathematics					
12	The use of Grapes and GeoGebra enabled me to understand abstract concepts in mathematics.					

APPENDIX IV: BUDGET

S/NO	PARTICULARS	COST (KSH)
1	**Equipments**	
	Computer/ lap top	50,000
	Printer	20,000
	Stapler	300
	Paper punch	300
2	**Expendable suppliers**	
	Printing papers	5,000
	Flash disk	1,200
	Pens, pencil, rulers and rubbers	500
	Telephone expenses	4,000
3	**Local travelling and transport**	
	Traveling	10,000
	Accommodation	6,000
	meals	10,000
4	**Publication**	
	Typing and printing	5, 000
	Photocopying	4, 000
	Binding proposals	300
	Binding 1st and 2nd drafts	600
	Binding Theses	6, 000
5	Research assistant	12,000
6	Miscellaneous	15,000
	TOTAL	**150,200**

APPENDIX V: LETTER TO THE SCHOOL PRINCIPAL

RICHARD K LANGAT

MOI UNIVERSITY

P.O. BOX 3900

ELDORET

DATE:

THE PRINCIPAL

____

____

Dear sir/ Madam,

RE: REQUEST TO CARRY OUT RESEARCH IN YOUR SCHOOL

I am a PhD student at Moi University pursuing **Doctor of Philosophy in Educational Communication and Technology**. As part of my course, I am required to carry out a research on "**The Effect of Geogebra and Grapes on Students' Achievement in the Teaching and Learning of Mathematics in Secondary Schools in Bomet County, Kenya".**

The purpose of this letter is to request you to allow me collect the required information from teachers and students in your school. If allowed, I promise to abide by your rules. Attached are copies of my research abstract, questionnaires and a letter from the university.

Thanking you in advance

Yours faithfully

RICHARD K. LANGAT

APPENDIX VI: APPLICATION OF RESEARCH PERMIT

MOI UNIVERSITY

Office of the Dean School of Education

Tel: (053) 43001-8
(053) 43555
Fax: (053) 43555

P.O. Box 3900
Eldoret, Kenya

REF: EDU/D.PHIL.CM/02/10 **DATE:** 20th February, 2020

The Executive Secretary
National Council for Science and Technology
P.O. Box 30623-00100
NAIROBI

Dear Sir/Madam,

RE: RESEARCH PERMIT IN RESPECT OF RICHARD K. LANGAT – (EDU/DPHIL.CM/02/10)

The above named is a 2nd year Postgraduate Higher Degree (PhD) student at Moi University, School of Education, Department of Curriculum, Instruction and Educational Media.

It is a requirement of his PhD Studies that he conducts research and produces a dissertation. His research is entitled:

"The Role of Geogebra and Grapes on Students' Achievement in the Teaching and Learning of Mathematics in Secondary Schools in Bomet County."

Any assistance given to enable him conduct research successfully will be highly appreciated.

Yours faithfully,

MOI UNIVERSITY SCHOOL OF EDUCATION
20 FEB 2020

PROF. J. K. CHANG'ACH
DEAN, SCHOOL OF EDUCATION

Box 3900-30100, ELDORET

(ISO 9001 – 2015 Certified Institution)

APPENDIX VII: RESEARCH PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

Ref No: **996254**

Date of Issue: **28/March/2020**

RESEARCH LICENSE

This is to Certify that Mr.. LANGAT KIPNGETICH RICHARD of Moi University, has been licensed to conduct research in Bomet on the topic: THE ROLE OF GEOGEBRA AND GRAPES ON STUDENTS' ACHIEVEMENT IN THE TEACHING AND LEARNING OF MATHEMATICS IN SECONDARY SCHOOLS IN BOMET COUNTY. for the period ending : 28/March/2021.

License No: **NACOSTI/P/20/4188**

996254
Applicant Identification Number

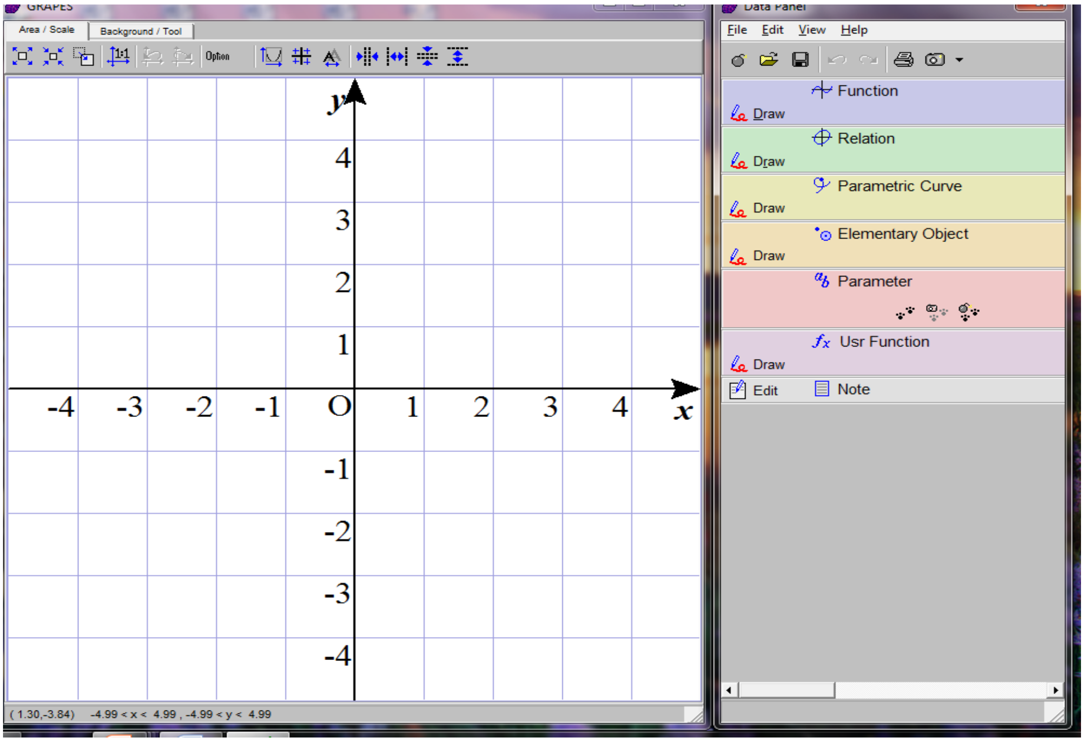
Director General
NATIONAL COMMISSION FOR SCIENCE,TECHNOLOGY & INNOVATION

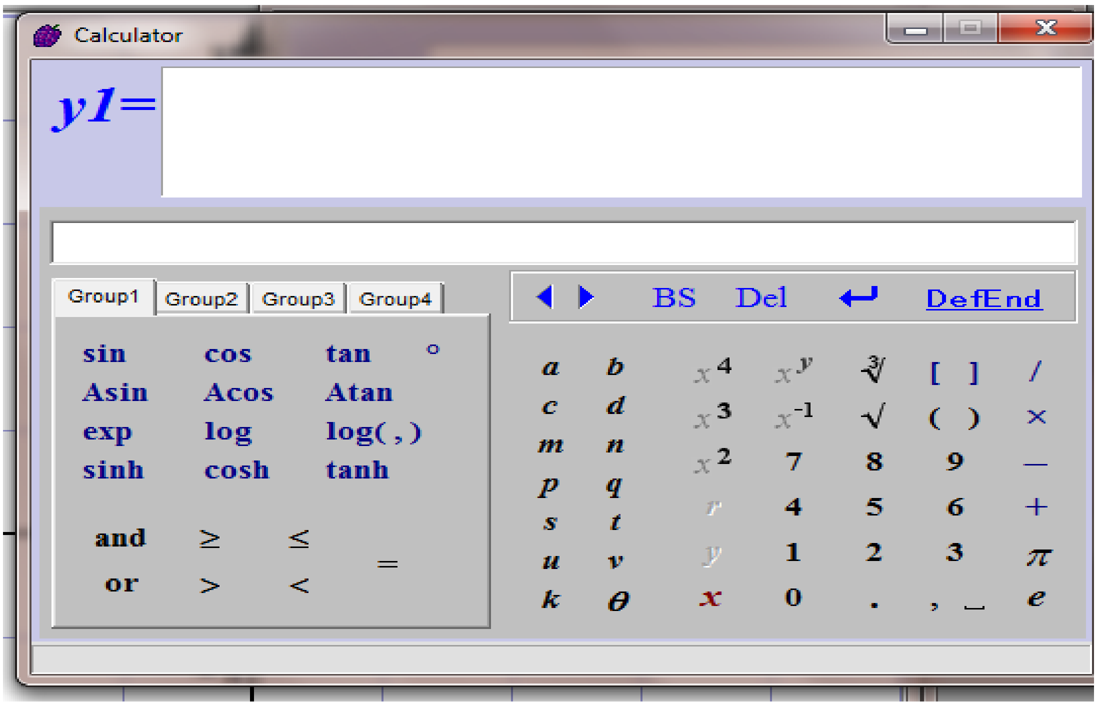
Verification QR Code

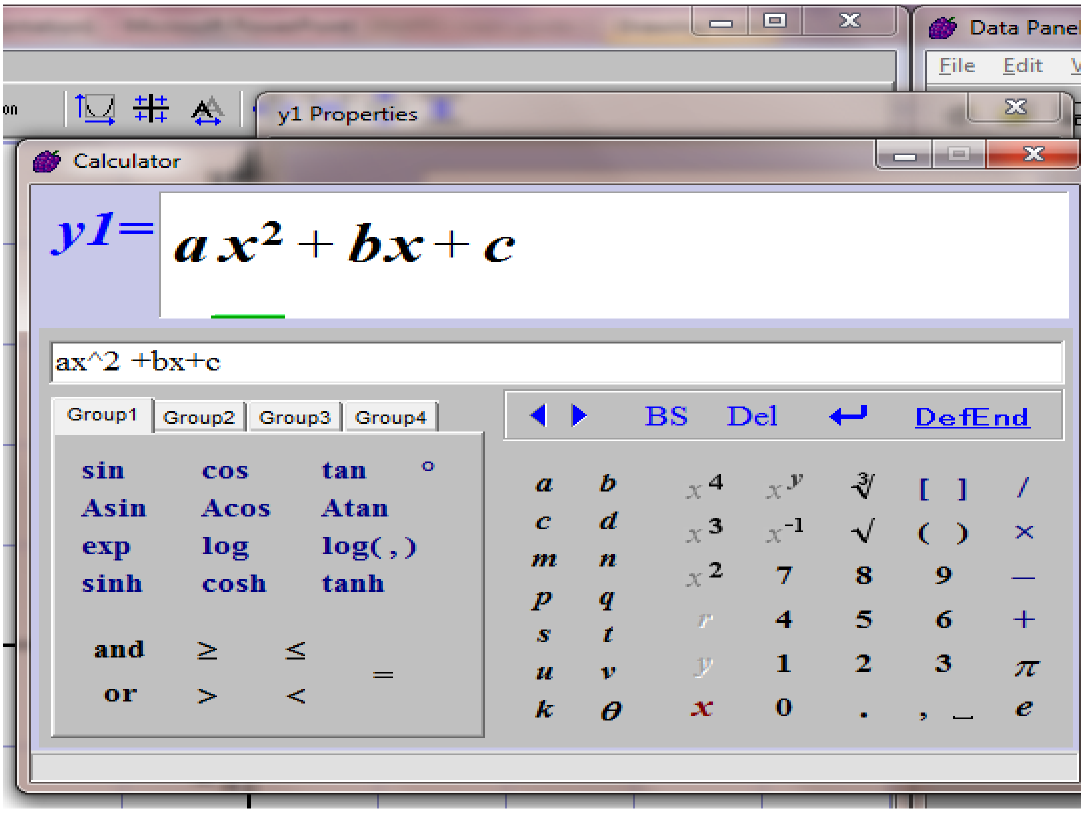
NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

APPENDIX VIII: TRAINING GUIDE ON GRAPES AND GEOGEBRA

Grapes-Graph window and the Data panel



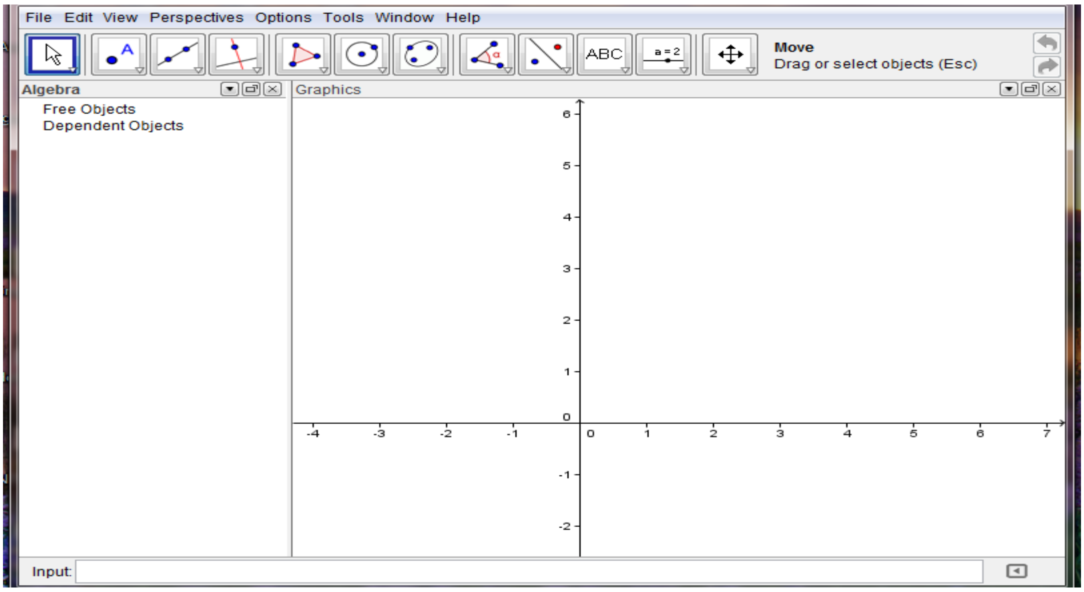




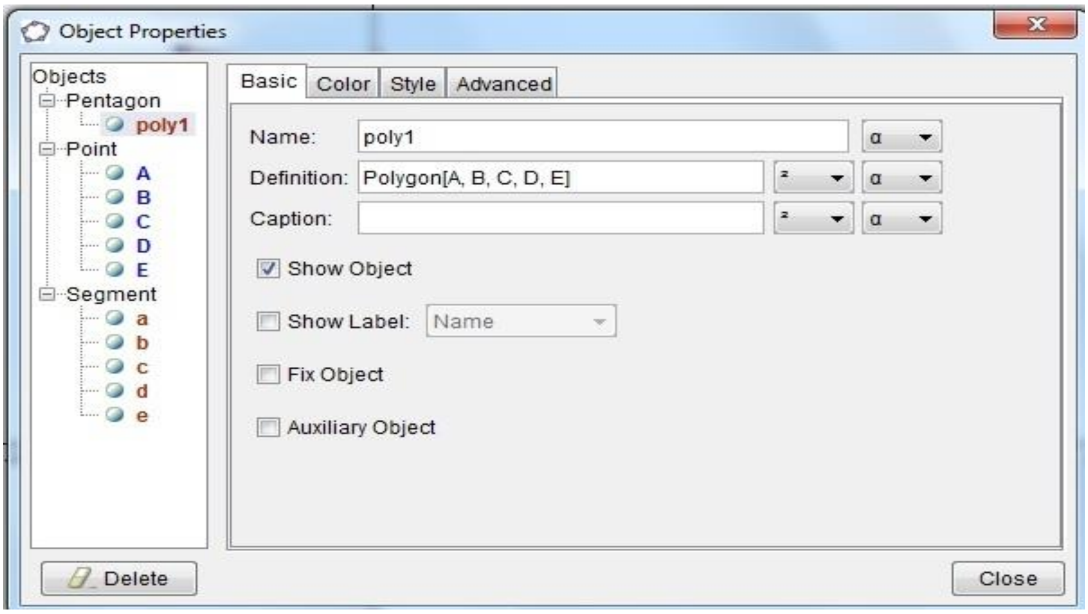
What is GeoGebra and How Does it Work?

- GeoGebra is dynamic mathematics software for schools that joins geometry, algebra and calculus.
- GeoGebra is an interactive geometry system. You can do constructions with points, vectors, segments, lines, and conic sections as well as functions while changing them dynamically afterwards.
- Equations and coordinates can be entered directly. Thus, GeoGebra has the ability to deal with variables for numbers, vectors, and points. It finds derivatives and integrals of functions and offers commands like Root or Vertex.

GeoGebra



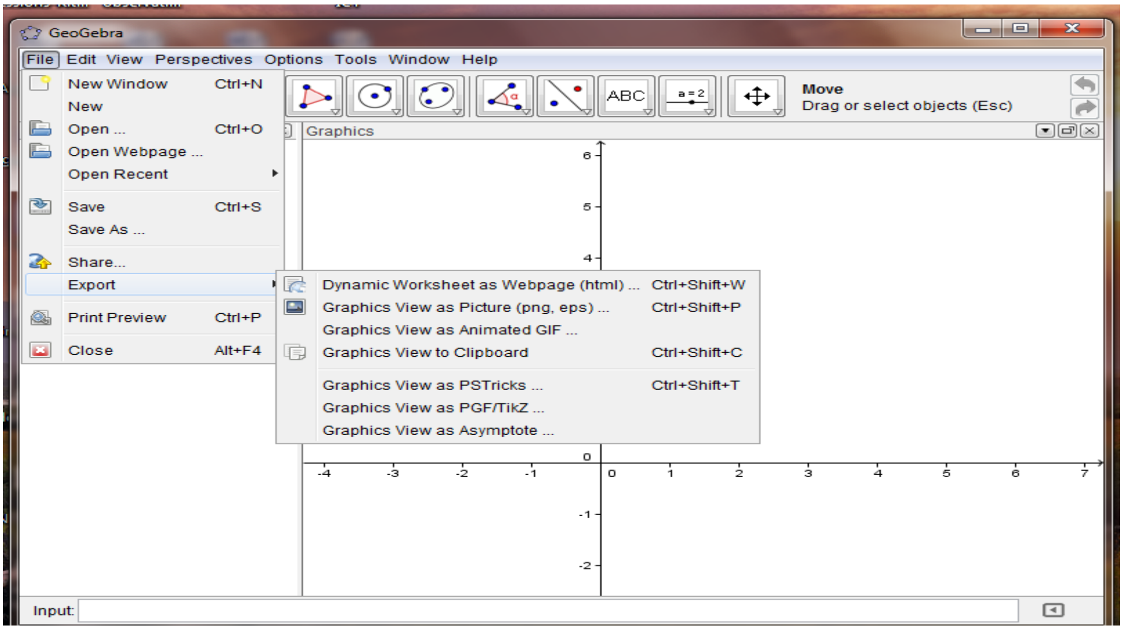
Object Properties



Export of Pictures to the Clipboard

- GeoGebra's graphics view can be exported as a picture to your computer's clipboard. Thus, they can be easily inserted into text processing or presentation documents allowing you to create appealing sketches for tests, quizzes, notes or mathematical games.
- After exporting a figure from GeoGebra into your computer's clipboard you can now paste it into a word processing document.

Exporting Pictures to the clipboard



Construction of graphs

1) **3x+2y=6**
2) **y=3x -4x-6**
3) **x +3x-2y -3y=25**
4) **y=3/x-2 -3**
5) **y=sin(x)**
6) **y=cos(x)**
7) **f(x)=2 cos(x°) +1**

Algebraic Input

- Open a new GeoGebra Window
- In the Input bar, type (a) a=6; (b) b=4;
- (c) f(x)=a x+b [space between *a* and *x*, or use *a*x*]
- Input A=point[f] and B=(x(A),a)
- Right Click on B and select Trace On
- Move point A and observe the Algebra View and Graphics View

ICT integration in Matrices and Transformations
a) Matrix and transformation

1) Create four sliders **a, b, c** and **d** (use the 10th menu) 

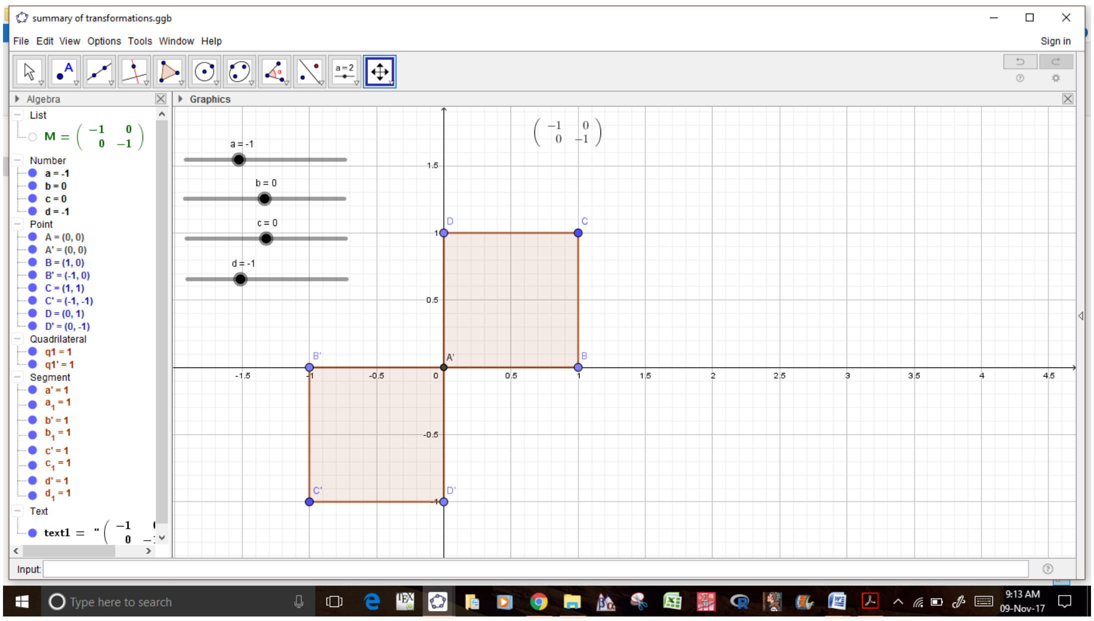
2) In the Input bar enter **M={{a,b},{c,d}}**

3) Insert a text box (10th menu) , select **M** from the object's menu and enable the LaTeX formula

4) Create a shape: e.g. to create a unit square **poly1** add points **A,B,C**, and **D**, select ' polygon' (5th menu)  and then click on each of the points **A,B,C**, and **D** (and **A** again to complete it).

5) In the input bar, enter: **ApplyMatrix(M,poly1)**

6) Manipulate the sliders to show the transformations.



b) Shear along the x-axis

1) Create a slider **k** (use the 10th menu)

2) In the Input bar enter **M={{1,k},{0,1}}**

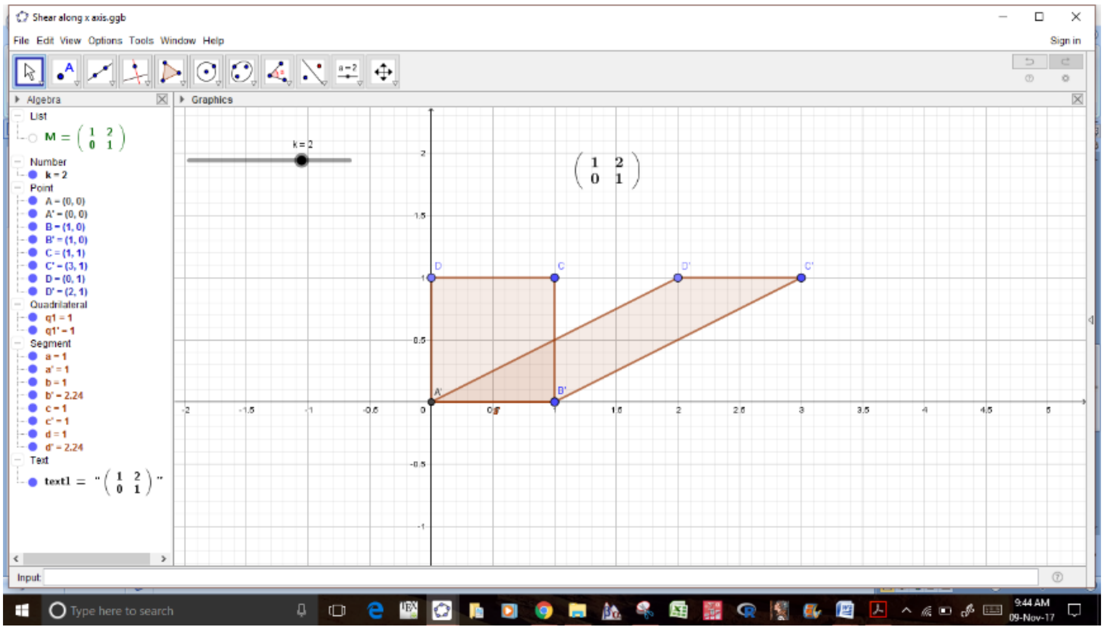
3) Insert a text box (10th menu) , select **M** from the object's menu and enable the LaTeX formula

4) Create a shape: e.g. to create a unit square **poly1** add points **A,B,C**, and **D**, select ' polygon' (5th menu) and then click on each of the points **A,B,C**, and **D** (and **A** again to complete it).

5) In the input bar, enter:

Apply Matrix (M,poly1)

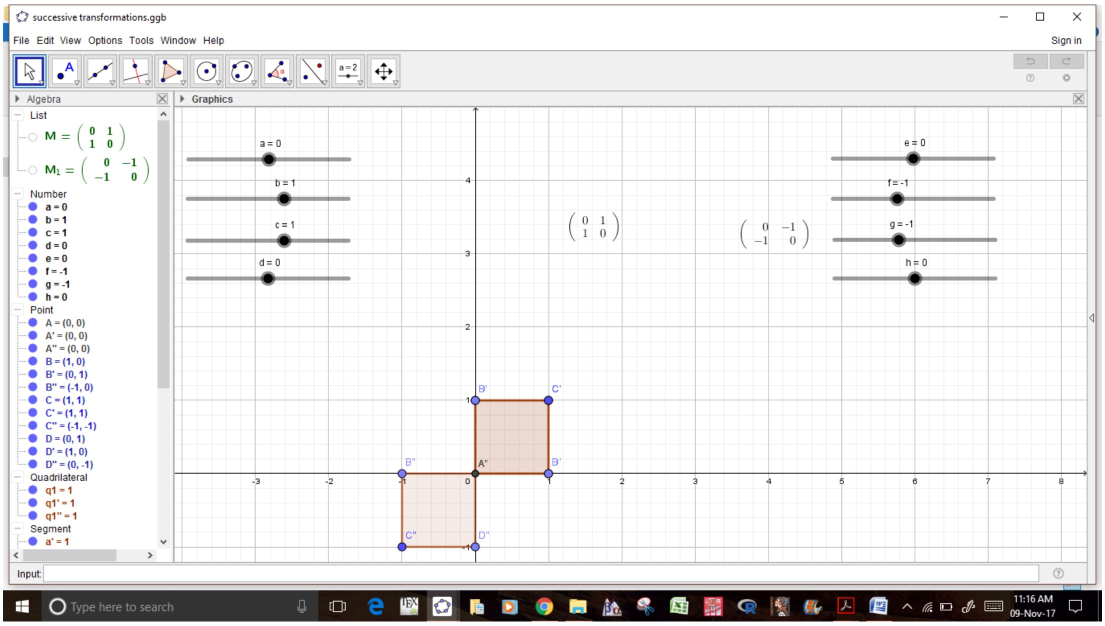
6) Manipulate the sliders to show the transformations.



c) Successive transformations

We define two matrices, N and M, using 8 sliders and apply those to the unit square.

We apply the matrix M to the image of the unit square under the transformation given by N. We do similarly with the order of the matrices reversed.


successive transformations.ggb
File Edit View Options Tools Window Help
Sign in
Algebra
Graphics
List
M = (0 1 / 1 0)
M1 = (0 −1 / −1 0)
Number
a = 0
b = 1
c = 1
d = 0
e = 0
f = -1
g = -1
h = 0
Point
A = (0, 0)
A' = (0, 0)
A'' = (0, 0)
B = (1, 0)
B' = (0, 1)
B'' = (-1, 0)
C = (1, 1)
C' = (1, 1)
C'' = (-1, -1)
D = (0, 1)
D' = (1, 0)
D'' = (0, -1)
Quadrilateral
q1 = 1
q1' = 1
q1'' = 1
Segment
a' = 1
Input:
Type here to search
11:16 AM
09-Nov-17