# EFFECTS OF THE USE OF COMPUTER ANIMATED LOCI TEACHING TECHNIQUE ON SECONDARY SCHOOL STUDENTS' ACHIEVEMENT AND MISCONCEPTIONS IN MATHEMATICS WITHIN KITUI COUNTY, KENYA

**SIMON WARUI MWANGI**

**A Thesis Submitted to the Graduate School in Partial Fulfillment of the Requirements for the Conferment of the Degree of Doctor of Philosophy in Science Education of Egerton University**

**EGERTON UNIVERSITY**

**NOVEMBER, 2019**

## DECLARATION AND RECOMMENDATIONS

### Declaration

This is my original work and has not been previously presented for the conferment of a degree or award of a diploma in this or any other University

Signature ______________________________ **Date**____________________

**Simon Warui Mwangi**

ED14/0445/14

### Recommendation

This work has been submitted with our approval as the University Supervisors

Signature ______________________________ **Date**____________________

**Prof. B. N. Githua, PhD**

**Department of Curriculum, Instruction and Educational Management**

**Egerton University**

Signature ______________________________ **Date**____________________

**Prof. J. M. Changeiywo, PhD**

**Department of Curriculum, Instruction and Educational Management**

**Egerton University**

**COPYRIGHT**

## DEDICATION

This work is dedicated to my dear wife Rebecca, my daughters Ruth, Ann and Rachel and my son Isaac. A Special dedication is made to my parents, Mr. and Mrs. Stephen Mwangi Warui, Mr. and Mrs. Macharia Mwangi and my grandmother Angelica Wambaire Githui.

## ACKNOWLEDGEMENTS

I wish to first thank the Almighty God for His love, support and provisions throughout the course of my study. My appreciation goes Egerton University for giving me this opportunity to learn and contribute to the growing body of knowledge. Exceptional special thanks go to my two supervisors, Prof. B.N. Githua and Prof. J. M. Changeiywo, from Department of Curriculum, Instruction and Educational Management of Egerton University. They tirelessly assisted, guided, encouraged and supported me from the initial to the final stages of my work. The other members of the Faculty of Education and Community Studies (FEDCOS) who helped to shape this thesis in the initial stages include Prof. A.K Sang, Prof. M Okere, Dr. H.O. Abungu, Dr. J. Ngeno, Prof. Fr. S. N. Mbugua, Prof. Wamutito and Mr. G. Korir who are greatly thanked for making valuable suggestions in piecing up the thesis ideas and developing the research instrument. My appreciation goes to the National Commission for Science, Technology and Innovations (NACOSTI) for granting me the permission to carry out the study. A Lot of thanks goes to Mr. Anguzu Stephen formerly the Principal St. Peters Thange Boys secondary school and Mr. Henry Mwali the Principal St. Peters Thange Boys secondary school for their support. I want to appreciate Mrs. T. Mativo and Mr. J. Kitiku for their support critiques. I also thank Mr. Ngolo the Principal, Mr. Singi the Deputy Principal and Mrs. Kathonde the HOD Mathematics all from Mutomo Mixed Secondary School. Dr. Eliza Mutinda the Principal, Mr. Musili R.M. the Deputy Principal and Mrs. Musembi the Mathematics teacher of Kisasi Mixed Secondary School are also appreciated. Special thanks go to Mr. Ndunda the Principal Athi Mixed Day Secondary School, Mrs. Musau the Deputy Principal and Mr. Musili mathematics teacher who made sure despite constant power interruptions the study was not interrupted. I also thank Mr. Muthembwa the Principal Kyanika Mixed Secondary School and Mr. Mutinda the Mathematics HOD. Mr. Matuta J. M. formerly Principal Kyanguli secondary school in Kibwezi Sub-county for his professional help. Special thanks go to Mr. Francis Wambua of Maasai Technical College for his professional guidance on computer animations. Finally great appreciations go to my dear family for their encouragement, patience and understanding during this study.

## ABSTRACT

Mathematics plays an important role in the scientific and development of all nations. In Kenya mathematics is compulsory in all Primary and secondary schools. However the performance in the subject at the National Examinations has remained below average with marked gender differences. The students' performance in some mathematics topics such as "Loci" has been wanting. The reason for the poor performance in mathematics and the Loci topic in particular has been attributed to several factors, which may include: poor teaching methods and lack of teaching/learning resources. This study sought to investigate effects of using Computer Animated Loci Teaching Technique on students' achievement and mathematics misconceptions held by learners in the mathematics topic. ICT has been used in teaching and learning of chemistry with remarkable improvement. The theoretical framework that guided the study was based on the Constructivist theory of learning where the students constructed new knowledge from real-life experiences. Computer Animations on Loci concepts were constructed to teach Form Four in Co-educational secondary schools. Solomon Four, Non-Equivalent Control Group Research Design was used with two treatment groups E1 and E2. The control groups were also two C1 and C2. Purposive random sampling method was used to choose a school for each group that had evenly distributed gender, graduate teachers teaching Form Four and a computer laboratory with at least ten computers. The two experimental groups were exposed to Computer Animated Loci Teaching Technique as the treatment while the two control groups were taught using the conventional teaching and learning methods. The sample size was 207 students consisting of 95 girls and 112 boys. A Mathematics Achievement Test (MAT), adopted from KCSE past Examinations papers on Loci was used to identify Students' mathematics misconceptions. The instrument was pilot tested to estimate its reliability. The instrument-MAT was validated for face and content validity by experts from the Department of Curriculum, Instruction and Educational Management of Egerton University. The reliability coefficient of the instrument was estimated to be 0.8826 using K-R 20 formula. A Pre-test was administered to the two groups (E1 & C1), one experimental and one control before intervention and then the same MAT was administered to all the four groups after intervention as a Post-test. The t-test, ANOVA and ANCOVA were used to test hypotheses at Coefficient alpha (ά) level of 0.05. The results of the research study indicated that Computer Animated Loci Teaching Technique improves students' mathematics achievement and reduced mathematics misconceptions. Both female and male students when exposed to the technique performed significantly the same. The findings may be useful to students, teachers, Universities and curriculum developers in secondary schools since the technique may improve the quality of education in the country.

## TABLE OF CONTENTS

**DECLARATION AND RECOMMENDATIONS** .......... **ii**
**COPYRIGHT** .......... **iii**
**DEDICATION** .......... **iv**
**ACKNOWLEDGEMENTS** .......... **v**
**ABSTRACT** .......... **vi**
**TABLE OF CONTENTS** .......... **vii**
**LIST OF TABLES** .......... **xi**
**LIST OF FIGURES** .......... **xiii**
**LIST OF ABBREVIATIONS AND ACRONYMS** .......... **xiv**
**CHAPTER ONE** .......... **1**
**INTRODUCTION** .......... **1**
1.1. Background to the Study .......... 1
1.2. Statement of the Problem .......... 13
1.3. Purpose of the Study .......... 13
1.4 Objectives of the Study .......... 13
1.5 Hypotheses of the Study .......... 14
1.6 The Significance of the Study .......... 15
1.7 Scope of the Study .......... 15
1.8 Assumptions of the Study .......... 16
1.9 Limitations of the Study .......... 16
1.10Definition of Terms .......... 17
**CHAPTER TWO** .......... **20**
**LITERATURE REVIEW** .......... **20**
2.1. Introduction .......... 20
2.2 Role of Mathematics in the Development of Society .......... 20
2.2.1. Definition of Mathematics .......... 20
2.2.2. Mathematics for Daily Lives .......... 21
2.2.3. Mathematics as Part of Cultural Heritage – Aesthetics and Recreation .......... 22
2.2.4. Mathematics for Workplace andfor Professionals .......... 25
2.2.5. Importance of Teaching Mathematics in Society .......... 26
2.2.6. Mathematics Misconceptions in society .......... 28
2.3. Abstract Nature of Mathematicsand How to Overcome it through Effective Teaching .......... 30
2.4. Mathematics Concepts and Their Formation .......... 36

2.4.1. Learners' Mathematics' Misconceptions ........ 40
2.4.2. Analysis of Students' Misconceptions in Mathematics ........ 44
2.5. Mathematics Achievement and Assessment ........ 52
2.5.1. Students' Mathematics Achievement ........ 52
2.5.2. Students' Mathematics Assessment ........ 54
2.6. Gender Differences in Mathematics Achievements ........ 57
2.7 Approaches, Strategies, Methods and Techniques of Teaching Mathematics ........ 59
2.7.1. Teaching Approaches in Mathematics ........ 60
2.7.2. Strategies of Teaching Mathematics ........ 62
2.7.3. Methods of Teaching Mathematics ........ 67
2.7.4. Techniquesof Teaching Mathematics ........ 73
2.8. Mathematics Teaching-Learning Resources ........ 77
2.9. Information and Communication Technology Use in Mathematics Education ........ 80
2.10. Geometry and Loci Topic ........ 85
2.11. Theories of Learning Mathematics ........ 88
2.12. Theoretical Framework of the Study ........ 92
2.13. Conceptual Framework of the Study ........ 93
**CHAPTER THREE ........ 96**
**RESEARCH METHODOLOGY ........ 96**
3.1. Introduction ........ 96
3.2. Research Design ........ 96
3.3. Location of the Study ........ 97
3.4. Population of the Study ........ 97
3.5. Sampling Procedures and Sample Size ........ 97
3.6. Research Instrument ........ 99
3.6.1. Validity ........ 100
3.6.2. Reliability ........ 100
3.7. Data Collection Procedures ........ 101
3.8. Data Analysis ........ 102
**CHAPTER FOUR ........ 105**
**RESULTS AND DISCUSSIONS ........ 105**
4.1. Introduction ........ 105
4.2. Results of the pre-test on MAT ........ 105
4.3. Test Item Achievement Analysis in MAT 5b (Appendix A) ........ 108

4.4. Effects of Computer Animated Loci Teaching Technique on Students' Achievements in Mathematics ... 109
4.5. Results of the pre-test on Loci topic Misconception scores ... 116
4.6. Effects of Computer Animated Loci Teaching Technique on Students' misconception in Loci topic of Mathematics ... 118
4.6.1. Some of the Observed Misconceptions Held by Students in MAT ... 119
4.6.2. Loci Mathematics Misconception analyses ... 121
4.6.3. Testing the Hypnosis HO2 to find out whether ComputerAnimated Loci Teaching Technique as Effects on Misconceptions ... 124
4.7. Effect of the use of Computer Animated Loci Teaching Technique on gender difference in students' achievements in Loci topic of mathematics ... 128
4.7.1. Test Item Achievement Analysis in MAT Question 8(a) (Appendix A) by gender ... 129
4.7.2. Testing the Hypnosis HO3 to find out whether Computer Animated Loci Teaching Technique has Effects on mathematics Achievent by gender ... 130
4.8. Effect of the use of Computer Animated Teaching Loci Teaching Technique on Gender Difference in Students' Misconceptionsin Loci Topic of Mathematics ... 132
4.8.1. Test Item Misconception Analysis in MAT Question 5(a) (Appendix A) by gender 132
4.8.2. Testing the Hypnosis HO4 to find out whether ComputerAnimated Loci Teaching Technique has Effects on mathematics misconception by gender ... 134
**CHAPTER FIVE ... 137**
**SUMMARY OF FINDINGS CONCLUSIONS, IMPLICATIONS AND RECOMMEDATIONS ... 137**
5.1. Introduction ... 137
5.2. Summary of Research Findings ... 137
5.3. Conclusions ... 138
5.4. Implications of the Findings ... 139
5.5. Recommendationsof the study ... 139
5.5.1. Areas for Further Research ... 140
**REFERENCES ... 141**
**APPENDICES ... 186**
APPENDIX A: MATHEMATICS ACHIEVEMENT TEST (MAT) ... 186
APPENDIX B: MARKING SCHEME OF MATHEMATICS ACHIEVEMENT TEST (MAT) ... 189
APPENDIX C: TEACHING MODULE FOR LOCI- TOPIC IN FORM 4 CLASS ... 199

APPENDIX D: TEACHERS' TRAINING MANUAL FOR LOCI TOPIC ............................ 203
APPENDIX E: SCRIPT ON COMPUTER ANIMATED LOCI TEACHING TECHNIQUE ........................................................................................ 206
APPENDIX F: RESEARCH AUTHORIZATION LETTER FROM NACOSTI .................. 222
APPENDIX G: RESEARCH PERMIT ........................................................................ 223
APPENDIX H: RESEARCH AUTHORIZATION LETTER FROM KITUI COUNTY COMMISSIONER ........................................................................ 224
APPENDIX I: RESEARCH AUTHORIZATION LETTER FROM KITUI COUNTY DIRECTOR EDUCATION ............................................................ 225

## LIST OF TABLES


Table 1: KCSE Mathematics Examination Mean Scores for Years 2013 to 2017 by Gender ........ 7

Table 2: KCSE Mathematics Results for Kitui County for the Years 2013 to 2017 ........ 7

Table 3: KCSE Mathematics Items Analyses Paper One 1993 Number 11 ........ 8

Table 4: KCSE Mathematics Item analyses Paper One 1994 Number 19 ........ 8

Table 5: Testing of Loci and Marks Awarded at KCSE (2012- 2017) ........ 9

Table 6: Learners' Mathematics Misconceptions in Geometry in General and Loci in Particular ........ 47

Table 7: Number of Co-educational SecondarySchools in Kitui County per Sub-County ........ 98

Table 8: Summary of Data Analysis ........ 103

Table 9: Number of Students who participatedin the Research Study in Experimental and Control Schools by Gender ........ 105

Table 10: Mean Scores on MAT forGroups E1 and C1 ........ 106

Table 11 : Independent Sample t-test of Pre-Test Scores on MAT Based on Groups E1 and C1 ........ 106

Table 12: The Mean Score and Standard Deviation of Pre-Test Score by Gender ........ 107

Table 13: Independent Sample t-Test of Pre-Test Scores on MAT Based on Groups E1 and C1by Gender ........ 107

Table 14: The pre-test Achievement Analyses of the students' in the item 5b ........ 108

Table 15: The post-test Achievement Analyses of the students' Solution to the 5b in MAT ........ 109

Table 16: The MAT Mean Scores Obtained by the Four Groups ........ 110

Table 17: One- Way ANOVA of the Post-Test Scores on the MAT ........ 111

Table 18: Scheffe's Post hoc Comparison of the Post-Test MAT Means for the Study Groups ........ 111

Table 19: Observed and Adjusted MAT post-test Mean Score for ANCOVA with pre-test MAT score as the covariate ........ 112

Table 20: Summary ANCOVA of the Post –test MAT scores with pre-test as covariate ........ 113

Table 21: Comparison of mean scores and mean gain obtained by students in the MAT ........ 114

Table 22: Mean Scores on Misconception in MAT for groups E1 and C1 ........ 116

Table 23: Independent sample t-test of pre-test scores on misconceptions in MAT based on groups E1 and C1 ........ 116

Table 24: Pre-Test Misconception Score by Gender and By Group C1 and E1. 117
Table 25: Overall Pre-Test Students' Misconception Score in MAT by Gender 117
Table 26: Independent sample t-test of pre-test scores on misconceptions in MAT based on groups E1 and C1 by gender 118
Table 27: Some of Misconceptions Identified in MAT that are Held by the Students. 120
Table 28: The number of students'who presents solutions as a dot, spiral, wave or blank. 122
Table 29: The number of students' who presents solutions as a blank, dot, spiral, wave or a straight line. 123
Table 30: Post –test misconception mean scores obtained by the students in the study groups 124
Table 31: One- way ANOVA of the post-test scores of Misconceptions on MAT 124
Table 32: Scheffe's post hoc comparison of the post-test misconception mean scoreson MAT for the study groups 125
Table 33: Observed and Adjusted MAT post-test Misconceptions mean Score for ANCOVA with pre-test Misconceptions mean Score as the covariate 126
Table 34: Summary ANCOVA of the Post –test Misconception mean scores with pre-test Misconception mean scores as covariate 126
Table 35: Comparison of misconception mean scores in pre-test and misconception mean score gain obtained by students in the MAT 127
Table 36: Pre-Test results Result for MAT Question 8(a) by Gender 129
Table 37: Pro-Test results Result for MAT Question 8(a) by Gender 129
Table 38: Post-Test Achievement Result for MAT by Gender per group 130
Table 39: Overall posttest Achievement Result for MAT by Gender 130
Table 40: Independent sample t-test of post-test scores on MAT based on gender 131
Table 41: Comparison of mean gain of students' pre-test and post-test scores in MAT by gender 131
Table 42: Pre-test Mathematics Misconceptions in MAT Held by gender per group. 133
Table 43: Pro-test Mathematics Misconceptions in MAT Held by gender per group. 133
Table 44: Post-Test Misconceptions Mean Score Result for MAT by Gender per group 134
Table45: Overall posttest Achievement Result for MAT by Gender 134
Table 46: Independent sample t-test of post-test scores on MAT based on gender 135
Table 47: Comparison of misconception mean score gain of students' pre-test and post-test scores in MAT 135

## LIST OF FIGURES

Figure 1: Pie Chart Showing Average Retention Rate From Different Teaching Methods ......... 35
Figure 2: The Diagrammatic Representation of the Relationship Between the independent, Intervening and dependent variables of the Study. ........................................................ 95
Figure 3: Solomon Four, Non-Equivalent Control Group Research Design ............................... 96
Figure 4: Some pre-test solutions from MAT item 5b .............................................................. 108
Figure 5: Geogebra Computer animation of a point on the wheel of a bicycle as the bicycle moves on a level ground. ........................................................................................... 109
Figure 6: Some of the Students' Solution to Item 5(a) Appendix A during Pre-test in MAT .... 121
Figure 7: Geogebra animation of an axle of a bicycle wheel as the bicycle moves on a level ground. ........................................................................................................... 122
Figure 8: Some of the Students' Solution to Item 5(a) Appendix A during Pro-test in MAT .... 123

## LIST OF ABBREVIATIONS AND ACRONYMS

| | |
|---|---|
| AIMS | African Institute of Mathematical Sciences |
| ASDSP | Agricultural Sector Development Support Programme |
| BCE | Before Common Era |
| CAI | Computer Assisted Instructions |
| CEMASTEA | Centre for Mathematics, Science and Technology Education in Africa |
| EU | European Union |
| ECZ | Examination Council of Zambia |
| FEMSA | Female Education in Mathematics and Science in Africa |
| FPE | Free Primary Education |
| GOK | Government of Kenya |
| ICT | Information, Communications and Technology |
| INSET | In-Service Education and Training |
| JAB | Joint Admissions Board |
| JICA | Japan International Cooperation Agency |
| KCEO | Kitui County Education office |
| KCSE | Kenya Certificate of Secondary Education |
| KICD | Kenya Institute of Curriculum Development |
| KIE | Kenya Institute of Education |
| KNEC | Kenya National Examinations council |
| LCD | Liquid Crystal Display |
| MAT | Mathematics Achievement Test |
| MIOE | Malawi Institute of Education |
| MOE | Ministry of Education |
| MOEST | Ministry of Education Science and Technology |
| NACOSTI | National Commission for Science, Technology and Innovation |
| NCTM | National Council of Teachers of Mathematics |
| OECD | Organisation for Economic Co-operation and Development |
| PISA | Programme for International Student Achievement |
| PTR | Pupil Teacher Ratios |
| QASO | Quality Assurance and Standards Officers |
| SAMSA | Southern Africa Mathematical Sciences Association |
| SDG | Sustainable Development Goals |

| | |
|---|---|
| SMASE | Strengthening of Mathematics and Science Education |
| SMASSE | Strengthening of Mathematics and Science in Secondary Education |
| SMASTE | Strengthening of Mathematics, Science and Technology Education |
| SPSS | Statistical Package for Social Sciences |
| STEM | Science, Technology Engineering and Mathematics |
| TIMSS | Trends in International Mathematics and Science Study |
| TSC | Teachers Service Commission |
| WECSA | Western, Eastern, Central and Southern Africa |

# CHAPTER ONE

# INTRODUCTION

## 1.1. Background to the Study

Mathematics is offered as one of the core subjects at primary and secondary school education in Kenya. At tertiary levels, core basic mathematics is offered in nearly all science-based programmes where it is not a core subject (JAB, 2013). This implies that mathematics is highly regarded in Kenya as a subject of great importance. The teaching of mathematics concepts and skills that the students encounter in school shapes their understanding, their ability to solve problems and their confidence in, and disposition toward mathematics (Too, 2007). Mathematics is vital in fostering logical, critical and rigorous thinking. Odhiambo, Maito and Ooko (2013) are of the views that mathematics all over the world plays a pivotal role in students' lives, it is a bridge to science, technology and other subjects offered in any formal education system. According to Vicki (2017), there are numerous examples of how mathematics supports manufacturing from optimizing production schedules through to simulating the performance of manufactured components. On a personal development Odili (2006) noted that mathematics subject helps students to become clear, brave, accurate, precise, and certain in their expression. Mathematics also helps learners to develop analysing and reasoning skills with the use of logical and structured thoughts. Everybody requires some competency in basic mathematics for the purposes of handling money, executing daily businesses, doing daily chores in our houses, interpreting mathematical graphs and charts as well as thinking logically (Bandura, 1997). Mathematics is a crucial skill that promotes learner preparedness to succeed in further studies, in his or her daily life and in the workplace (Robberts, 2016).

Despite the importance of mathematics subject to individuals and society globally, Miheso (2012) found out that it is poorly performed at national examinations by many secondary school students worldwide. Colwell (2000) indicated that the performance of American students in the International Mathematics Tests has been poor over the years. The same is also observed by Perveen (2009) who indicated that eighty percent (80 %) of the unsuccessful students in the secondary school examination in Pakistan failed due to poor grades in mathematics. Likewise Jamaica registers low test scores in mathematics at all levels of their education system suggesting that there are gaps in the system that negatively impact on the mathematics learning outcomes of many students (King, 2012). The EU (2018) also reported poor performance in Science and mathematics in both primary and secondary level of education among the Member States. Some of the Member States had considerably higher percentages of low achievement, with levels around 40 % recorded in Cyprus, Bulgaria and Romania. On the contrary some of Member States performed considerably well such as Estonia, Finland, Slovenia and Ireland with level of low achievement being lower than fifteen percent (15%). Kaur (2005) observed that since 1995, the Singapore students have been consistently ranked among the top performing Nations worldwide in the Trends in International Mathematics and Science Study (TIMSS).

Studies conducted by the Female Education in Mathematics and Science in Africa (FEMSA) both in Anglophone and Francophone countries in Africa and a report from a regional conference for countries in Western, Eastern, Central and Southern Africa (WECSA) held in 2001 established that poor performance in mathematics in primary, secondary level, and post-secondary institutions is prevalent in many countries across the Africa Continent (Ateng'ogwel, Odhiambo & Kibe, 2008). Fasasi as cited in Jebson (2012) found out that the students' performance in mathematics in Nigerian senior secondary school is very poor. This agrees with (Odili, 2006) who ascertain that despite its utility, mathematics has been one of the subjects which Nigerian students especially at secondary schools level develop a dislike for and likewise perform poorly. Maliki, Ngban and Ibu (2017) ascertain that the poor performance of students in mathematics tests has become a great concern to all stakeholders such as parents, teachers, and government in Nigeria. They also found that students from the rural school performed better than students from urban schools in mathematics examination and also students from private schools performed better than those from public schools in Bayelse state of Nigeria.

Mahlabela (2012) observed that learner's mathematics performance is poor in South Africa, despite it being held in high esteem by the society. Tachie and Chireshe (2013) also noted the learners' poor performance in mathematics in South Africa generally and particularly in Mthatha District. This calls for the establishment of the factors that attribute to learners' high failure rate. The student's poor performance is also a major concern in Zimbabwe as noted by Sunzuma, Masocha and Zezekwa (2013). Despite the importance attached to mathematics, it is disappointing and heart breaking for stakeholders to see learners continually failing year in year out in both internal and external examinations. Kafata and Mbetwa (2016) noted the poor performance in Mathematics and Science subjects by students in secondary schools in Kitwe District of Zambia. The report by Examination Council of Zambia (ECZ) (2014) also noted that one of the perennial problems of the education system in Zambia is a high failure rate of students at grade 12 examinations in sciences and mathematics subjects. Due to consistent poor performance of mathematics worldwide; majority of students find mathematics boring, mostly irrelevant and unrewarding (Colgan, 2014), this has made them lose interest in the subject resulting poorer performance.

The search for the cause of poor academic achievement in mathematics is unending (Aremu &Sokan, 2003). The results of the search provide encouragement to look at what is going on in schools and classrooms and what can be done to improve the situation; especially for low-achieving students at all the levels of education. Some of the major factors attributed to the poor mathematics performance include: unsuitable methods of teaching; low learners' self-esteem/self-efficacy; poor learners' study habits; students rarely consults their teacher on area that they find challenges and poor interpersonal relationships among students-teachers and students-students (Attwood, 2014). Other causes of poor performance in mathematics among senior secondary school student as observed by Tata, Abba and Abdullahi (2014) include misconceptions of the Mathematics as difficult subject which is feared and causes a lot of anxiety. Vudla (2012) cited in Aberdein (2013) was of the view that shortage of well trained teachers, inadequate of teaching/learning facilities, lack of fund to purchase necessary equipment, poor quality of textbooks, large classes, poorly motivated teachers, lack of laboratories and libraries, poorly coordinated supervisory activities, interference of the school system by the civil service and politicians, incessant transfers of teachers and principals, automatic promotions of pupils, the negative role of public examinations on the teaching/learning process and inequality in education opportunities all hamper the smooth acquisition of mathematics knowledge. Abiam and Odok (2006) in their research observed that gender stereotypes in mathematics area contributing factor to the poor performance in the subject. In this study some of causes of poor performance that were studied are mathematics misconceptions, teaching methods and use of ICT integration in teaching and learning of mathematics.

Students often hold strong misconceptions be they historical, mathematical, grammatical, or scientific. The misconceptions held by students while carrying out mathematical operations may be contributed to the poor performance level of students (Usman & Harbor, 1998). Therefore, if their poor performance must be improved upon, these misconceptions should be identified and remedied. Swan (2005) in his study observed that teaching becomes more effective when misconceptions are systematically exposed and remediated. For mathematics teachers to expose mathematics misconceptions they need to understand how they are formed. Students have misconceptions because of many reasons. Among the reasons are: using only teacher-centred approaches; lacking of depth in the curriculum; some mathematics concepts are too abstract for students to understand without concrete model; not establishing connectivity between the subjects and concepts; not relating the subjects to daily life; not encouraging the students to participate in the subjects; not paying attention to student's prior knowledge; inappropriate teaching style; teachers' own misconceptions and teaching the concepts to students in a wrong way (Abimbade, 1997). One of the reasons why mathematics misconceptions may persist is that many of the mathematics procedures that students attempt to use are ones that will lead to a correct solution for some problem situations (Koedinger & Booth, 2017). This is also collaborated by Echesa (2003) noted one such mathematics procedure in ratio. He gave an example that; if x: y = 2: 3, find the ratio of (2x+y): (3x─y). Many students he noted just substitutes x= 2 and y=3 and get their solutions as (2 ×2+3): (3×2─3) =7:3. The solution is correct but the procedure is wrong since the values of x and y in the ratio x: y are unknown. The correct procedure should have been x: y = 2: 3 is interpreted to be $\frac{x}{y} = \frac{2}{3}$ therefore x =$\frac{2}{3}y$, by substituting x in the ratio (2×$\frac{2}{3}y$ +y): (3×$\frac{2}{3}y$ ─y) = ($\frac{4y}{3} + y) = \left(\frac{6y}{3} - y\right) = \frac{7y}{3} : y = 7:3$. The remedial measures need to be put in place to ensure students' mathematics misconceptions are reduced or eradicated. Teachers can help students eliminate their misconceptions by providing an adequate knowledge base and clear understanding of these mathematics concepts.

Stereotypes about female inferiority in mathematics are prominent among children and adolescents, parents, and teachers. The stereotypes can have a deleterious effect on the learner's actual performance in mathematics. Aronson, Fried and Good (2002) found out what they termed as "Stereotype threat effects" to have affected female achievement in mathematics. The threats of socio-economic factors, Customs and circumstance leading to a range of cultural practices and differential classroom treatment of male and female students by teacher among others may lead to gender differences in mathematics performance.

Gender differences in mathematics performance and ability remain a concern in the USA at all level of education but more pronounced at the highest levels of mathematics (Hyde, Lindberg, Linn, Ellis& Williams, 2008). This is supported by Ellison and Swanson (2010) who found that gender gap in mathematics achievement, appears to get even more amplified among students at high achievement levels in the USA and similarly in Denmark, the gender differences in mathematics exist at all levels of education as observed by Joensen and Nielsen (2013). Gender difference is also noted in both France and Czechoslovakia by Örs, Palomino, and Peyrache (2013) who found out that not only does gender difference exist but males dominate at the top of the mathematics test score distribution. Gender differences in mathematics and science emerge in early childhood, develop over time, and ultimately reflected in secondary and tertiary education in Germany (Farrell, Cochrane & McHugh, 2015). According to Pourmoslemi, Erfani and Firoozfar (2013) gender differences in mathematics exists among students at higher levels of learning in Hamedan Iran. On the contrary in Britain secondary schools, the research by Lubienski, Robinson, Crane and Ganley (2013) found that girls do better in mathematical proficiency than boys.

Research by Ajisuksmo and Saputri (2017) revealed that in Ghana's high school students, the boys get high scores in mathematics achievements than the girls. The same is observed by Kolawole (2007) who found out that boys performed better than girls in both mathematics and sciences in Nigeria. The study agrees with Aguele and Agwugah (2007) who found that male students achieved significantly better than female students in science and mathematics. Gender differences in mathematics achievement in Seychelles are particularly substantial (Cole, 1997) while, Mali, Senegal and Tunisia show gender differences across grade levels in mathematics education (Ross, Saito, Dolata & Ikeda, 2004). On the contrary, Yusha'u (2013) found no gender difference between men and women in mathematics in Nigeria.

Despite the effort of the Kenya government on the development of mathematics teaching/learning and provision of opportunities for the improvement of teaching/learning methodologies, such as introduction of Strengthening Mathematics and Science in Secondary Education (SMASSE) programme, there are still problems of mathematics teaching and learning. The programme is supposed to provide mathematics and science teachers with an opportunity to understand and practice techniques and strategies that create learning experiences for learner's growth. Specifically strategies enable them to effectively develop learner's experiences that promote their critical thinking, encourage, capture and use learner ideas, develop their manipulative, observation and recording skills in the classroom. As noted by Novak & Tassell (2017) mathematics is part and parcel of our daily life; as such the provision of quality education and subsequent high performance is inevitable for the realization of Sustainable Development Goals (SDGs) and the vision 2030. There is an enormous amount of pressure on children to do well in mathematics in school due to the fact that traditionally education has been the only method of raising one's social status, attainment of higher education and pursuing a good career at the University as an important goal for Kenyan children. If Kenya is to achieve the Vision 2030, whose aim is making Kenya a newly industrialised middle-income country (GOK, 2007), then we must excel in sciences, and the vehicle for this is mathematics.

In Kenya mathematics has consistently been ranked the last in performance in comparison with the other subjects offered at the KCSE (KNEC, 2015). The subject is seen to be favouring the performance of male students at KCSE level in Kenya as noted by Kiptum, Rono, Too, Bii and Too (2013). They attribute favouring due to factors like attitude, methods used for teaching among others. This has resulted in gender differences between male and female students in Mathematics performance. O'Connor, Kanja and Baba (2000) in their research and reports carried out (KNEC, 2006) have established the causes of the appalling poor state of Mathematics performance. Some of the causes identified were: (a) Negative attitude of students towards Mathematics, (b) Misconceptions and Errors as students solve mathematics problems (c) lack of appropriate teaching methodology (d) inadequate assignments to students and (f) inadequate coverage of syllabus. To remediate the poor mathematics performance, SMASSE project opted to organise National and County In-Service Education and Training (INSETS) for mathematics and science teachers that emphasised on the students and teachers attitudes toward mathematics, teaching/learning methods and technique that are students centred. They also addressed the issues of teaching and learning recourses where the teachers are supposed to be innovative and improvise.

A critical look at the students' overall performance in mathematics at the KCSE from the year 2013 to 2017 national examinations reveals that the students' performance persistently remained low with gender disparities in mathematics performance with boys doing better in overall performance at the KCSE national mathematics examinations as shown in Table 1.

**Table 1: KCSE Mathematics Examination Mean Scores for Years 2013 to 2017 by Gender**

| Year | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Female KCSE Mean% Scores | 24.51 | 21.26 | 24.27 | 18.25 | 23.54 |
| Male KCSE Mean% Scores | 30.13 | 26.40 | 29.16 | 23.03 | 27.29 |
| Grade Total KCSE Mean% Scores | 27.56 | 24.02 | 26.88 | 20.78 | 24.48 |

**Source: KNEC, 2013 pp (xii), 2015 pp 10& 2018 pp 12**

The KCSE mathematics examination results from Kitui County shown in Table 2 indicate that the performance index was below 4 points out of 12 points for five consecutive years. This shows that the poor performance in mathematics has persisted in the County. Despite the effort of the stakeholders, among them: students, teachers, principals, education officers, SMASSE County trainers and parents, Kitui County has persistently been doing poorly in mathematics at KCSE. Among the factors attributed to this poor performance in mathematics are: poor teaching methods; inadequate teaching and learning resources both human and physical; abstract nature of mathematics; insufficient monitoring of teaching and learning (CEMASTEA, 2012).

**Table 2: KCSE Mathematics Results for Kitui County for the Years 2013 to 2017**

| Year | 2013 | 2014 | 2015 | 2016 | 2017 |
|---|---|---|---|---|---|
| Mean score (out of 12 points) | 3.111 | 3.586 | 3.507 | 3.810 | 3.721 |

**Source: KCDO, 2015(a), Pp 10, 2018(a) pp 11**

Vashist (2007) defines Geometry as a branch of mathematics that deals with the measurement, properties, relationships of points, lines, angles, surfaces and solids. She further ascertain that specifically, students construct and measure the angles, length of various geometric figures and study the relationship that exists between their parts. Gale and

Davidson (2006) reported that geometry is important for it used in such fields as astronomy, surveyors, architecture and engineering. Loci is a topic in geometry that deals with construction under specified conditions, thus according Shinwha and Noss (2001) locus is a path traced by a point as it moves so as to satisfy certain conditions. Locus can be a line, an area or region in two dimensions or a volume in three dimensions (Kibui & Macrae, 2005) that satisfies a give condition or set of conditions. Loci as a topic of geometry that is taught to Form Four students of secondary schools in Kenya is not well understood by learners of mathematics as revealed by mathematics examinations results at KCSE (KNEC, 1995). The prerequisites to Loci are taught in Form One class as geometrical construction and common solid, in the Form Two class as angle properties of circles and in the Form Three class as tangents and circles. The common types of loci among them: locus of points equal distance from a fixed point; angle bisector locus; constant angle locus; loci of chords, loci involve inequalities and intersecting loci (MOE, 2006) plays a key role in loci problem-solving. If the concepts are not understood then the performance in loci questions is poor. The Tables 3 and 4 shows KCSE analyses of question that tested loci as reported by KNEC (1995).

**Table 3: KCSE Mathematics Items Analyses Paper One 1993 Number 11**

| **Marks** | **0** | **1** | **2** | **3** | **4** |
|---|---|---|---|---|---|
| % of candidates scoring the marks | **80** | **1** | **17** | **0** | **2** |

**Source: KNEC, 1995 Mathematics Report pp 12-13**

The question tested candidates' understanding of loci. It was a compulsory question where 80% of students scored a zero mark out of a possible maximum of 4 marks. The first mark was awarded for correctly identifying the common type locus of which 80% could not identify. Only 2% of candidates were able to score the maximum 4 marks. The other candidates faced challenges in answering the question, implying the topic needs more attention. Van der Sandt (2007) concedes that in South Africa geometry is regarded as a 'problematic topic' at the secondary school level.

**Table 4: KCSE Mathematics Item analyses Paper One 1994 Number 19**

| Marks | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
|---|---|---|---|---|---|---|---|---|---|
| % of candidates scoring the marks | 67 | 22 | 6 | 2 | 1 | 0 | 1 | 0 | 1 |

**Source KNEC, 1995. Mathematics Report Pp 66-67**

The question was optional and tested candidates' ability to construct simple geometric figures, and the locus at a point. KNEC (1995) observed that the question was poorly performed with a mean score of 0.59 out of 8. This implies that Loci is a challenging topic as indicated with 67% of the students who attempted this question being unable to score even a mark in the question.

There are sixty eight (68) topics that are covered in the secondary school mathematics syllabus from Form One to Form Four. KNEC chooses the topics to be tested annually ensuring to test all the levels of Benjamin Bloom taxonomy. The basic topics are tested annually and concepts that are challenging to the students repeatedly tested until the KNEC is satisfied that the concepts are fairly understood. Some topics are tested annually, with KNEC putting a lot of emphasis on given concepts. If all topics are given equal chances of being tested then every topic is supposed to be awarded approximately three marks from both Paper One and Paper Two combined. Table 5 shows the consistency testing of Loci by KNEC from 2012 to 2017 and the marks awarded to each question a given paper.

**Table 5: Testing of Loci and Marks Awarded at KCSE (2012- 2017)**

| Year | 2012 | | 2013 | | 2014 | | 2015 | | 2016 | | 2017 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Paper | P1 | P2 | P1 | P2 | P1 | P2 | P1 | P2 | | P1 | P1 | P2 |
| Question No. | 8 | 21 | 6 | 5 | 22 | 23 | 19 | 10 | 12 | 22 | 21 | 9 |
| Marks | 4 | 10 | 3 | 4 | 10 | 10 | 10 | 3 | 3 | 10 | 10 | 3 |

**Source: KCSE (2012 -2017) Mathematics Past papers**

In Table P1 and P2 denotes KCSE mathematics papers one and two respectively. Question No. denotes the question in the paper that tested loci. The marks represent the total marks awarded to the question. The Table shows that the topic Loci was tested annually from 2012 to 2017, indicating the importance attached to the topic. Students may have losta lot of marks in KCSE mathematics papers if the concepts of loci were not properly understood. For instance in 2014 a student would have lost a total of 20 marks in both paper one and two. This translated to 10% of the overall grade for a candidate in KCSE mathematics score in 2014. A loss of 10% in mathematics examination is a major concern that needs to be addressed seriously. The advice given to mathematics teachers is to ensure the students are taken through the concepts of construction in details and be given more practice and provide real-life practical examples (KNEC, 2007).

Mathematics is a difficult subject to learn as well as to teach (SMASSE, 2005). According to Salman (2005) students dislike certain topics in mathematics because they believe that they are difficult to learn, while the teachers also dislike teaching certain topics which they find difficult to teach. Kinyua, Maina and Ondera (2005) note that Loci is a topic that is sometimes labeled as difficult by many students. This is also supported by CEMASTEA (2009) who reported that teachers experience challenges in teaching Loci topic and learners have difficulties in learning the topic. Makueni County trainers carried out a Baseline Survey research on 10th May 2007 in Makueni County. One objective of the Baseline Survey research was to find out the topics that are challenging to students in Science and Mathematics. When the mathematics topics were arranged in order of difficulties, the topic of Loci was rated as the second most challenging topic in the Form Four mathematics syllabus (Makueni, 2007).

Vashist (2007) contends that there is no proof that any particular teaching method is the best in teaching a given subject in all situations across the topics. She further notes that teaching/learning methods need to be blended to suit the situation. Some of the teaching methods used in the teaching of mathematics include lectures, demonstrations, group discussions, question and answer, problem-solving, drill and practice, project work, programmed learning, experimentation, and games (Murphy & Moon, 2004). Mathematics has traditionally been taught using paper, pencil and chalkboard (Brown, 2006). If the issues of poor performance in mathematics are to be addressed then the teaching need more attention. Harbor (2001) asserted that the issue of poor performance in mathematics examinations was due to the problems of teaching methods. Teaching methods and techniques that appeal to multiple representations have been found to play a special role in students' mathematics achievement (Anika, Sebastian & Lerman, 2015). Mathematical concepts can only be accessed through representations, they are crucial for the construction processes of the learners' conceptual understanding (Duval, 2006). Using computers in mathematics teaching allow students to engage in those real world problems on a conceptual level that prepares them for life challenges. Computers uniquely allow combination of different representations that enriches mathematics concepts (Dreher & Kuntze, 2015). This helps teachers in designing mathematical activities that focuses on the main purpose of multiple representations in keeping pupils' interest.

The role of Information and Communications Technology (ICT) tools in the school's classroom has become prominent in primary, secondary education and tertiary institutions. Seyed and Sina (2013) views ICT as among the most novel scientific achievements of mankind which have apparently presented numerous capabilities to the human society and it is expected that they can be effective and useful in alleviation of the current problems of human society. For a country to compete effectively in the digital world, teachers need to play an important role in integrating computer technology into the curriculum (Magliaro, 2007). Despite the challenges of 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, Gambari, Falode and Adegbenro (2014) noted in their research that computer has been used in the developed countries to tackle most of the teaching and learning challenges since 1980s. when appropriate instructional method are used as noted by Anyagh (2006) then the ability to remember takes place more effectively as experiences are passed across to the learner. Computer has potential of arousing students' interest, motivation and achievement of better results (Yusuf & Afolabi, 2010). The 21st century children are growing up with different digital experiences and exposure than their teachers at all levels of learning institutions in many parts of the world (Jukes, 2008). They are then, more likely to be inspired and motivated by different technologies. Computer can also influence students' attitudes and interest towards mathematics which may positively affect their achievements and retention (Golden, McCrone, Walker & Rudd, 2006).

Computer Assisted Instruction (CAI) package can be used to teach all subjects including sciences and mathematics. Mathematics education embracing use of ICT in teaching and learning provide students with an opportunity to be successful in the 21st century (English, 2002). Mathematics is known to be of great practical value in scientific and technological fields (Ng'eno, Githua & Changeiywo, 2013). In mathematics education, technology is often viewed as a provider of learning devices and tools such as: calculators and computers which may be used in the classroom (Simonson & Thompson, 1997). Computer technology has great potential to impact the teaching and learning of mathematics, but the presence of its hardware does not automatically produce desirable schooling outcomes in mathematics education (Li, 2004). The increased use of computer technology in education institutions has been incorporated as a way to improve educational opportunities, while enhancing student performance (Picciano, 1994). ICT gives rapid and accurate feedbacks to students and this contributes towards positive motivation. These agrees with Sottilare and Gilbert (2011) who observed that CAI can be used to provide opportunities for students to learn using drill and practice, tutorial, games and simulation activities, animation, and among others. The National Council of Teachers of Mathematics (NCTM, 2000) in support of Picciano's views emphasized the importance of the use of technology in mathematics education, stating that "technology is essential in teaching and learning mathematics for it influences the mathematics that is taught and enhances students' learning". PowerPoint and CD-ROM tutorials have been incorporated into teaching to address the unique characteristics of technologically-competent millennial learners who prefer active learning, group activities and instantaneous feedback (Hunter & McCurry, 2013).

Successful and effective use of technology for the teaching and learning of mathematics depends upon sound teaching and learning strategies that come from a thorough understanding of the effects of technology on mathematics education (Coley, Cradler & Engel, 2000). Simulations and animations bridge the gap between the concrete world of nature and the abstract world of concepts and models (Yair, Mintz & Litvak, 2001). Computer animations have been studied in teaching and learning and found to help students confront and correct the errors and students' mathematics misconceptions (Zietsman & Hewson, 1986).The errors and misconceptions that students often make, may involve vital learning concepts which may prevent meaningful learning. Studies by Jiang and Potter (1994) supported the potential of computer animations in helping accomplish needed conceptual change and avoid misconceptions.

It is against this backdrop that the study chose to explore the use of Computer Animated Loci Teaching Technique for teaching loci a geometry topic and then find out whether using the technique would improve students' mathematics achievement and reduce learners' misconceptions in mathematics. The main concern is to investigate whether the approach would ultimately improve the sorry state of Mathematics performance at KCSE level. Another concern is the challenge of Integrating ICT) into classroom teaching and its potential impact on the nature of learning and on the relationship between curriculum and pedagogy (Alakanani, & Liu, 2013).

## 1.2. Statement of the Problem

Mathematics is important for understanding other academic disciplines such as science and technology, medicine, economics, and engineering among others. Despite the importance attached to mathematics, it is generally performed poorly globally, regionally, nationally and specifically in Kitui County with boys' performing slightly better than girls. Some of the reasons for the learners' mathematics misconception and poor performance in the subject have been argued to be unsuitable teaching methods and lack of teaching and learning resources among others. Some topics in mathematics are quite challenging to teach and learn among them being "Loci" a geometry mathematics topic that is taught to Form Four students. If mathematics concepts are not well understood they could lead to misconceptions and hence poor performance. Computer Animations have been used in some mathematics topics such as Three-Dimensional Geometry with promising results. In an attempt to seek a teaching technique that can improve learners' mathematics achievement and reduce the mathematics misconceptions they hold, the Computer Animated Loci Teaching Technique was used during instruction of the "Loci" topic. Traditional approaches to learning geometry emphasize more on how much the students can remember and less on how well the students can think and reason. To close the gap such that students' mathematics achievement is improved and their mathematics misconceptions reduced then, this research investigated the effects of the use of Computer Animated Loci Teaching Technique on secondary school students' achievement and misconceptions in mathematics within Kitui County, Kenya.

## 1.3. Purpose of the Study

The purpose of this study was to investigate effects of the use of Computer Animated Loci Teaching Technique on secondary school students' achievement and misconceptions in mathematics within Kitui County, Kenya.

## 1.4 Objectives of the Study

The following objectives guided the study:

i) To establish the effects of the use of Computer Animated Loci Teaching Technique during instruction on secondary school students' mathematics achievement mean score**,** in "Loci" a geometry topic.

ii) To establish the effects of the use of Computer Animated Loci Teaching Technique during instruction on secondary school students' mathematics misconceptions**,** in "Loci" a geometry topic.

iii) To determine whether there is gender difference in Student's Mathematics achievement when they are taught "Loci" a geometry topic using Computer Animated Loci Teaching Technique during mathematics instruction.

iv) To determine whether there is gender difference in Student's Mathematics misconceptions mean score in the topic "Loci" a geometry topic when they are exposed to Computer Animated Loci Teaching Technique during mathematics instruction.

### 1.5 Hypotheses of the Study

The following null hypotheses were statistically tested at coefficient alpha (α) level of a value equal to 0.05.

**$H_O$1:** There is no statistically significant difference in the mathematics achievement mean scores between students exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci.

**$H_O$2:** There is no statistically significant difference between the mathematics misconceptions mean scores held by students exposed Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci.

**$H_O$3**: There is no statistically significant gender difference in mathematics achievement mean scores among secondary school students when exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci.

**$H_O$4**: There is no statistically significant difference between the misconceptions mean score of male and female students when exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci.

### 1.6 The Significance of the Study

The findings of this study are likely to benefit the society at large considering that mathematics plays an important role in science and technology. Particularly it may benefit the secondary schools students and mathematics teachers during mathematics instructional process in general and geometry in particular. The other likely beneficially include teacher training colleges and universities in Kenyan as they prepare mathematics teachers. The SMASE programme as it engages teachers in ways of improving teaching methodologies through creative innovations of making teaching and learning resources and improvisation of teaching models. The greater demand for good performance in mathematics justifies for more effective and life-changing teaching approaches. Thus, schools that apply the recommended approach of computer-animated technique will be able to teach their students in a better way and hence improve in mathematics performance. For researchers, the study will help them uncover critical areas in the education technology that many had not explored. Animating the mathematics concepts is a technical process and requires expertise in computer technology. This opens a door to a partnership between mathematics teachers and computer graphic designers to improve mathematics teaching/learning. This may lead to a good business venture. Finally, the outcomes of the study adds to the growing body of research on learning mathematics with animation and learning in general, by illustrating the use of an animation technique in relaying the culturally relevant visual aesthetics for curriculum-based content to address gaps in conceptual mathematics understanding.

### 1.7 Scope of the Study

The study focused on Form Four students from four Co-educational schools in Kitui County of Kenya. The Co-educational schools were selected on the bases of them forming the bulk of the secondary school students. The County was selected because of its poor performance in mathematics as evident from the past KCSE examination results. The topic covered in the study was Loci, consisting of prerequisites knowledge to Loci; Definitions of Loci; common types of Loci and application of Loci to real-life situation as stipulated in the (KIE, 2002) mathematics syllabus and mathematics teachers' guide (KIE, 2006). The topic was selected because of the students' poor performance in the topic at KCSE examinations as noted by KNEC (2013). The baseline survey by Makueni (2007) placed Loci as the second most challenging topic in form four after linear programming. This agrees with Kinyua *et al*.

(2005) who observed that the topic “Loci” was challenging to students. Animations of the geometrical concepts were extensively covered in both two and three-dimensional geometry.

### 1.8 Assumptions of the Study

In the study, it was assumed that:

(i) The mathematics teachers in experimental groups would cooperate and carry out the interventions according to the Teaching Module (Appendix-C). By adhering to script on Computer Animated Teaching Technique (Appendix-E) to the latter then we may get genuine results for the study. Supervision of the examination is vital and is assumed that the teachers will strictly adhere to the examination rules and regulations.

(ii) The respondents would willingly participate in the research and provide honest responses.

### 1.9 Limitations of the Study

The study never covered all categories of secondary schools and as such generalization of the results was therefore confined to Co-educational Secondary Schools in Kitui County. The study did not cover the full cohort in secondary education cycle and as such, the generalization of the findings was limited to Form Four students in Co-educational Secondary Schools. The topic covered was “Loci” a subset of Geometry. The findings are confined to Geometry in general and Loci in particular. The generalization to other counties and other mathematics topics should be done cautiously.

## 1.10 Definition of Terms

The following operational definitions were used in this study:

**Computer animation:** The art of creating or manipulating electronic images by means of a computer in order to create moving images (Alakanani & Liu, 2013). In this study computer animation referred to manipulation of geometrical figures to make them move in order to display pre-determined Loci characteristics for study.

**Computer-Assisted Instruction (CAI)**: Refers to use of computers to present drill-and-practice, tutorial, or simulation activities offered either by themselves or as supplements to traditional, teacher-directed instruction (Usun, 2004). In this study CAI referred to animations and simulations activities that were teacher directed instructions.

**Computer simulation:** Refers to use of a computer-generated system to represent the dynamic responses and behaviour of a real or proposed system (Alakanani & Liu, 2013). In this study computer simulations were used to denote Loci real-life activities that were computer generated.

**Conventional Teaching Methods:** According to Mallet (2007), conventional teaching methods are the teacher- centred traditional methods of instruction used in a mathematics classroom. In this study it referred to other teaching methods used to teach mathematics such as lecture and worked out examples which are mainly teacher centred with exceptional of use of computer animations on loci concepts.

**Geometry**: is concerned with obtaining insights into shapes, the nature of space and visual phenomena (Malkevitch, 2013). In this study geometry implied collections of topics taught in secondary school curriculum dealing with construction of two and three-dimensional figures.

**Gender:** Either of the two sexes (male and female), especially when considered with reference to social, cultural and biological differences. (Farlex, 2017). In this study gender referred to the characteristics associated with being male or female.

**ICT:** Is the abbreviation for Information, Communications Technology "ICT" means Information and Communication Technology and refers to the combination of manufacturing and services industries that capture transmit and display data and information electronically (Saitis,2000). In this study ICT referred to the tools that were used in teaching Loci such as Computers, LCD projector, Video camera among others.

**Learning/teaching resources:** Refers to facilities and resources available for teaching and learning such as textbooks, teachers and time (Ruthven, Hennessy& Brindley, 2004). In this study teaching/ learning resources referred to human as a resource and the tools used in teaching mathematics such as textbooks, computers, calculators, and projectors among others.

**Loci:** Locus (Loci in plural) is a Latin word which means “place” (Robert and Glenn, 1992). In this study loci referred to paths traced by points, lines and planes in geometrical construction that is taught in secondary school mathematics. Loci was used to refer to the mathematics topic of geometry taught to Form Four students in secondary schools.

**Manipulatives:** Refers to objects that appeal to the senses and can be physically or mentally moved or touched as in blocks, computer images, or Touch-points (Aburime, 2009). In this study manipulatives referred to computer animated and simulated graphic designs that the students and teachers used in teaching and learning Loci.

**Mathematics achievement:** This is a measure of the degree of success in performing tasks in mathematics after teaching or instructions (Farlex, 2017). In this study it referred to performance in mathematics examinations measured in percentage scores in a mathematics test or a national examination (KCSE).

**Mathematics Classroom Environment:** Refers to teachers and students’ activities; discussion, time, language, and instructional materials used during mathematics lessons (Cross, 2009). In the study this referred to all the activities that go on in class when teaching and learning is taking place.

**Mathematical misconceptions:** Are Systematic and recurrent wrong responses methodically constructed and produced by students when they respond to mathematical questions (Green, Piel & Flowers, 2008). In this study mathematical misconception referred to wrong and erroneous working which students portray emanating from methods used in Geometry to solve problems.

**Misconception:** Refers to "a line of thinking by learners that causes a series of errors all resulting from an incorrect underlying premise, rather than sporadic, unconnected and nonsystematic errors" (Mathematics Navigator, 2016). In this study misconception referred to wrong responses students gave that were methodically constructed when learning.

**Students' mathematics achievements score:** An achievement score is a piece of information, usually a number that conveys the performance of an examinee on a test (Kolen &Brennan, 2004).). In this study it means students' score in a mathematics test based on Loci a topic taught in Form Four class in Kenya's secondary school.

**Students' mathematical misconception score:** An arbitrary measure assigned to a misconception for analyses purpose (Sanger & Greenbowe, 1997). In this study it means a number assigned to mathematics misconceptions held in Mathematics Achievement Test (MAT) based on Loci a mathematics topic taught to Form Four students.

# CHAPTER TWO
# LITERATURE REVIEW

## 2.1. Introduction

This chapter presents a review of literature on the role of mathematics in society; definition of mathematics, mathematics for daily life, mathematics as part of cultural heritage – aesthetics and recreation, mathematics for workplace and for professionals, importance of teaching mathematics in society and mathematics misconceptions in society are discussed. The abstract nature of mathematics and how to overcome it through effective teaching, the mathematics concepts and their formation, the learners' mathematics misconceptions, and analysis of students' misconceptions in mathematics are also discussed. Students' mathematics achievement, students' mathematics assessment, gender differences in mathematics achievements, approaches, strategies, methods and techniques of teaching mathematics, mathematics teaching-learning resources are discussed. Use of information and communication technology use in mathematics education, computer animations, geometry and loci topic are discussed and finally the theories of learning mathematics, theoretical framework of the study and conceptual framework of the study are discussed.

## 2.2 Role of Mathematics in the Development of Society

The involvement of a society in mathematics is determined by cultural has its own intrinsic beauty and aesthetic appeal, but its cultural role is determined mainly by its perceptions of society member. The achievements and structures of mathematics are recognized as being among the greatest intellectual attainments of the human being, therefore, are seen as playing a key role in the development of the society. Furthermore the potential for sharpening the wit and problem-solving abilities fostered by study of mathematics is also seen as contributing significantly to the general objectives of acquiring wisdom and intellectual capabilities of the members of the society.

### 2.2.1. Definition of Mathematics

Rising and Johnson (1972) defines mathematics as a way of thinking, an organised structure of knowledge, a study of pattern, a tool/instrument, an art and a Science.  Mathematics can generally be defined as an art and science of communicating logically using numbers and symbols to solve abstract or real-life problems. Kafata and Mbetwa (2016) emphasised that mathematics being one of the oldest fields of study in the history of mankind then it forms the most central components of human thought. Mathematics sharpens the human mind, develops their logical thinking; enhances their reasoning ability and spatial power. OECD (2003) looks at mathematics literacy as being able define and shape an individual's capacity to identify and understand the role that mathematics plays in the world, in making well-founded judgments. The same view share by Katrin and Äli (2014) who note that the usage and engagement in mathematics activities meets the needs of that individual's life as a constructive, concerned and reflective human-being.

### 2.2.2. Mathematics for Daily Lives

George and Kutty (2015) argued strongly that mathematics is not only needed by an academicians; scientists; engineers; but also shopkeepers; grocers; housewives; sportsmen and even employee needs it; and who does not? Just like a language, we need mathematics to communicate. Any person ignorant of mathematics will be at the mercy of others and will be easily cheated. Kelly (2013) noted that each society has their own mathematical languages, terms, symbols and counting system. Countries such as Chinese, American, Japanese and Arabian among others in have different mathematical systems such as counting all contributing to mathematical knowledge worldwide. Mathematics is crucial in counting which has vital role in our daily life; just imagine if there were no mathematics at all, it would not be possible for us to count members of the family, number of students in the class, money in the pocket, scores in a games, days in a week or in a months or years. EU (2011) viewed mathematical numeracy, analytical, computer digital competences and an understanding of science as vital for full participation in the knowledge society and for the competitiveness of modern economies.

Acharya (2017) described ancient mathematics scholars as being passionate about developing mathematics practically based on the day-to-day problems. Some of the day-to-day activities in human life are buying and selling which involve money truncations. Managing ones budget, saving money and requesting loans are all to do with mathematics. In all these aspect, there are financial estimations, calculation of simple interest and compound interest, tax calculation (Salomon, 2002). Before establish business, you must estimate the cost to manufacture or acquire product or perform service. All expenses associated with buying or selling items helps in realizing if ones business is competitive with other businesses and profitable enough to sustain the business and make a reasonable income. Putting into consideration the costs of production, such as materials and machinery, shipping, labour, interest on debt, storage and marketing requires mathematics (Salisu, 2013). The basis of business plan is an accurate representation of how much is to be spent on each item and the likely profit to be made in each item.

Mathematics is used when buying different items in shops and supermarkets some of which end up in the kitchen for preparing food. People use mathematics knowledge when cooking. The topics such as mixture, proportion, rates, percentage, measurements, integer and fractions among others are very useful in food and beverages preparation. Recipes are mathematical algorithms or self-contained, step-by-step sets of operations to be performed (Sidhu, 1995). There are more mathematics found in the kitchen than anywhere else in the house in terms of cooking and baking. Food and beverages is an industry that uses sciences and mathematics in ensuring quality and healthy products. The processing of food products is a complex, expensive, risky process and special requirements should be considered in this process, such as consumer demands, price, operational conditions and legislation background (Bas & Boyaci, 2007). Calculating cooking time per each item and adjusting accordingly improves the quality of food as noted by Trevisan and Areas (2012). The typical production conditions can only be optimum if the right temperature isachieved. This makes mathematics part and parcel of the kitchen for quality, healthy and delicious meals are to be realized**.**

#### 2.2.3. Mathematics as Part of Cultural Heritage – Aesthetics and Recreation

Barton (1996) defined culture to consist of the values, beliefs, systems of language, communication and practices that people share in common and that can be used to define them collectively. Culture also includes the material objects that are common to that group or society. D'Ambrosio, a Brazilian mathematician, coined the term "Ethno-mathematics" in the 1980s and defined it as the way different cultural groups use mathematics to count, measure, relate, classify and infer (D'Ambrosio, 1984). Mathematics is one of the greatest cultural and intellectual achievements of human-kind and citizens should develop an appreciation and understanding of that achievement, including its aesthetic and even recreational aspects. Alan Bishop, noted that ethno-mathematicians have suggested that people across the world and throughout time have used mathematics to count, measure, design, locate, explain, and play (Bishop 2000). Mathematics is used in almost every aspect of human being, thus making it part and parcel of human culture.

Aesthetics is about the principles that govern and define beauty as an art of creativity, innovation and making something better (Blasjo, 2012). While mathematics is about numbers, equations, theorems, logic and proofs (Aberdein, 2013), aesthetics is about the beauty in the society (Gagliardi, 1997), when mathematics and aesthetics are combined they form the beauty we see in the plane figures in our society. Mathematics aesthetic has long been claimed to play a fundamental role in the development and appreciation of mathematical knowledge. It is important to note that the amusement found in games, the elegance and gracefulness of mathematical relationships touch our emotions, much like music and art; they can reach inside the psyche and make us feel truly alive (Clawson, 2004). If art is about creating something that will make an aesthetic appeal to us, something beautiful, then mathematics is about representing that 'Creation' in numbers, equations and dimensions, thus make it measurable, re-creatable, scalable, make it understandable by simplifying the design and breaking it into smaller pieces for a 'not-so-creative' person to understand (Blasjo, 2012).

A good painting is said to be beautiful based on what we see; a good sculptured figure is said to be beautiful based on what we see, touch and feel; when we hear a good song we either feel good about the composition or the lyrics or the use of notes or the tempo, everything we hear will add to its beauty. An aerodynamically designed car, a well architecture house, a well-designed chair, a bunch of colorful flowers, nicely painted walls of a room, an origami made out of color papers, the texture of a greeting card, a symmetrically designed 3-dimensional structure among others are examples where beauty in mathematics is displayed(Stigler & Hiebert, 1999). In this study the mathematics aesthetic was displayed in the animations of various real life concepts in Loci.

In USA, graffiti has been used as cultural simulations with students expressing their artistic skills crosses all race, class, and gender barriers (Lin, 2011). He noted in his study that culture is global, through examples of graffiti everywhere in other countries such as Iran and Costa Rica. Graffiti helps to promote positive social values as well as highlight geometric traditions invented by and for the youth themselves. Roy (1990) asserts making a connection between graffiti and mathematics provides a strong learning motivation for many students, particularly those in urban and inner-city settings. He observed that the mathematical connections made included Cartesian mapping, geometry as well as polar coordinates, linear spirals, and logarithmic spirals made using computer graphic software.

Ghana is rich in cultural artwork of the Asante people who provide the context for Symbols. These symbols are stamped across cloth by skilled artisans and they convey traditional ideals and beliefs that connect to local proverbs (Kuntaa, 2012). In making the art exploration of concepts in geometry, measurement, plane figures and data analysis is done as they examine the many ways mathematics is used to create art, communicate and maintain their culture. Gerdes (1999) indicates that the people of Africa south of the Sahara Desert constitute a vibrant cultural mosaic, extremely rich in its diversity. Among these people are a variety of geometrical ideas as manifested in the work of wood and ivory carvers, potters, painters, weavers, mat and basket makers. Many other laborious and creative African men and women just like South African contribute creatively to these geometrical shapes as evident in their clothing and household goods. Gerdes (1995) had earlier alluded to the work that women do in artifacts like decorated handbags, coiled baskets, string figures, decorated pottery, grass brooms, tattooing and body painting, bead ornaments, and mural decorations. The Tonga women are known for constructing and decorating round huts using different geometrical shapes in Zimbabwe. Zaslavsky (1994) used the shapes of the Tonga houses to motivate learners to calculate the maximum area that were to be occupied by a given perimeter. This way of calculating mathematics challenges gave the learners an opportunity to accept and appreciate mathematics as a cultural product.

Mathematics is one of the greatest cultural and intellectual achievements of human-kind and everyone should develop an appreciation and understanding of that achievement, including its aesthetic and even recreational aspects (Roy 1990). Mathematics plays a key role in sports. Construction of the fields and courts used in sports and games involves mathematics measurements, plane shapes and common solids. Sports fields include soccer, handball, rugby, hockey and athletics among others while some of courts include volleyball, basketball badminton and Tennis court Briskorn (2009). Mathematics plays a critical role in our recreational activities which include video games, computer games, puzzles, riddles, hockey, cricket, kho- kho, kabaddi, football, basketball among others (Roohi, 2017). Coaches constantly try to find ways of getting the best out of their athletes and sometimes they turn to mathematics for help (Briskorn & Knust, 2010). Geometry and trigonometry has been used in finding the angle of trajectory in Discus Throws that gives the longest range. Sarafian (2000) observed that scoring in soccer requires a lot of calculations of speed, vertical and the horizontal distance of a projectile. Mathematics is also used in ranking players and determining playoff scenarios. Matrix, Statistics and Formulas are something used to determine a players or teams order of play (Anderson, 1989), mathematics is an integral part of games and sports activities. In this study the geometrical shapes used in the animations reflected the real-life scenario representing the beauty of our culturally reach environment which the students can easily identify with.

### 2.2.4. Mathematics for Workplace and for Professionals

Odom (1998) emphasized that on a basic level everybody needs to be able to count, add, subtract, multiply and divide. The knowledge of mathematics, its fundamental processes and the skills to use them are the preliminary requirements of human being (Sidhu-1995). British Academy (2012) contends that mathematics address society needs especially in the workplace, in professional areas ranging from healthcare to graphic design. Fleischman, Hopstock, Pelczar and Shelley (2010) ascertain that the ability to compute using technology and the geometrical understanding of space-time, that is the physical world and its natural patterns, show the role of mathematics in the development of a Society**.** Mathematics underpins a wide range of activities that benefit society, including engineering, economics and computer technology. As technology continues to play an increasingly vital part in virtually every aspect of modern society, mathematics continues to be indispensable (Kelly, 2013). The ambitions of a Country determine the place of mathematics in that society. Mathematical competence is essential in preparing citizens for employment and it is needed to ensure the continued production of highly-skilled persons required by industry, science and technology (House, 2006).

A national campaign is needed in USA to inform parents, students, educators, and the general public about the importance of mathematics and science learning in the changing society (Gainsburg, 2005). Parents need to learn that while they may not have needed a high-level mathematics and science background to be “successful” in life, their children will. Pew Research Centre (2018) found out that jobs employment in USA requiring higher levels of social or analytical skills is concentrated in more rapidly in the growing sectors of the economy. Norris (2012) on the other hand noted that jobs requiring higher levels of analytical skills generally pay more than jobs requiring higher physical skills. Hodgen and Marks (2013) in ascertaining the importance of mathematics in the society noted that it is generally agreed that mathematics is a critical skill for all citizens in UK, including to those who have not achieved a Grade C at GCSE by age 16. A further argument is put forward that in today's world of 'rapid change' (ACME, 2011), particularly in terms of technological change, the demand for mathematical skills is increasing (Norris, 2012). Even though a good percentage of people are unaware of the relations between Society and Mathematics, it does not mean that the relations are insignificant. The structure and functioning of the society is highly depending on mathematics. The societies need intelligent people who can address the daily challenges facing them. Mathematics occupies a crucial and unique role in the human societies and represents a strategic key in the development of the whole mankind (Boydm & Richerson 2009). In this study the importance of mathematics in the society is demonstrated in the use of the study topic in the day to day life. The topic plays a vital role in employment industry especially in the building and construction industry. The road networks, the Standard Gauge Railway (SGR), buildings, household goods among others are all manifestation of geometry at work in our society. There many professionals whose daily bread comes from mathematical concepts.

### 2.2.5. Importance of Teaching Mathematics in Society

Mathematics is an important subject globally. Hodgen and Marks (2009) argued that all children should be taught mathematics because it is a very important and necessary life skill that one cannot do without. Hence globally, mathematics is compulsory from kindergarten to college (Ding, Song, & Richardson, 2007). This has a worldwide teaching of mathematics as noted by George and Kutty (2015) with little or no effort made to show its social history, its significance to human lives and its dependence to mankind civilization. Acharya (2017) noted mathematics has been accepted as an important component of formal education from ancient period to the present day. Sunzuma *et al*. (2013) further added that mathematics in general is linked with the development of any nation in the world. Mathematics permeates the whole society and its use seems to assume an ever-increasing importance as our societies become more technological (Azuka, 2000).It is not possible do away with mathematics. This is echoed by Kiamanesh (2006) who posited that mathematics is not just an important subject in the school's curriculum but an important body of knowledge and skills applicable to daily life.

The National Research Council (1989) reported that students learn mathematics well only when they construct their own mathematical understanding and that this understanding requires them to examine, represent, transform, solve, apply, prove and communicate. The report also indicated that mathematics is important and of significant value to all irrespective of gender, socioeconomic status and background. Mathematical competence has been identified by the European Parliament and the Council of the European Union as one of the key competences necessary for personal fulfillment, active citizenship, social inclusion and employability in modern society. In the year 2008 Council of European Union concluded that to prepare young people for the 21st century then, the acquisition of mathematics literacy and numeracy should be the main priority for European cooperation in education (Wiśniowski, 2009). Mathematics should develop critical reasoning, inference and analytical skills in learners as posited by Goldin (2003) in his study of the role of mathematics in students' individual growth.

Steen (2001) argued that teaching mathematics empowers people with the capacity to control their lives and also provides science a firm foundation for effective theories; it also guarantees society a vigorous economy with many opportunities for advancement. In Germany there is promotion of a comprehensive approach to mathematics teaching where federal institutions launched a programme called SINUS to increasing the efficiency of teaching mathematics and science. The aim of the programme, which is organised at the state level, is to make the teaching of mathematics and sciences more effective (EU, 2011). Mathematics teachers across the Western world are faced with an expectation that they make significant change to their teaching techniques, but repeated attempts have shown little success (Golding, 2017). Recent years have seen global education policy attempt to move school mathematics learning towards deep conceptual understanding, rigorous reasoning and genuine problem solving, in response to the perceived needs of 21st-century society. Such changes, although widely embraced as noted in EU (2014) have proved highly challenging.

Teaching Mathematics in African Countries has a lot of importance attached to its professional courses. Ethiopia, South Africa, Malawi, Kenya, Morocco, Nigeria, Egypt, Senegal, Ghana and Botswana among others African countries, being aware of the importance of teaching mathematics and its importance to development have in their development agenda put every effort to improve both primary and secondary school education in mathematics (IMU, 2014). This is done through programmes such as SMASE, SAMSA, AIMS and facilitating international and regional conferences on mathematics education. Mathematics is an important subject whose knowledge enhances a person's logical reasoning, problem-solving skills and in general, the ability to think critically. Hence it is important for understanding other academic disciplines such as science and technology, medicine, economics, and engineering. Cockcroft (1982) stated that every child should study mathematics at school. He noted that most people regard the study of mathematics, together with that of science as being essential. Mathematics as a discipline opens and shuts more doors for men and women than any other content academic discipline (Burton, 1999). Whether it's in science, engineering or technology, it is important that a person be well-armed with mathematics if they are going to have a variety options in their lives (Thompson, 1993). In Kenya the importance attached to mathematics is seen in various facets. Mathematics forms basic education in Kenya institutions of learning. Most of the courses offered in the high institutions require mathematics (JAB, 2013).In this study the importance of teaching mathematics was emphasised in its application to real-life situation problems solved in loci which show the importance of mathematics in general and loci in particular.

#### 2.2.6. Mathematics Misconceptions in society

Mathematics knowledge in many ways informs our decisions in areas of our lives. Golding (2017) sees teaching and learning of mathematics as being at the heart of education. IMU (2014) describe the sole purpose of learning mathematics as to link school mathematics to everyday real life problems that need mathematical solutions. Ontario Ministry of Education (OMoE) (2005) observed that the purpose as to provide skill acquisition, prepare students for the workforce and foster mathematical thinking. Dewey (1915)cited in Haynes (2007) lamented the learners' inability to utilize the experiences they gets outside the school in any complete and freeway within the school itself; while, on the other hand, they are unable to apply in day-to-day life what they are learning in school. That is the isolation of what is learnt in school from what goes on in real life. Students have issues with some of the mathematics topics taught and they wonder where in their day to day life after school they will apply them. George and Kutty (2015) emphasised that the mathematics that is taught in the classroom should cater for the need of every individual and they should apply what they have leant in future in their working places.

When concepts are misconceived during teaching it may pose challenges late in life if no remedial measures are taken. Although the concepts of area and perimeter are widely used in everyday life, there are misconception held in the land adjudication (Watson, Jones and Pratt, 2013), this happens when members of the society want sub-divide a piece of land without involving a professional land surveyor. Asyura et.al (2017) gives an acre of land to be usually taken to be a square of 210 ft by 210 ft or approximately 70 steps by 70 steps. It is a common misconception in traditional land sub-division to find that if the land is not a square the remaining length is added to the longer side to complete the measure. For instance in a field measurement we may have an acre given as 50 steps (70 – 50 = 20) steps by 90 (70+20) steps. In working the size of an acre this way the concept of area is completely misconceived. The area of an acre should be 4,900 square steps. The area arising from the misconception is 4500 square steps which meant the buyer 400 square steps. The correct procedure would have been 50 steps by $\frac{4900}{50}$= 98 steps. These would give the same area as a squared acre.

Weight is not the same as mass, yet even among the people who went to school and learnt the topics on weight, mass and density; we still find them using the terms synonymously. A teacher may have taken time to explain the difference between weight and mass, only for learners to hold a misconception and use the two interchangeably when measuring. Transfer of misconceptions can be especially detrimental to student learning and future application of the concepts at workplace (Colgan, 2014). It is a common practice in society to give the weight of a sack of maize as 90 kg, whereas weight is a force, mass is the quantity of matter in the substance. Lave (1988) observed various groups of people at work and showed that the mathematical knowledge and skills utilised by some shoppers and weight watchers, bore little resemblance to the mathematical routines, procedures and even formulae taught in school. Beam balances are used to measure mass. In many market places in Africa tins of various volumes are used to measure mass of items being sold such as beans, maize, pigeon pea and ndengu among others (Rossi, Cesare, Flavio, Russo & Ferruccio, 2009). By using the tins, the volume of the item is measured and not the mass, this represents a misconception held by the business community about mass and volume.

Mental mathematical skills are important and are often used in commerce, work and everyday activities, yet many students are calculator dependent. Victoria State Government (2009) advocated for use of mental mathematics strategies in school for they are different from paper and pencil strategies and need to be cultivated in all students. Government argues that students should be taught mental mathematics strategies and to develop these strategies at school throughout the grades. Workers, past and present, generally do not regard what they do in the place of work as being mathematics nor themselves as being mathematicians (Wedege, 2011). This has resulted to mathematics misconceptions held by members' society as manifested in their workplaces. In this study, the mathematics taught in school was linked to the real-life situations and their application to the workplace and misconceptions held by students addressed. This ensured they do not transfer misconceptions to their place of work in future. The use of ICT reduces the mathematics misconception held by students. Animations were intensively used in this study.

## 2.3. Abstract Nature of Mathematics and How to Overcome it through Effective Teaching

Roschelle, Pea, Hoadley, Gordin and Means (2001) sees abstraction of mathematics concepts as a potential barrier that prevents learners understanding of mathematics subject matter. Jebson (2012) observed that Science in general and mathematics in particular has consistently been criticized by students and teachers alike to be full of abstract ideas. Ernest (1998) agrees with Jabson that mathematics is perceived to be full of abstract concepts; in additional the society at large sees mathematics as cold and inhuman. The narrative mathematics being abstract and inhuman subject is also advanced by Wong (2005). This has greatly affected public image of mathematics negatively and its objective questioned. If people want to give an example of a difficulty and impossible subject, mathematics features prominently. This has made mathematicians to be often perceived to as human beings born with special talents in logical reasoning and skillful manipulation of arcane symbols.

Jinfa, Kaiser, Perry and Ngai (2009) noted reluctance to teach and encourage students to learn abstract principles evident, especially in the Australia and USA. The Chinese teachers however, believe that even young children can understand abstraction and that concrete experience only serves as a mediator for understanding (Stigler & Perry, 1988). Students retain more content and learn more effectively when they are actively engaged in their own learning (Wolfe, 2001). Majority of Nigerian school children generally dread mathematics. Most of them consider it difficult, complex and abstract. Worse still, many students do not immediately see the use or applicability of the subject to their lives and to the world of work and so wonder why they should be troubled with the study of the subject (Okafor & Anaduaka, 2013).

Wolfinger and Stockard (1997) emphasizes that to develop an understanding of mathematics on the part of children there is need to use familiar examples in order to develop abstract concepts. Roschelle *et al.* (2001) indicated that when abstract ideas are made tangible, teachers can easily build upon students' prior knowledge and skills, emphasize the connections among mathematical concepts, connect abstractions to real-world settings, address common mathematics misconceptions and introduce more advanced ideas. Salman (2004) noted that when students are presented with mathematics problems and are first allowed to develop a concrete understanding of the mathematics concept, then they are likely to perform better in that mathematical problem or skill and understand mathematics concepts at the abstract level. Skemp (1982) noted that students who have previously displayed proficiency at using algebraic techniques often have difficulty in applying these techniques in unfamiliar contexts. He attributed this to students' failure link the new context to tangible prior knowledge. When teachers use instructional methods and techniques linking student's prior knowledge then the students are likely to handle familiar concepts and easily apply the same to unfamiliar situations (Even, 1990).

Fasasi (2009) observed that using teaching techniques without the correct modes of mathematical concepts representations is one of the major contributory factors to learners' inability to comprehend abstract mathematical concepts that lead to poor performance in mathematics. The abstract nature of mathematics and its focus on problem-solving requires exposure of mathematics teachers to instructional techniques that could assist their teaching of mathematics especially those concepts perceived difficult to teach (Salman, 2004). Teachers who only work from the textbook or merely explain worked example in textbook as noted by Ainsworth (2006) do not offer a very abstract approach to the classroom. However, innovative teachers who look for new ways to implement technology in the classroom often help students pick up on abstract ideas. By presenting information in various ways, from readings and discussions to videos and computer applications, teachers utilize abstract thinking that extends beyond the concept. Advancements in technology have given teachers new ways of expanding on materials, allowing teachers more freedom in presenting information and giving students more chances to get involved.

Many mathematics concepts are difficult for students to fully understand. To unpack the abstract mathematical concepts for learners to understand and use them correctly, Tripathi (2008) emphasized that using "different representations is like examining the concept through a variety of lenses, with each lens providing a different perspective that makes the concept richer and deeper". A representation is defined as any configuration of characters, images and concrete objects that can symbolize or "represent" something else (Goldin, 2003).Oftentimes, rote memorization is not enough for students to succeed. Students must develop critical-thinking skills to carefully evaluate information and solve abstract problems with more than one possible option. The more students understand the process of thinking through problems and bringing in several possible answers, the better they will become at thinking outside the "box". Teachers should use all the famous five modes of mathematical concepts representations. Representations are useful in all areas of mathematics because they help us develop, share, and preserve our mathematical thoughts. They help to portray, clarify and extend a mathematical idea by focusing on its essential features (NCTM, 2000).

Under visual representation, illustrations such diagrams, pictures, numbers, lines, graphs and other drawings are used to show or work with mathematical concepts. Ainsworth (2006) observed that students who use accurate visual representations are six times more likely to correctly solve mathematics problems than are students who do not use them. This agrees with Boonen, van Wesel, Jolles and van der Schoot (2014) who noted visual representation help student to interpret and hence solve problems accurately. They also observed that students who use inaccurate visual representations are less likely to correctly solve mathematics problems than those who do not use visual representations at all. Students must first know what type of visual representation to create and use for a given mathematics problem before they attempt the problem. Some students, especially high-achieving and gifted students are able to visualize the representation automatically, whereas others need to be explicitly taught how. This is especially the case for students who struggle with mathematics and those with mathematics learning difficulties. Without explicit, systematic instruction on how to create and use visual representations, these students often create visual representations that are disorganized or contain incorrect or partial information. When students are able to represent a problem or mathematical situation in a way that is meaningful to them, the problem or situation becomes more accessible. Using visual representations helps students organize their thinking and try various approaches that may lead to a clearer understanding and solve mathematical problems correctly.

Verbal representation includes phrases and sentences. Words are essential in communicating mathematical ideas and in thinking about them. Students use language to interpret, discuss, define, or describe mathematical concepts, bridging informal and formal mathematical language. Van der Walt (2009) observed that developing the language of mathematics is an essential aspect of teaching mathematics to young children. He also noted that this development continues throughout an individual's mathematics education. Students often confuse the meanings of the same word when used in everyday situations and in mathematics. The word "root" is used in day to day life to mean part of the tree that under the ground, while mathematically the same word is used to mean solutions to a cubic or quadratic equation. This problem becomes more acute when students learn mathematics in a foreign language or meet unfamiliar terms.  Although the language of mathematics can be confusing (Rubenstein & Thompson, 2002), it is necessary for the communication of higher order mathematics reasoning (Sloyer, 2003).

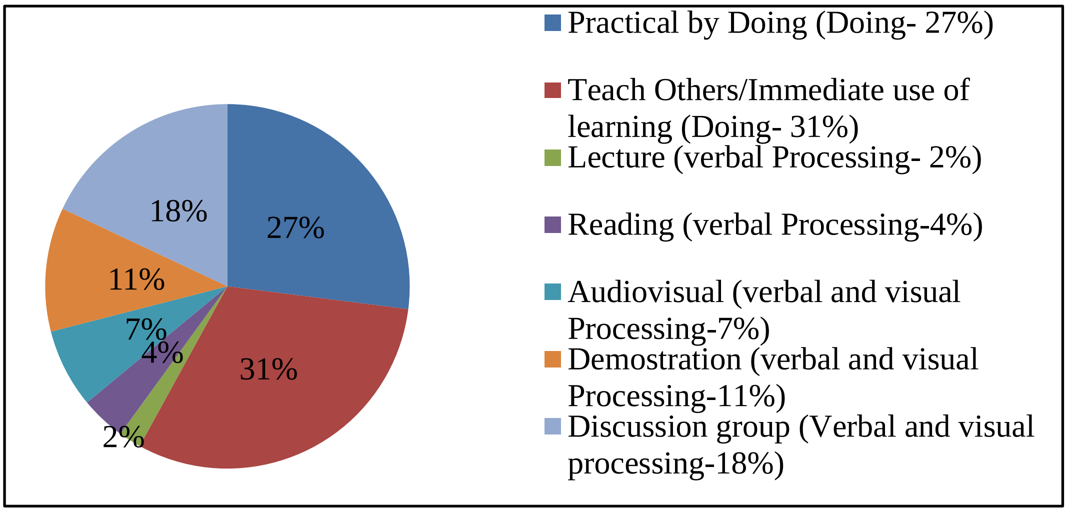
Frigo (1999) suggests that contextual representation of mathematics is ways of providing experiences and strategies in which students can gain mathematical ideas in everyday, real life or imaginary situations in order to develop the appropriate language that enables them to extend their skills of problem solving. Contextual representation thus provides a strong sense of purpose, in that it has a meaningful learning outcome for students in terms of the mathematical understanding developed (Ainley, Pratt & Hansen, 2006).For students to understanding geometrical concepts a teacher may ask students to find and explain examples of geometry in their environment, such as building, roads, machines and furniture among others. In this way the teacher and the students contextualized the concept of geometry, giving a strong sense of purpose to the activity and richer meaning to the mathematics.

Mathematical physical representations are manipulatives objects that allow learners to interact with mathematical concepts. These include Cuisenaire rods, logos, blocks and models among others that get students touching, moving and experiencing mathematical concepts. When students explore with manipulatives, they have the opportunity to see mathematical relationships. They have tangible and visual models that help develop their understanding. Without these concrete references, students have no concrete connection or comprehension of abstract mathematical concepts. The concrete manipulatives and the activities for which they are used are only as valuable as the students' reflection on the mathematical concepts. Ruzic and O'Connell (2001) found that long-term use of manipulatives has a positive effect on student achievement by allowing students to use concrete objects to observe, model and internalize abstract concepts

Mathematics is full of symbols. Symbolic representation is where learners and teachers discuss both the surface and deep structures of mathematical symbols that are used in mathematics teaching and learning (NCTM, 2014). Symbolic representation consists of numbers, operations and connection signs, algebraic symbols and some interconnected actions. Students record or work with mathematical concepts using numerals, variables, tables, symbols such as Greek alphabets and Roman numbers among other symbols. Then students could make the symbol used as a variable that the value is unknown. By using the symbol students could perform a series of calculation to obtain the value of the symbol. Symbols created by students are very helpful and facilitates students in solving problems. Azuka (2000) observed that symbolic representation is characterized by the skill of transforming mathematical problems into the representation of arithmetic formulas. The symbols are used effectively by students in simplifying the problem solving in mathematics. Anderson *et al*. (1997) also observed that symbolic representation is used in high school by students to represent solving problems, clarifying or expanding mathematical ideas starting from the process of collecting facts (data) to arranging tables or graphs, until the development of symbolic representation (algebra).

Teachers need to use the different modes of mathematical representations to unpack the abstractness of mathematics. This may build confidence, openness, persistence and commitment for learners in the face of mathematics uncertainty (Bull & Gilbert, 2012). Before students are able to understand an abstract mathematical concept; they need to have a concrete understanding of the basic mathematical concept (Moore, 2012). In this study mathematics topic Geometry in general and Loci in particular were studied. The topic is seen as too abstract to teach and learn as noted by Jones (2002) and Toptas (2007).

The purpose of teaching mathematics concepts from concrete to abstract is to ensure students thoroughly understand the mathematics concepts they are learning. Some of the elements cannot be described in any concrete way (Salman, 2004) hence the need to use technology to animate or simulate the abstract concepts. Students retain more if they are using multiple senses to process information and are given opportunity at regular intervals to participate in a variety of rehearsal activities that will help them to make sense of the information (Ganeshini, 2010). Figure 1 shows the retention rates if multiple senses are used in learning as researched by Ganeshini. From his research "Doing" helps a student to retain 58% of his/her learning. If teachers use a combination of discussion, demonstrations and practically doing mathematics activities as it was done in this study then students are likely to retain 87% of the mathematics concepts in accordance with Ganeshini's research. His research is supported by Kinyua *et al*. (2005) who emphasised that students need to be engaged in activities that are mind-on and hands-on for better understanding of mathematical concepts.




**Source: Ganeshini (2010) pp 16**

**Figure 1: Pie Chart Showing Average Retention Rate From Different Teaching Methods**

Hands-on experiences allow students to understand how numerical symbols and abstract equations operate at a concrete level, making the information more accessible to all students (Maccini & Gagnon, 2000). Altun, Yiğit and Alev's (2007) in their study stated that the reason for not obtaining the objectives in the lessons involving abstract concepts like Law of Snell in Physics was because of the application of traditional approaches. Use of computer simulations brings close to reality real-life problems where many senses are addressed (Mustafa, Aslıhan & Turgay, 2011). The students learn in an effective and permanent way, when they become active learners, form their own knowledge, learn to think and develop mathematical understanding (Altun *et al*., 2007). Mustafa *et al*. (2011) described simulations as useful for making abstract concepts concrete in teaching physics. Mathematics is abstract and visual communication is needed to put the concepts across. The abstract nature of mathematics is noted in some mathematics topics such as "Loci" and need to be addressed (Kinyua *et al*., 2005). In this study, Computer Animated Loci Teaching Technique was used to provide the bridge from concrete to abstract.

### 2.4. Mathematics Concepts and Their Formation

A concept is an idea or thought conceived in the mind. The word concept is formed from the Latin word conceptum, which means to conceive (Sjögren, 2011). According to Bettina and Katrin (2007) mathematical concepts are ideas explicitly concretised in formal definitions. Sierpinska (1994) ascertain that one of the earliest concepts to be developed is that of classification. Mathematical classification involves discrimination, matching and grouping or categorising according to attributes and attribute values. The attributes are Shape, Size and Length among others. Globally mathematical concepts are viewed as universal. Some of the concepts that are learnt in mathematics include: the concepts of numbers are fundamental to mathematics which is represented by integer, fraction, decimal and percentage; the concepts algebra which studies structure, relation and quantity. By substituting concrete numbers with symbols, it generalizes arithmetic; the concept of Pi ($\pi$), a mathematical constant, represents the ratio of any circle's circumference to its diameter; the concept of function expresses dependence between two quantities: one given (independent variable), the other produced (dependent variable); the concept of exponent operation originally meant repeated multiplication, just as multiplication means repeated addition and the concept of Pythagoras Theorem, square of the hypotenuse of a right triangle equals the sum of the squares on the other two sides.

A triangle is two dimensional figures, with three sides and the sum of the interior angles is $180^o$. The concept of triangle can be observed, generalised in the mind, discriminated or differentiated from other figures and finally abstracted in the mind. It can be identified by a label or name or word that symbolizes meaning of the concept. The concept of triangle was an essential part of daily lives of the Mediterranean and the Greek civilisation. Ancient cultures knew a considerable amount of geometry as practical measurement and as rules for dividing and combining shapes of different kinds for building temples, palaces and for civil engineering (Leo, 2011).

Roets (1995) observes that the formation of concepts in the cognitive structure is not purely a result of direct observation and past experience, but cognitive process such as organization; interpretation and combination of thoughts play major part. Fischbein (1987) examined students' individual concept formation and elaborated how it influences the learning of mathematics. Concepts and formal statements are very often associated, in a person's mind, with some particular instances. Students form concepts that are more cognitive based (Harel & Sowder, 2005) or more visual oriented ( Presmeg, 2006), but all share a constructivist view on students' learning and especially refer to students' intuitive thinking as decisive part of acquiring new knowledge.

Arends (1990) describes concept learning as the process of constructing knowledge and information into comprehensive cognitive structures. Surface learning includes subject matter vocabulary and the content of the lesson. Strategies include record keeping, summarization, underlining and highlighting, note taking, mnemonics, outlining and transforming, organising notes, training working memory and imagery. Students who adopt such an approach are characterised by: concentrating solely on assessment requirements, accepting information and ideas passively; memorising new ideas as a collection of rules without any attempt at integrating with the old ideas; failing to reflect on underlying purpose or strategy (Monica & Ferguson, 1996). Surface learning, involves simply studying, without carrying out any meaningful processing of the content. Surface representations are essentially the same as external representations (Meissner, 2002). The surface learning as contended by Goldin (2003) is way of communicating mathematical thoughts, ideas, reasoning to other people. It serves as an interface between the inner world of thought and the outer world. In surface learning words and symbols may be names or labels of mathematical objects, and are thus instrumental in forming abstract concepts. For instance, the word “sixteen” and the symbol “16” are needed to separate this number from other numbers and to create a single concept, that of number 16. In geometry an angle is defined as amount of turn between two lines around their common point referred to as vertex. Students are able to differentiate between 30 and $30^{o}$ due to the symbol of degrees as a measure of an angle.

Dunleavy and Milton (2008) defined deep learning as a level of syntactic representation with a number of properties that need not necessarily go together. The deep learning means the quality of the initiated learning processes and in particular, the internal learning sequences, or operations that students follow to appropriate knowledge, develop socially, solve problems and acquire skills (Oser & Baeriswyl, 2001). The deep learning of mathematical concepts is a well-formed abstract idea which includes the meaning of the concept, its properties and its relationships with other concepts, both mathematical and non-mathematical in the real life (Goldin, 2003). Deep Learning may join several concepts, apply them to real life situations (Lyke & Young, 2006) and students are more likely to read related materials, discuss and reflect upon the content (Tait, 2009). Any deep learning needs to take a closer look at the students’ cognitive capability.

In order to tackle real problems it is necessary to acquire skills of formulating a problem in mathematical terms, interpreting the solution and analysing its sensitivity, all of which require a good understanding of the underlying concepts of the topic. Usiskin (2012) highlighted a situation where a student was asked to approximate the height of the flag post and gave it as two centimeters. This demonstrates lack deep learning and understanding of a measure in centimeters. Students, who adopt a deep learning approach, want to make sense of what they are doing and to build their own personalised knowledge structures. They tend to follow the general pattern of: endeavouring to understand material for themselves; interacting critically with content; relating ideas to previous knowledge and experience; examining the logic of arguments and relating evidence to conclusion (Ajaja, 2009).

Problems should be designed such that children get an opportunity to explore the world around them by using their creative ideas and imaginative power. Showing students how mathematics can be used creatively and be actively involved brings prior knowledge of mathematical concepts to class. Research shows that working with that prior knowledge can lead to deeper understanding and long-term learning (Askew, 2002). In solving problems students need to use and interconnect mathematical concepts and operations (Lesh & Zawojewski, 2007). Young children can actively construct from their everyday experiences a variety of fundamentally important informal mathematical concepts and strategies, which are surprisingly broad, complex and sometimes sophisticated. During their learning of mathematics, students are faced with a wide range of information. How they choose to integrate new mathematical aspects and develop concepts depend on their beliefs, values and previous experiences. The concepts of loci in this study were formed collaboratively during discussions and demonstrations of computer animated loci concepts.

There are many barriers to concept formation in mathematics. If learners have the barriers then they have difficulty understanding mathematics concepts because they do not have the necessary conceptual background (Gaghardi, 1997). Human being has always sought better ways to facilitate the acquisition of mathematics (Zadshir, Reza and Abolmaali, 2013) and anything that would hinder this acquisition should be known and addressed appropriately. Some of the barriers as noted by Carey (2000) are poor vocabulary and command of the English language which has made the majority of learners to find it difficult and even impossible to express themselves in terms of their own experiences and capacities.

The language in textbooks, can sometimes act as a barrier for student understanding. Though the language of mathematics needs to be taught to students, they do not necessarily come to the classroom understanding certain mathematical concepts in that language (Lee, 2006). Mathematical word problems provide a lot of challenges in a linguistically dense context, coupled with the logical nature of many mathematics problems, requiring the reader to rely on the sentence to convey clear and unambiguous meaning (Dale &Cuevas, 1987). The textbook authors should use simple language that the students can easily understand. The mathematical terms used in the textbook should be properly defined to avoid confusion. Students' ability to read in the language of instruction is vital to their performance in all academic disciplines.

Bilingualism and multilingualism is prevalent in classrooms worldwide. In most mathematics classrooms, however, only dominant regional or national languages are used, often for practical or political reasons (Adler, 2001). Sometime students and teachers in these multilingual classes switch back and forth from one language to the other. This switching requires translation from one language to the other which is complex and not always possible. If a students' aim is to achieve success in mathematics, then the gap in communication between teachers and learners need to be reduced. It is further complicated by the multiple and idiosyncratic interpretations that learners construct about a particular mathematical concept and their own linguistic backgrounds as noted by Clarkson (1992). In this study the gap was reduced by ensuring that prior knowledge of the students in geometry was continually addressed to avoid students' misconceptions.

Most of the countries worldwide use the metric system. The use mathematics concepts based on feet, inches, miles, pounds, ounces, cups, pints, quarts, among others have to be relearned and practiced (Furner & Duffy, 2002), if the concept are not re-learnt properly then they become a barrier to further learning. The teaching of concepts should be developed in a way which will develop the mathematical thinking abilities of the students (Safro, 2009). There is need for the assimilation and accommodation of new mathematical knowledge with prior knowledge being put into consideration. This raises questions about the nature of links teachers should make with students' prior knowledge so as to expect learners to construct new knowledge. The teaching of mathematical concepts and skills the students encounter in during instructions shapes their understanding, their ability to solve problems and their confidence in and disposition toward Mathematics (Too, 2007). In this study among the loci concepts such as perpendicular bisectors, angel bisectors, circles, intersecting loci were discussed and linked to real-life situations that students are familiar with.

#### 2.4.1. Learners' Mathematics' Misconceptions

Green *et al*. (2008) define misconceptions as systematic and recurrent wrong responses methodically constructed and produced by students. Learners' mathematics misconception may arise due to previous inadequate teaching of mathematical concepts, informal thinking or poor remembrance. Misconceptions are mistaken ideas or views resulting from a misunderstanding of something (Raman & Osman, 2014). Misconceptions may also be caused by faulty, inaccurate or incorrect thinking due to previous wrong construction of concepts and hence formation of wrong schemata of knowledge. A misconception does not exist independently, but is contingent upon a certain existing conceptual framework. The misconception can change or disappear when conceptual framework changes. Allen (2007) argues that one problem that leads to very serious learning difficulties in mathematics is misconceptions student may have from previous inadequate teaching, informal thinking, or poor remembrance. Students have misconceptions because of many reasons. Among the reasons are:, using only teacher-centered approaches, lacking of depth in the curriculum, not establishing connectivity between the subjects and concepts, not relating the subjects to daily life, not encouraging the students to participate in the subjects, not paying attention to student's prior knowledge, inappropriate teaching style, teachers' own misconceptions and teaching the concepts to students in a wrong way, are the important factors of misconceptions in the student (Haluk,2004).

It is important to establish the difference between an "error" and a "misconception" as both seems to be equivalent regarding the incorrect result they produce and many times used synonymously. An error might be caused due to a misconception. Other factors causing errors may include carelessness, problems in reading or interpreting a question and lack of numbers knowledge (Spooner, 2002). The views of Mohyuddin and Khalil (2016) are that errors have taken place when a person chooses the false as the truth or wrong as the right. He notes that the errors students make may include the concept, value, problem-solving and carelessness. A misconception, on the other hand, is the result of a lack of understanding of concepts or in many cases misapplication of a concept "rule" or mathematical generalization (Spooner, 2002). Characteristically, misconceptions are intuitively sensible to learners and can be resilient to instruction designed to correct them (Smith, diSessa & Roschelle, 1993). Misconceptions show that there is structure in the misconceptions learners have and that these misconceptions emanate from prior acknowledge as learners attempt to construct mathematical meanings (Kakoma & Makonye, 2010). These misconceptions have to be addressed during instruction. Some of the common misconceptions in geometry include: recognition of geometric shapes, solids, drawings of their nets and geometry constructions (SMASE, 2011).

There are general misconceptions about mathematics in the society among them are: mathematics is incorrectly viewed as a collection of rigid rules and mysterious procedures that seem to be unrelated to each other and require total mastery with little or no understanding; mathematics is perceived by many to be difficult and demanding and is considered to be a subject in which it is socially acceptable to do poorly; mathematical thinking is regarded as essentially unimportant to people that do not actually "do" mathematics in their employment capacity; the pervasive role of mathematics is underestimated in the world of everyday living.

Koedinger and Booth (2017) argues that one reason why use of these misconceptions may persist is that many of the procedures that students attempt to use are ones that will lead to a successful solution for some problem situations. Unfortunately, without adequate knowledge of the problem features, students are unable to distinguish between the situations in which the strategy will work and the ones where it is not applicable. Machaba (2013) observed that students who previously used flawed procedures and worked for that particular situation, develop challenges when they encounter new problems where the incorrectly generalise procedure do not work. Koshy and Murray (2002) on the other hand contend that a large number of misconceptions originate from reliance on rules which have not been understood, forgotten or only partly remembered. Some students may even modify the correct rules and formulae to fit the new problem encountered (Schunk, 2004), instead they are supposed to extrapolate the rule or formulae to fit the new situation. The modification may lead to misconceptions.

Students do not come to the classroom as "blank slates" (Resnick, 1983), instead, they come with theories constructed from their everyday experiences. They have actively constructed these theories and activities crucial to all successful learning. Some of the theories that students use to make sense of the world are, incomplete or half-truths (Mestre, 1986). Additionally the previous knowledge does not affect conceptual learning but it also impend a student’s insight and ability to focus (Baloyi, 2017). All pupils acquire a range of ideas during their learning of mathematics, which can lead to misconception (QCA, 2003). The misconceptions that students bring to class can effectively be addressed during instructions. Dickson, Brown and Gibson (1984) noted that many of the misconceptions that children make about mathematics concepts are due to primarily inadequate teaching. Students are emotionally and intellectually attached to their misconceptions, because they have actively constructed them. They give up their misconceptions, which can have such a harmful effect on learning, only with great reluctance. Repeating a lesson or making it clearer may not help students who base their reasoning on strongly held misconceptions (McDermott, 1984).

Students who overcome a misconception after ordinary instruction often return to it only a short time later since students actively construct knowledge, teachers must actively help them dismantle their misconceptions.

Mathematics is an abstract subject and as argued by Sanger and Greenbowe (1997) the origin of some misconceptions might be from the students' lack of awareness of the abstract nature of mathematics concepts. To help student address the abstract nature of mathematics and to avoid or reduce misconception, then the use of concrete materials in mathematical contexts help both in the initial construction of correct concepts and procedures and in the retention and self-correction of these concepts and procedures through mental imagery as noted by Fuson (1992). Misconceptions often interfere with understanding and interpreting the new ideas or concepts. Bell (2005) suggests that when students face a challenge due to abstraction then their cognitive structure are equally challenged and use of concrete examples may help them to stretch themselves intellectually. Conceptual gains realised in this manner promote "transfer from the immediate topic to wider situations" (Bell & Swan, 2006).

Teachers can help students eliminate their misconceptions by providing an adequate knowledge base and clear understanding of these concepts. Swan (2005) emphasised that teaching becomes more effective when misconceptions are systematically exposed. Bell (2005) argues that without exposure of pupils' misconceptions and their resolution through conflict discussion, students may not know why a mistake occurred. Misconceptions affect subsequent learning negatively (Bodner, 1986), the correction or remediation of students' misconceptions is as important as identification of them. Mathematics interventions should use a subtle process to expose flawed thinking and allow students to confront their own misconceptions and consequently, discover for themselves the source of their mistakes (Bell & Swan 2006). To effectively correct the students' mathematics misconceptions then teachers must help students to deconstructed and reconstruct correct conceptions. Lochead and Mestre (1988) describe an effective inductive technique for deconstructing misconception involving: probe for and determine qualitative understanding; probe for and determine quantitative understanding and probe for and determine conceptual reasoning. Sometimes misconceptions can even be hidden in correct answers (Smith *et al.*, 1993), when correct answers are accidental. Most teachers are unaware of mathematical misconceptions held by their learners (Riccomini, 2005).

Gonca (2014) opined that students come to school with wide range of prior knowledge with lots of misconceptions. Therefore school has an important responsibility in terms of finding out the misconceptions and creating a conceptual change. Hung and Khine (2006) argue that computers can make a unique contribution to the clarification and correction of commonly held misconceptions of phenomenon by visualizing those ideas. He suggests that the computer can be used to form a representation for the phenomenon in which all the relational and mathematical wave equations in trigonometry are embedded within the program code and reflected on the screen by the use of graphics and visuals. Such use, as noted by Anderson and Skwarecki (1986) cited in Hung and Khine (2006) makes the computer an efficient tool to clarify scientific understanding of waves and other Mathematical topics.

In Kenyan secondary school like anywhere else in the world the students come to school with a wealthy of real life experiences and prior knowledge to various geometrical concepts. They also have misconceptions in geometrical concepts that need to be addressed. KNEC (2013) revealed from KCSE mathematics examinations analyses that the students have been performing poorly in Geometry due to careless mistakes, errors and misconceptions in the concepts. KNEC advises the teachers to give the students more questions during teaching of mathematics concepts in order to give learners adequate practice, perfect their skills and re-conceptualize the mathematics concepts correctly. In this study the misconceptions made in Geometry in general and Loci in particular were sought and addressed through the use of animations during teaching of Loci concepts.

### 2.4.2. Analysis of Students' Misconceptions in Mathematics

Misconception analysis involves discovering and understanding the misunderstandings students have in given concepts and exposing false assumptions. The assumptions has great influenced on how we solve problems and even relate to our day to day life. The assumptions that the earth is flat ruled the world for quite sometime and the interpretation of the concept about the earth and the universe depended entirely on the assumption (Russell, 1991). If a modern science teacher were to teach about the universe to students of 300 BC, the teaching would be uncoprehesible to them. They would resist these teachings if the teacher first did not demystify for them modern information about the earth and the universe (Cohen, 1972).)

Students' misconception can be detected by: a) giving structured assignments; b) giving diagnostic test in the before the start of a new topic; c) Asking open questions to students verbally; d) Asking inverted questions; e) Providing correction to the students for the taken steps in solving problem; and f) Holding interview (Maryati & Priatna, 2018). Misconceptions analyses are useful for teaching and learning, they help students to understand where they are likely to go wrong and they avoid it. There are several procedures to diagnose students' misconceptions in mathematics. Observation of a student at work, misconceptions analyses, which is careful scrutiny of the written product of a student to understand the logic behind the thinking that led to an misconception, think aloud protocols, and diagnostic interview procedures are the most common among others. Booth (1988) noted that, "one way of trying to find out why students find geometry difficult is to identify the kinds of errors students commonly make in geometry and then to carefully examine the cause for these misconception". If the reasons that students misunderstand mathematical concepts can be well understood, it would be helpful to design remedial measures to avoid the misconceptions. Dowker (2005) emphasised the importance of identify early signs that may indicate problems and to remediate the situation in good time to prevent future mathematical difficulties.

Croark, Mehaffie, McCall and Greenberg (2007) have clearly documented that the early identification of children who experience difficulties to learning is of critical importance in enabling them not only to make greater progress but to become participants in self-regulating their learning. It is important to identify children who experience difficulties to learning as early as possible so as to minimise or eliminate learning difficulties. For instance Asyura et.al (2017) developed the following criterion steps of ensuring the misconceptions are reduced in teaching and learning of Algebra:

(i) Students become aware of their own conceptions in the beginning of the instruction by thinking about it and making predictions before activity begins.
(ii) Students express and criticize their views by checking and discussing them in groups.
(iii) Students work to settle the conflicts between their ideas and their observations, by accommodation of a new concept.
(iv) Students extend concept by attempting to make connections between the concept learned in the classroom and other situations, including real-life experiences.

(v) Students are encouraged to go further, by pursuing extra questions and problems related to the concept

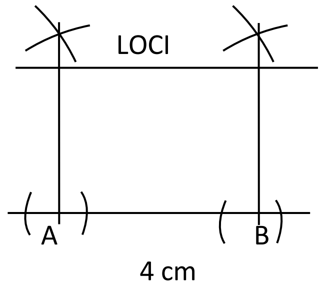
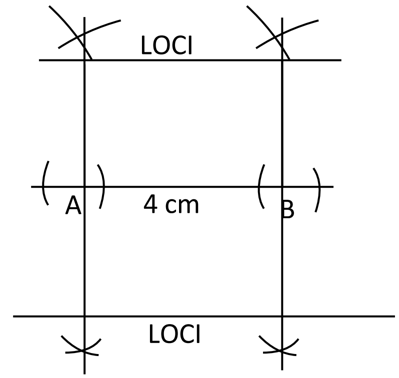
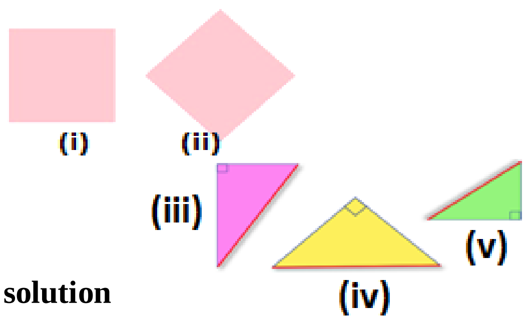
To learn about children's conceptual understanding and the strategies behind their answers, whether right or wrong, teachers need to engage children in a dialogue, which is 'flexible interviewing', asking the child to elaborate on his or her ways of interpreting and approaching a problem (Ginsburg, 1997).

The use of formulae method of solving a problem relies heavily on arithmetic and remembering formulae accurately to solve problems (Wright, 2008) this leaves students with numerical values that lack clear meaning and conceptual understanding, thus leading to an increased incidence of misconceptions. Daymude (2010) noted that it is often difficult to understand the reason a student may have missed a test item in the examination, especially if the item was left blank. This leaves the examining teacher with many questions such as: did the student accidentally skip the item? Did the student mean to come back to that item and forget to do so? Did the student have trouble understanding the item? Or was the item too difficult for the student? These questions can only be answered by the student if the student is interviewed by the teacher (Greene, 2007). Ayşen (2012) observed that most commonly encountered students' misconceptions were notions regarding measurements using a ruler directly and protractor without any regard to Parallax error. Researches by Ayşen (2012), EChesa (2003) and Lim (2000) highlighted misconceptions in students' thinking in various mathematics topics at the secondary school level some of which are discussed in Table 6 which shows mathematical misconceptions in geometry in general and Loci topic in particular.

**Table 6: Learners' Mathematics Misconceptions in Geometry in General and Loci in Particular**

| Topic | Concepts | Misconceptions | Remedial measure |
|---|---|---|---|
| Vocabulary | Naming mathematical shape | Students often confuse the names of 2D and 3D shapes | Provide opportunities to compare and contrast shapes that are likely to be confused. Ask students to tell how they are different. |
| Components of shapes | Faces, edges, height and slant height of 3D shapes | Students might confuse the names of components of 3D shapes | Emphasize the correct terminology |
| Counting components of 3D shapes | vertices, edges, and faces | Having trouble counting vertices, edges, and faces | Ask them to mark a starting point from where they count and use of concrete objects. |
| Identifying the base of a prism | Naming 3D figures | Students have trouble identifying the base of the prism | Build prisms by stacking pattern blocks and emphasize that the base of a prism is the plane figure un two dimensions. |
| Attributes and properties | Shapes | They confuse attributes of shapes with their properties | They need the opportunity to explore each shape in many different forms and provide opportunities for students to examine and sort them |
| Changes in orientation | Drawing shapes | Students think the way a shape is oriented is part of what defines it. | Working with concrete shapes such as pattern blocks and models to show shapes can be shown in different ways. |
| Parallelogram and reflective symmetry | Lines of symmetry | Students think the diagonal of a parallelogram is the line of symmetry | Provide many opportunities to test for symmetry by folding and using a transparent mirror. |

**Table 6 continued…**

| | | | |
|---|---|---|---|
| Loci | Locating locus | Locate the locus of points 2.1 cm from a fixed line AB=4 CM<br>Solution  | The students should recognize that loci from the line AB are on its two sides.  |
| Geometrical shapes | Identify geometrical shapes correctly. | Identify the following regular shapes<br><br>**solution**<br>(i) square (ii) kite ( iii )triangle<br>(iv) isosceles triangle (v) right triangle | The students need to be exposed to regular geometrical shapes drawn from different perspectives.<br>ii – is a square and not a kite |

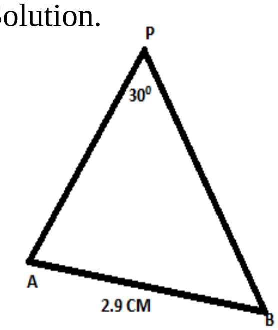
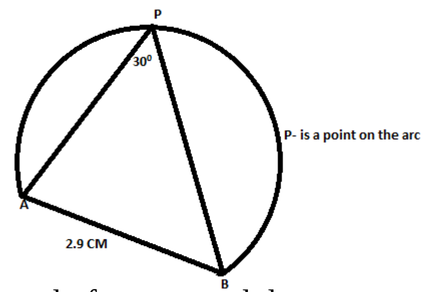
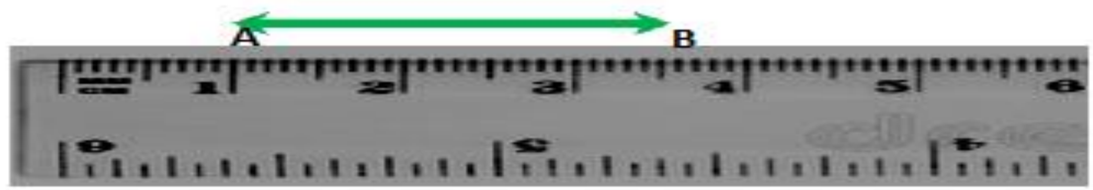
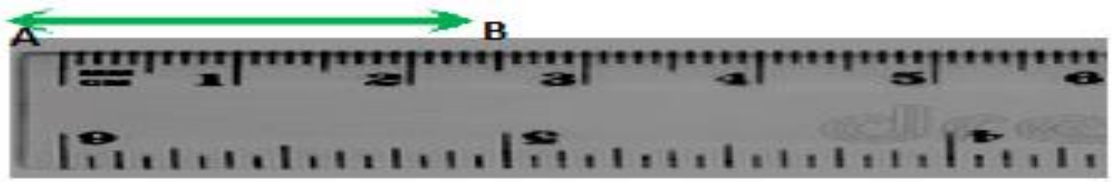
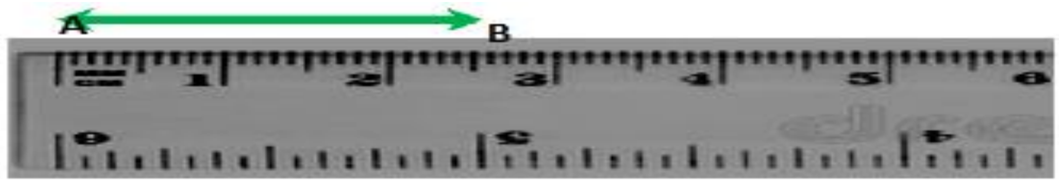
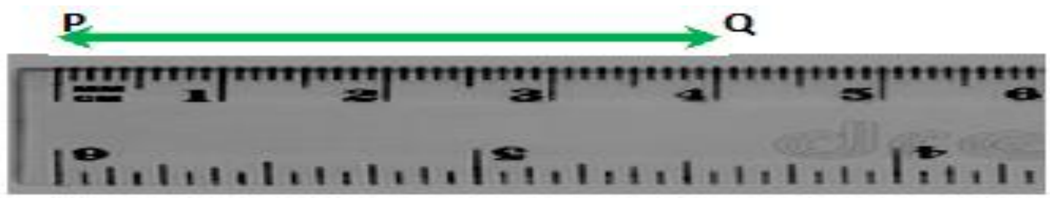
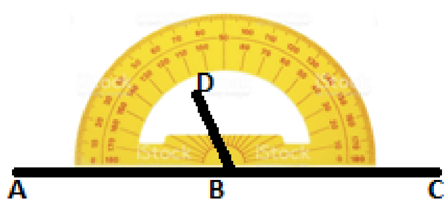
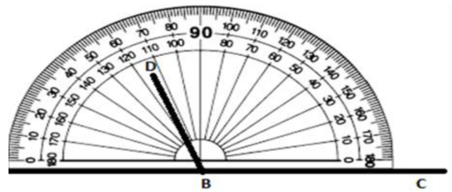
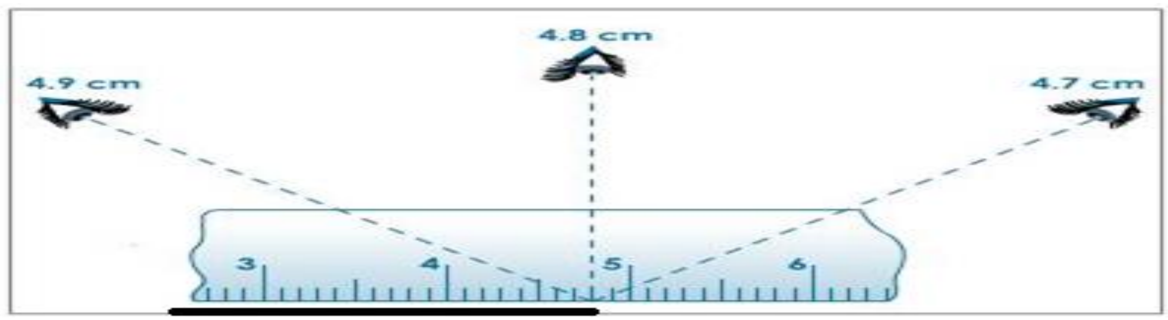
<table>
<tr>
<td>Loci</td>
<td>link concept to geometrical properties</td>
<td>Locate to locus of points P such that angle APB = $30^0$ given that AB = 2.9 cm<br>Solution.<br>
</td>
<td>The students locate only one point. They fail to relate the loci with angles subtended at the circumference of a circle by the same chord.<br>
</td>
</tr>
<tr>
<td>Measurements</td>
<td>Using a ruler</td>
<td colspan="2">Student begins measuring at the number 1 instead of at zero and does not compensate thereby giving measurement as 3.8 cm instead of 2.8 cm.<br>
<br>
• Student begins measuring at the end of the ruler instead of at zero thereby giving the measurement of line AB as 2.3 cm<br>
</td>
</tr>
</table>

**Table 6 continued…**

| | | |
|---|---|---|
| | | • Correct way of measurement thereby giving the measurement of AB as 2.5 cm<br><br><br>• When measuring with a ruler, student counts the lines instead of the spaces there by giving measurement of PQ as 5cm instead of 4cm.<br><br> |
| Measurement | Using protractor | <br><br>Some of the protractors used are not compact; if the lines do not reach the calibrated scale then the students are likely to approximate the angle thereby making errors which may lead to misconceptions. |

| | | |
|---|---|---|
| Starting from zero |   | Some students fail to start from zero mark in the protractor. This may lead to errors and if consistently done may be termed as misconception. |
| Parallax error in measurements. | Many students rarely use the divider to transfer measurement to the ruler. As the result of using the ruler to directly measure the length they make parallax error. Parallax error occurs when the measurement of an object's length is more or less than the true length because of your eye being positioned at an angle to the measurement markings.<br> <br>The correct position to use the ruler to measure length is to postion the eye perpendularly at the mark on the scale to avoid parallax error. | |

**Source: Ayşen (2012),pp 724-729,Echesa (2003),pp 2-5, Lim (2000), Mathematics Navigator (2016), Riccomini**,**2014, 322-325)**

## 2.5. Mathematics Achievement and Assessment

Mathematics assessment is synonymous with mathematics achievement. That one cannot do without the other. There is need to examine the effect of classroom assessment on mathematics achievements (Gronlund, 2004).Assessments are used to evaluate students, teachers, and the entire educational system. Good performance in the mathematics is crucial for students' admission to scientific and technological professions.

### 2.5.1. Students' Mathematics Achievement

According Eluwa, Akubuike and Bekom (2011) mathematics achievement is the proficiency of performance in any or all mathematics skills usually designated by performance on a test. Students' mathematical achievements in secondary school have an influential effect on their performance in college/University and their future careers. Having a solid background in mathematics helps students develop focused perspectives in life with a wide range of career options. The importance of mathematical learning has repeatedly been emphasized by educators and politicians (Wilkins & Ma, 2002). Both teachers and parents have paid attention to students' performance in mathematics and their progress every year. Politicians have also called for improving students' overall performances and closing students' achievement gaps. Despite the important role mathematics play in society, there has been persistent poor performance in the subject globally as indicated by several researches.

According to Noraini (2006) indicate that the performance of Malaysian's students in mathematics has not been good. Colwell (2000) found that the performance of American students in the international mathematics tests to be poor. The reports on PISA assessment, ascertains that in USA students are performing in mathematics (Kloosterman & Ruddy 2011). Teachers in Asian countries have stronger mathematics knowledge and more training, on average, than teachers in the USA, which explains why students in Asian countries perform better than students in the USA on International Mathematics assessments (Ball, 2003). The United Kingdom and Hungary point to the fact that there is a high academic value placed on mathematics in terms of accessibility to further study and future careers. Further emphasis is placed by schools on the mathematics examinations taken by students in England, Wales and Northern Ireland at age 16. Although this is not the end of upper secondary education, the results of these examinations are part of the criteria used to benchmark the performance of schools. Despite the high value placed on mathematics attainment, it is interesting to note that the four regions of the United Kingdom were found to have some of the lowest levels of participation in mathematics beyond age 16 (Hodgen *et al*, 2010).

The status of students' mathematics performance in African is poor as portrayed by various researches and studies. For instance in Ghana the poor performance of students in mathematics year-in-year-out has been a constant source of concern, worry and anxiety to all stakeholders in the education sector (Adetunde & Asare, 2009). The same is replicated South African as noted by Mashile (2001). He calls for a concerted effort on measures that may lead to its improvement of recurring poor performance in mathematics. Aburime (2009) have expressed concerns about low achievement in mathematics in Nigerian secondary schools. Poor academic performance of students in Nigeria has been linked to poor teachers' performance in terms of accomplishing the teaching task, negative attitude to work and poor teaching habits which have been attributed to poor motivation (Ofoegbu, 2004).

Knowledgeable Educators help students transform their everyday mathematics into a more formalized understanding that can be transferred and applied to other situations (QCA, 2003). Several researchers refer to this as "Mathematization" which requires students to abstract, represent and elaborate on informal experiences and create models of their everyday activities (Clements & Sarama, 2009). When children are helped to understand the specific problems in mathematics that are holding them back, they are likely to make remarkable progress. Teachers could be very effective in helping underachievers. Teachers' mathematical knowledge for teaching positively predicts students' achievement gains in mathematics (Hill, Rowan & Ball, 2005). Students who never study efficiently do not usually perform well on tests of academic achievement (Putwain, 2009). Student's study habits may be influenced by the schools' academic emphasis and trust bestowed in the school. Schools with strong academic emphasis positively affect achievement of poorly academic performing students (Goddard, Sweetland & Hoy, 2000).

Mathematics performance in the Kenya Certificate of Secondary Education (KCSE) has been low over the years countrywide. Rates of failure are high every year nationally- a clear indication that there is little or no acquisition of mathematical knowledge and skills by majority of students at the end of their four years' "course". This has created worries among the parents, students, teachers and other stakeholders. Due to this poor performance the ministry of Education Science and Technology entered into joint venture with Japan International Cooperation Agency (JICA) to improve the performance in Mathematics, Biology, Chemistry and Physics, hence started a project SMASSE (CEMASTEA, 2012).The purpose is to improve the quality of teaching mathematics and science education by enhancing pedagogical skills of teachers which in turn is expected to help young Kenyans in secondary schools develop and acquire relevant core competences such as communication and collaboration, critical thinking and problem solving, creativity and imagination, citizenship, self- efficacy, digital literacy and learning to learn. In this study the students' mathematics achievement was obtained from MAT done by the students after leaning the topic loci.

### 2.5.2. Students' Mathematics Assessment

Across the world, student assessment takes a variety of forms and uses different assessment instruments and methods. Assessment is formally defined as a measure of performance (Gagne, Wager, Golas & Keller, 2005). Educational assessment is the process of documenting, usually in measurable terms, knowledge, skills, attitudes and beliefs. Most teachers think that testing takes away time from learning, but there is considerable learning during and from testing and other forms of assessment (Stenmark, 1991).Daymude (2010) argued that assessment should support the learning of mathematics and should furnish useful information to both teachers and students. Teachers are frequently called upon to construct and use assessments to appraise the learning that takes place in their classrooms. They are also expected to understand the results of those assessments sufficiently enough to interpret them for students and parents, and to plan instructional programs that meet the needs identified by those results. Vicki and Back (2011) noted that assessment in mathematics focuses on children's abilities to work increasingly skillfully with numbers, data, mathematical concepts and processes using them in a range of contexts. With the increasing use of` information and communication technology, there is need to use varieties of assessing techniques (Eluwa *et al*., 2011).

Thorpe (1993) defines evaluation as the collection analysis and interpretation of information about an educational programme. It is a recognised process of judging, effectiveness, efficiency and any other outcomes of such educational programme. Learners' performance may be observed, recorded and is evaluated during assessment for the purpose of grading and certification. The different types of evaluation are placement, formative, diagnostic and summative evaluations. Placement Evaluation is a type of evaluations carried out in order to fix the students in the appropriate group or class. In some schools, students are assigned to classes according to their subject combinations, such as science, technical, arts and commercial among others, where before this is done an examination is carried out (Obimba, 1989).

Formative evaluation is a type of evaluation designed to help both the student and teacher to pinpoint areas where the student has failed to learn so that this failure may be rectified (Black & William, 1998). It is used to help formulate plans for teaching/learning and to modify instructional methods and materials during the course of an educational programme. Information about both learning processes and learning outcomes is used in formative evaluation (Fountain & Amaya, 2003). Formative Evaluation helps reduce the learning gap between struggling and positive achieving students; it raises overall achievement levels (Black & William, 1998). Using Formative Evaluation as an instructional practice can be challenging for teachers.

Diagnostic Evaluation is a type of evaluation that is carried out most of the time as a follow up evaluation to formative evaluation (Worthen & Sanders, 1989). The value of prior mathematical knowledge is explored by use of diagnostic evaluation. Teachers need to be able to determine the level of development, prior knowledge and understanding, so that appropriate teaching support can be initiated. Diagnostic assessment does not need to be a formal assessment but could consist of a diagnostic interview, observation, pretests, questioning and listening. However, through effective questioning and observation a teacher can determine where children are in attainment of knowledge and skills and help them access the next level of conceptual understanding.

Summative assessment gives information about the achievement of students at the end of a school year, or the end of a course or workshop. Summative assessment draws primarily on information about learning outcomes (Fountain & Amaya, 2003). Summative assessment is done at the conclusion of a course, some larger instructional period or at the end of the program (Akanmu & Fajemidagba, 2013).The purpose is to determine to what extent the program/project/course met its goals. The aim of assessment should be "to monitor improvement of students' learning; to provide feedback about students; to inform future action of both learners and teachers; and to report students' progress." A good evaluation system provides invaluable information that can inform instruction and curriculum, help diagnose achievement problems and inform decision making in the classroom, the school, the sub-county, county and country. Testing is about providing useful information and it can change the way schools operate (USA, 2004). At the school level, mathematics assessment is usually in the form of formative tests such as short tests or monthly tests, as well as summative tests given at the end of every year or after four years (Akanmu & Fajemidagba, 2013).

Assessments are designed based on the purpose. Criterion-referenced assessment allows judgments to be made about a pupil's attainment against pre-specified criteria, irrespective of the performance of other pupils (Kiruhi, Githua & Mboroki, 2009).Norm-referencing aims to provide information on the students' level of achievement in relation to others in the class. This is done by scoring assessment measures and giving students a grade, or ranking them in comparison with each other (Fountain & Amaya, 2003). It is most appropriate when one wishes to make comparisons across large numbers of students or important decisions regarding student placement and advancement (Brown, Bull & Pendlebury, 1997).

Cattell (1944) used the term "Ipsative" when "scale units were designated relative to other measurements on the person himself". This was coined from the Latin word ipse meaning "he, himself". Implying the assessment is on "he and himself". Hicks (1970) stated that "Ipsative measurement yields scores such that each score for an individual is dependent on his /her own scores on other variables, but is independent of and not compared with the scores of other individuals". Ipsative referenced assessment is used for self-comparison either in the same domain over time, or comparative to other domains within the same student (Freeman & Lewis, 2002). Ipsative tools indicate only orientations and the strengths of the person are being tested relative to his previous orientations and strengths (Rice, 2010). They compare the strength of orientations within a person, not compared to other people. Students who develop a habit of self-assessment will also develop their potential for continued learning (Stenmark, 1991). Ipsative assessment in a learning context compares a test results taker's against his or her previous results. Forbes (2014) noted that Ipsative tests may be appropriate when used for applications like development, coaching, team building and interpersonal conflict resolution, where comparisons among people are not necessary. According to Englert (2010) Ipsative tests are not recommended for use in ranking and selection because their goal is not to compare performance among people. Such test measure progress and development of individuals on some stated desirable variables.

Kenya's education system is dominated by examination-focused teaching, where passing examinations is the only benchmark for performance. There is no other way of assessing learning achievements at other levels within an education cycle. National examinations performance is viewed as extremely important in Kenya. Examinations are generally acceptable as valid measures of achievement (Maiyo & Ashioya, 2009). It is a common practice in Kenya of the mass media (such as television and local newspapers) to highlight the examination results and the names of schools and individual students' outstanding performances. Teachers have to make sure that they complete teaching the content of the assigned syllabus so that they have ample time to revise with their pupils before the national examinations. It is a common practice for teachers to complete the syllabus three to six months ahead of the examination date. Examination results are used for Certification that a student has achieved a particular level of performance (Ohuche & Akeju, 1977). The students in Kenya are expected to take the first recognised national examination after primary school education (KCPE) then KCSE after secondary school education that will usher them to higher education at various fields of training or direct entry into the world of work (Koech, 2006). Critics, of this examination practice however, point to evidence that testing for accountability encourages educators and schools to narrow the curriculum, reshape the testing pool and focus their resources on students most likely to pass the test (Smith, 2014). Holding different actors responsible for student achievement scores in examinations has shifted the blame from low performing students to low performing schools (Apple, 1999). Mathematics assessments however should not be the end of instruction and learning, but should support future learning and instruction (NCTM, 2000). In this study the students' achievement was assessed using a mathematics achievement test on loci topic of geometry that was given to students. The higher the test scores the better the students' mathematics achievement was.

### 2.6. Gender Differences in Mathematics Achievements

According to Leder (1996) gender differences in learning mathematics cannot be explained in a simplified manner because there is the multiplicity of forces and environments that operate apart from gender which influences a child's learning. It is suggested that cultural differences may influence how mathematics is performed and taught through different approaches. The different cultures affect the associated values of gender (Seah, 2003). The gender differences in mathematics among learners may vary due to socioeconomic status and ethnicity, school environment, the mind-set of the teacher among other things.

Fennema (2000) in her study showed that gender differences existed in mathematics achievements and in learning mathematical tasks in middle and secondary schools in the USA. Vale (2009) found that many studies conducted between 2000 and 2004 in Australia showed no significant differences in achievement in mathematics between males and females, though males were more likely to obtain higher mean scores. In Netherlands boys are significantly more likely to take mathematics classes in secondary school than are girls while in France, secondary school students deciding on which sets of classes to enroll in, girls are less likely to choose the mathematics and science-heavy options (Niederle, Muriel, Segal & Vesterlund, 2013). According to Laura, Mendolia and Contini (2016) the gender gap in educational outcomes advantaging boys has been completely filled up in most industrialized countries such as Italy and Germany. This has now reversed the situation in favour of girls who tend to do better than boys in reading test scores, in grades at school, in the propensity to choose academic educational programs in upper secondary school, in tertiary education attendance and graduation rates. Ericikan, McCreikth and Lapointe (2005) indicated that there was no significant difference in achievement between boys and girls in mathematics in Mexico. A study by Alkhateeb (2001) found that among high school students in the United Arab Emirates, females scored higher in mathematics achievement test than males. Umoh (2003) opined that there is societal gender stereotype associated with males and females where each gender ascribes to in conformity to societal norms. Udousoro (2011) stated that male in secondary schools are more likely to take difficult subjects areas and challenging problem-solving situations, while females will prefer simple subjects and less difficult tasks easy problem-solving situations.

Many research findings in Nigeria have shown that boys perform better than the girls in mathematics generally despite the fact that they are put under the same classroom situation (Alio & Harbor, 2000; Jahun & Momoh, 2001). In Nigeria as noted by Agwagah (1993) the female students perform significantly better in some mathematics topic such algebra than their male counterparts. This agrees with Etukudo (2002) who found girls doing better than boys in statistics. However a study by Abiam and Odok (2006), found no significant relationship between gender and achievement in some mathematics topics in Nigeria. Galadima and Yusha'u (2007) investigations on students' mathematics performance of Senior Secondary School in Sokoto Nigeria revealed the existence of learning difficulties in mathematics and confirmed no gender difference in performance. The researchers have not been able to identify a single direction of difference in mathematics performance between male and female students in Nigeria (Kadiri, 2004). Studies in Botswana by Finn (1980) and Duncan (1989) indicated that cultural expectations of society could result to differences in performance between girls and boys in certain school subjects like mathematics.

The underachievement and gender differences in mathematics performance in Kenya are attributed to ineffective teaching methods employed in mathematics classrooms (O'Connor, 2000). Most girls underestimate their own academic ability and believe boys to be relatively more superior and intelligent in handling difficult subjects like mathematics (Mondoh, 2001). This is more of a stereotypical perception, which makes boys feel superior to girls in studying what is regarded as tough subjects (Githua, 2002). Many secondary school students, parents and some teachers regard mathematics as a male domain (Shuard, 1982). There is also widespread belief that boys are better in mathematics than girls (Burton, 1989). Further review by Gutbezahl (1995), also suggests that some females' underachievement in mathematics might be related to the negative expectancies and attitudes of their parents, teachers and peers. The negative expectancies may lower their self-confidence and consequently their lower performances in mathematics. Gender differences in mathematics achievement exist in varying degrees in different countries.

Books and curriculum materials tend to portray girls as inactive and performing traditional roles (Sinnes, 2004). This fact discourages girls from learning efficaciously and restricts their career choices (Kagume, 2010). The studies of Fox and Soller (2001) have shown that the learning styles of boys are generally different from the learning styles of girls. They stated that boys and girls prefer competitive and cooperative learning styles respectively. KNEC (2003) reported that there were gender disparities in mathematics performance with boys doing better in overall performance at the KCSE national mathematics examinations. A research done in Baringo County by Mbugua (2012) found out that boys performed better than girls in Science, Mathematics and Technology subjects. The same results are confirmed from other Counties in Kenya (Sifuna, 2006; Wambua, 2007). The various researches conducted on gender differences on learners' mathematics achievement globally, regionally and in Kenya indicate that girls could achieve in mathematics as well as boys when factors affecting girls' performance are minimized. In this study gender as an extraneous variable was studied to find out if using Computer Animated Loci Teaching Technique can reduce the gender differences in mathematics achievement and misconceptions among secondary schools learners of mathematics in Kitui County.

## 2.7 Approaches, Strategies, Methods and Techniques of Teaching Mathematics

The teaching and learning of mathematics have always been a major concern to all stakeholders worldwide. Various commissions and committees have laid great emphasis on raising the quality of instruction in mathematics. Consequently, understanding and differentiating the terms approaches, strategies, methods and techniques of teaching mathematics is of paramount importance to teacher. No single approaches, strategies, methods and techniques works for all situations signifying the futility of finding the one and only way of teaching mathematics for better achievement. A teacher who can blend mathematical teaching approaches, strategies, methods and techniques stands out to be a better experimenter and hence an excellent teacher

### 2.7.1. Teaching Approaches in Mathematics

Gustafson and Branch (2002) define instructional approach as the practice of creating instructional experiences to help facilitate learning more effectively. Instructional approaches or model represent the broadest level of instructional practices and present a philosophical orientation to instruction (Kagan, 1989). An instructional approach provides guidelines to organize appropriate pedagogical scenarios to achieve instructional goals. Driscoll & Carliner (2005) states that "approach is more than a process and resulting product, represent a framework of thinking". Richardson (1996) outline several characteristics that should be present in all instructional approach: Instructional approach is learner centered; it is also goal oriented; focuses on real world performance; help learners perform the behaviours that will be expected of them in the real world; focuses on outcomes that can be measured in a reliable and valid way and data are empirical in nature.

The approaches can be divided into four categories Behaviourism focuses on the importance of the consequences of those performances and contends that responses that are followed by reinforcement are more likely to recur in the future. In behaviourism no attempt is made to determine the structure of a student's knowledge or to assess mental process which is useful necessary for learning (Winn, 1996). The learner is characterized as being reactive to conditions in the environment as opposed to taking an active role in discovering the environment. Behaviourism approach in mathematics may entail classroom activities as drill and practice, memorization, teach and re-teach (Reimer & Moyey, 2005).Information processing strategy is simply a way to describe how students learn.

Information refers to the curriculum content (Lakoff & Nunez, 2000). Processing refers to how teaching is done it, the steps in the instructional process that maximize comprehension and retention. Implementing an information processing model of curriculum and instruction helps students understand essential material. Information processing is concerned with the stages of processing that supports learning throughout learners' development and contributes to purposeful and effective sensing and thinking skills, making performance quick and easy (Chapparo & Lane, 2012). The first stage of processing comprises registration and attention to sensory information which is important to task performance (Schneck, 2009). The second stage in processing is memory. Working memory are short-term memory and long-term memory. The approach is used to assign meaning to sensory information registered from the environment together with a store of knowledge from past experiences to enable students to predict what will happen next and direct the appropriate action. The transfer of information to the long term memory is important, as information cannot rest in the short term memory for long. An overload in the short term memory can result in cognitive overload. Teachers can help students who are suffering from information overload by letting students know the critical elements of the information and all they need is prioritizing the information. Teachers should make sure they have the students' attention and help students to make connections between new material and what they already know.

The social interaction approach states that the development of a student's intelligence "results from social interaction in the world and that speech, social interaction and co-operative activity are all important aspects of this social world" (Sutherland, 1993). The student uses language to build cognitive tools over which he or she has conscious control. The role of the teacher plays a central to this approach in that the teacher must convey the relationship between the concepts and the meaning of the concepts. In the approach knowledge is conceived as being socially constructed. According to Nunes, Light and Mason (1993) mathematical knowledge is seen as exterior and pre-existing in the subject. This implies that the learner's task is to find out meanings of that knowledge in order to apprehend it. Facing the social dimension of mathematical learning obliged us to conceptualize learning as a much more complex process, in which teachers and students play dynamic roles (Wertsch, 1991), socially to ensure learning take place. The relations established teachers and students build the main points in students' performances and school achievement. Peer to peer interactions promotes better relations among students, an increase in their self-esteem and in their ability to construct knowledge together. Thus, implementing peer interactions within the mathematics classes proves to be an effective way of promoting learning of concepts (César& Torres, 1997). In this study the social interaction between the teachers-students and students-students played a key role in construction of knowledge.

SMASE (2011) noted that teachers did not employ practical approach in construction of models, construction of angles, identifying angles and plane figures. Findings indicated that teachers explained how it should happen and not the actual practical work. In the context of this study, 'practical work' refers to tasks in which students observe or manipulate real objects or materials in order to understand key concepts in geometry. By the terms 'practical work', it is implied that students have a chance to observe and manipulate real objects, materials or witness a teacher's demonstration. Practical activities enhance the pupils' understanding in addition to sharpening their creative skills (Mugo & Kisui, 2010). An effective teacher plans practical work with specific learning objectives in mind. By using different pedagogical approaches the same practical task can be used to achieve different learning outcomes (KIE, 2012).

### 2.7.2. Strategies of Teaching Mathematics

Ingram (2011) defines strategies as clear decisions and statements about a chosen course of action for obtaining a specific goal or result while Kiruhi *et al*. (2009) define teaching strategies as the overall way or broad approach in which the teaching process is organised and executed. Oxford (1990) defines teaching strategies to be certain activities that a teacher does for the purpose of making learning process easier, quicker, funnier, more self-directed, more effective and more pushing towards new situations. They categorise strategies broadly into two groups namely: the discovery (heuristic) teaching strategy and Expository (transmission) teaching strategy.

Direct instructional strategy falls under a broader category of expository strategy. Borich (2004) opined that direct strategy is for imparting basic knowledge or developing skills in a goal-directed in a teacher-controlled environment. The teacher identifies and clearly defined learning outcomes as he/she transmits new information or demonstrates a skill and provides guided practice. The teacher also monitors student understanding and provides feedback to them on their performance. Eggen and Kauchak (2006) submitted that direct instructional strategy is designed to maximize academic learning time through a highly structured environment in which students are "on task" and experience high degrees of success. Direct instruction strategy has four key components: clear determination and articulation of goals;

teacher-directed instruction; careful monitoring of students' outcomes; consistent use of effective classroom organization and management methods. Piasta, Pelatti and Miller (2014) views direct instructional strategy as effective. The strategy being based on behaviouralist learning principles then obtaining students´ attention, reinforcing correct responses, providing corrective feedback and practicing correct responses becomes it prime purpose. Increasing the academic learning time for students to attend to the learning tasks may results to higher success rate. Students learn basic skills more rapidly when they receive a greater portion of their instruction directly from the teacher.

Popham (2008) views indirect instructional strategy as one in which teaching and learning of concepts, patterns and abstractions are taught in the context of strategies that emphasize concept learning, inquiry learning and problem-centered learning. Indirect strategies can either be teacher-directed and or students. A lot of time in this strategy is spent in planning and designing instructional activities. The strategy is based on constructivist approach where students construct concepts based on personal experiences and past learning to bring meaning to and make sense out of the content provided (Ingram, 2011). Teaching for higher-order outcomes requires instructional strategies that represent the indirect strategy. In this strategy concepts serve as the building blocks for student higher-order thinking. The thinking being the main ideas used to help to categorize and differentiate information. The strategy encompasses comparisons, classifications, metaphors and analogies, using questions, drawing examples and non-examples in order to define the essential and nonessential attributes needed for making accurate generalizations. Salman (2005) advocated for the strategy effectively production of the desired results in teaching and learning then teachers should actively involve the students in inquiry, discovery and problem solving. When students are given open-ended questions then they become creative in seeking knowledge, consisting of following steps to identify and clarity the problem hypotheses, collect data, brainstorm solutions, formulate questions, investigate, analyze and interpret the data to test hypotheses, discuss, reflect, draw conclusions and present results. In this study the indirect strategy played a key role in the teaching and learning of the loci concepts through computer animated.

An interactive teaching strategy involves dialogue mode. Piasta *et al*. (2014) explained the word interactive is formed from synonyms "inter" for "reciprocity" and "act" for "do" or "perform". The strategy calls for a lot teacher-student and students-student reciprocating each other's efforts in the performing of the tusks assigned to them. Dumitru (2000) affirms that the strategy is based on social interactive theory by Vygotsky, who tries to explain that any person, who has a better understanding of a certain concepts, when he or she assists another who doesn't have any idea of it then there a likelihood of learning taking place resulting in cognitive development. The strategies aim at promoting critical and reflective thinking, research and evaluation skills that will help students to take positive action to in learning. Students use personal and social capability to work collaboratively with others in learning activities, to appreciate their own strengths and abilities and those of their peers and develop a range of interpersonal skills such as communication, negotiation, team work, leadership and an appreciation of diverse perspectives (Kirkey, 2005).

The teacher's role as facilitator in interactive learning strategy is directed towards achieving the goals of students in the process of teaching (Ingram, 2011). The teacher makes a lesson, plan for interactive activities and assignments, through the working of which students acquire new information and eventually an individual task is transformed into a group task. Each member of the group contributes to the whole group's success. In this strategy teachers cater for individual differences among the students. This does not mean that every student must be given an individual work program or that instruction is on a one-to-one basis. When teaching and learning is individualized it is reflected in classroom organization, curriculum and instruction. Teaching and learning in interactive strategies can include a range of whole class, group and individual activities to accommodate different abilities, skills, learning rates and styles that allow every student to participate and to achieve some moments of success (Senthamarai, 2018).

In the interactive strategy the teachers use different styles so as to achieve the objective. Madona and Marine (2017) opined that use of different teaching styles in an interactive lesson makes the students to achieve better. Some of the styles of teaching in an interactive class included: interactive brainstorming is typically performed in group sessions. The process is useful for generating creative thoughts and ideas. Brainstorming helps students learn to pull together; think, pair, and share: - in the style the teacher gives a problem or a question, then pairs students. He or she gives each pair sufficient time to form a conclusion, and permit each participant to define the conclusion in his or her personal terms; in a Buzz style participants come together in session groups that focus on a single topic. Within each group, every student contributes their ideas. This encourages discussion and collaboration among the students within each group. Students learn from one another's input and experiences.

Experiential learning strategy is an engaged learning process whereby students "learn by doing" and by reflecting on the experience (Wurdinger & Carlson, 2010). Experiential learning activities can include, but are not limited to, hands-on laboratory experiments, practicum, field exercises and studio performances. The proponents of the strategy were psychologists such as John Dewey, Carl Rogers and David Kolb (Haynes, 2007). They argue that we learn from our experiences of life on a day-to-day basis. They also treated reflection as an integral part of such learning. Experiential learning involves a number of steps that offer student a hands-on, collaborative and reflective learning experience which helps them to fully learn new skills and knowledge (Jarvis, 1994). Concepts are also learnt through discovery and exploration. The emphases in the doing are clearly stated in the maxims:-

"I hear and I forget, I see and I remember, I do and I understand"

~ Confucius, 450 BC

(Ackman & Mysak, 2009) pp 272

"Tell me and I forget, Teach me and I remember, Involve me and I will learn"

~ Benjamin Franklin, 1750

Matias (2017) pp2

According to Haynes (2007) students should be involved in making products or models, role-playing, giving a presentation, problem-solving and playing a game. A key facet of experiential learning is what the students learn from the experience rather than the quantity or quality of the experience. Students share the results, reactions and observations with their peers. Students also get other peers to ideals as they give their own experience, share their reactions and observations and discuss feelings generated by the experience. The sharing equates to reflecting on what they discovered and relating it to past experiences which can be used for future use. Azuka (2013) ascertained that in this strategy learners are guided by the teacher to discover mathematical facts and formulae through observations and organized activities. Ajaja (2013) sees teaching strategy as involving presenting students with information in a form which requires them to discern relationships within the information and to structure and make sense of the information and relationship. The strategy enables students to actively participate in the learning process and discover things for themselves, rather than teachers giving formulae to students, they should create activities for the students to discover mathematical facts, formulae and concepts.

Katrin and Äli (2014) defined self-directed learning strategy as process in which individuals take the initiative, with or without the help of others, in diagnosing their learning needs, formulating learning goals, identifying human and material resources for learning, choosing and implementing appropriate learning strategies and evaluating learning outcomes. Being able to think and act independently remains one of the most important skills that a student can learn. Students' exploration of mathematics concepts for themselves is at the core of learning. Making discoveries from a task the teacher sets for learners who are genuinely interested in finding the challenges is wonderfully rewarding for learners as well as an incredible life tool. The failure to prepare students for the demands of a world where teachers will not be available to provide all the answers is to do them a great disservice. While spoon-feeding styles of teaching can sometimes offer the most direct route to ensuring that all students are making demonstrable progress, it is possible to teach in a way that allows room for independence without sacrificing those all-important results. But to create a more independent learning environment we must first start by adjusting the mindsets of everyone in the classroom from both the students and the teachers. This form of self-directed learning could promote higher forms of thinking (Borich, 2004).

Moving away from the traditional teacher-dominated way of learning, active learning approaches encourage pupils to participate in their own learning through discussions, project work, practical exercises and other ways that help them reflect upon and explain their mathematics learning (Kyriacou, 1992).There is need for us to ‘’shift the emphasis from teaching to learning from the teachers' world to the students' world as noted by Dienes cited in Briggs (1968) indicated,. Above all, we should provide opportunities for the children to think for themselves, so that learning for them is an active and creative process. Our main objective in the teaching of mathematics at all levels should be to give our students the opportunity to think for themselves, the opportunity to appreciate the order and pattern which is the essence of mathematics, not only in manmade world but in natural world as well and the needed skills. In this study the students were guided on the ways of working with computer animations and were given an opportunity to explore and discover some of Loci concepts on their own.

### 2.7.3. Methods of Teaching Mathematics

Kiruhi *et al*. (2009) refers to teaching methods as the process or set procedures of teaching which tends to promote specific strategy of teaching. A teaching method is a systematic plan for the presentation of mathematics, which is based in the approach and a strategy that we have chosen (Meissner, 2002). A teaching method's design includes objectives, syllabus, activities, teachers´ roles, students´ roles and materials. Basically, a teaching method is a procedure or way of materializing a teaching approach through a systematic plan. Among the factors that influence the achievement of learners in mathematics is teachers' effectiveness as measured through the acquisition and use of good instructional skills and methodologies (Max, 1988). A carefully designed teaching method can make teaching and learning effective (Kurumeh & Opara, 2008). The teachers' choice of the methodology plays a key role in students' achievement.

Riasat (2010) noted that besides its importance attached to mathematics it is one of the most poorly taught. This agrees with House (2006) who also noted that poor and inappropriate teaching methodology is one of the factors attributed to students' failure in mathematics. Some of the teaching methods used are: Lecture, Guided Inquiry, Demonstration, Discussion/learning groups, Question and answer, Problem solving, Drill and Practice, Project work, Programmed learning, Experimentation and Games (Murphy & Moon, 2004; Kinyua *et al*., 2005; KIE, 2006; Kiruhi *et al*., 2009). None of this method is perfect for all situations. One can use more than one method during mathematics instruction. Granström (2006) shows that using different teaching methods in classrooms influence the outcomes for students in different ways. The choice of the teaching method depends on the objectives the teacher intends to achieve. Each method is used for a particular purpose.

Cooperative teaching method is defined as "instructional methods in which teachers organize students into small groups, then work together to help one another learn academic content (Slavin, 2010). Although each student in the same group has his or her own task which is part of the whole group task, they are evaluated on the basis of the whole group performance (Slavin, 1980). In a cooperative learning environment students are presented with concepts which they share intensively among themselves resulting into influences and conflicting ideals. The students express their own thoughts to other students when they are sharing in cooperative learning. The previous knowledge is brought onboard during sharing and if there are misconceptions then they should be addressed as the teacher harmonizes the students' ides

(Bosco, 2004). Lower ability students benefit more from mixed ability grouping because they can get assistance from other members (Tutty & Klein, 2008).

During interaction, students could better understand questions and successfully finish tasks. Same ability grouping can positively influence high and average ability students while it does not affect low ability students (Baer, 2003). The social cohesion perspective holds that members in a group will study hard and support other group members to achieve more (Slavin, 2010). Wageman (1995) argued that group members' interdependence means that they can positively or negatively affect one another by behaviours, attitudes and experiences. In cooperative learning, group members have to complete his or her part of the whole task in order to achieve group goals (Wageman, 1995). The interactions such as the helping and sharing depend on high level of interdependence (Wageman & Baker, 1997) which makes the group to meet their objectives.

Kafata and Mbetwa (2016) ascertained that discussion methods take variety of forms from open-ended to collaborative exchange of ideas among a teacher and students or among students for the purpose of furthering students thinking, learning, problem solving, understanding and literary appreciation. Other terms for discussions used for pedagogical purposes are instructional conversations (Tharp & Gallimore, 1988) and substantive conversations (Lavy & Shriki, 2010). Discussion involves two-way communication between participants. Participants present multiple points of view, respond to the ideas of others, and reflect on their own ideas in an effort to build their knowledge, understanding, or interpretation of the matter at hand. In the classroom situation the teacher and learners all participate in discussion. Various proponents of personalized instruction, collaborative instruction and constructivism claim that the active exchange of ideas within small groups not only increases interest among the members of the group but also promotes critical thinking and academic achievement (Bautista, 2012). The shared learning during small-group discussion gives students an opportunity to engage in discussion, take responsibility for their own learning and thus become critical thinkers (Bautista, 2008). Discussion provides students with the opportunity to explore variations between their own and their partners' knowledge and thinking, correct misconceptions and fill gaps in understanding (Granström, 2006). Small-group discussion also engenders further thinking since students are engaged in activity, reflection and conversation where the learners become responsible for defending, proving, justifying and communicating their ideas to the other members of the group (Jasmin, 2005).

According to Cockcroft (1982) mathematics teaching at all levels should include opportunities for discussion between teacher and students and between students themselves. Discussions assist the development of understanding. Discussion-based teaching creates opportunities for students to practice important skills such as argumentation, critical thinking, and collaboration (Sun, Anderson, Lin & Morris, 2015). When considering the merits of group discussions mathematics problems are well suited for this type of learning environment. Most mathematics problems can be solved in a reasonable length of time. In addition, logical arguments can be used to demonstrate how to find the solution. Discussion is focused and objective oriented. Different approaches to a problem can be discussed and the merits of each graded by the group. Learning takes place when students have the ability to communicate concepts to others. Gould (1991) asserts the importance of discussion in learning mathematics for the following reason: we should aim for relational understanding that is knowing why the rules work and logical understanding for being able to explain them to others rather than the instrumental understanding which implies using rules without knowing why they work which results from learning mainly by imitation and memorizing. In this study the students had an opportunity to engage in discussions and presented their idea to others for further discussions. This made the concepts of loci clearer.

Olajengbesim (2006) note that lectures are probably the best teaching method in many circumstances and for many students; especially for communicating conceptual knowledge and where there is a significant knowledge gap between lecturer and audience. Lecture method is most appropriate in secondary schools when a teacher is introducing a new concept Kinyua *et al*. (2005). Mathematics has been taught using the lecture format as noted by Buckner (2011). He further observed that teachers presents the mathematics idea, provides an example or two and then assigns the problems for the students to perform. Kara and Yesilyurt (2007) observed that lecture method is not suitable for mathematics and sciences. He further noted that the lecture method hinders the secondary schools' students from active participation in the teaching and learning processes. The method has been described as ineffective by researchers and educationists worldwide. The thinking required by students in traditional pedagogy (Stoblein, 2009) has been low level of comprehension that goes from the ear to writing hand

and leaves the mind untouched. Azuka (2013) note that the in traditional lecture method the teacher revises the previous day's lesson first, then the teacher-directed explanations is used to present materials for the new lesson without much involvement of the learners. Using this method, the author has observed that: the teacher is very active while the students are passive in the teaching and learning processes; the teacher tells students formulae and concepts in mathematics and students just try to listen and copy; retention and recall of concepts by students are not enhanced. Hence students forget concepts few days after lesson.

Alro and Skovsmose (1996) define Inquiry-based learning as a teaching method that casts a teacher as a coordinator who provides guidance and support for students throughout their learning process, rather than a sole authority figure in the teaching and learning. Teachers encourage students to ask questions and consider what they want to know about the world around them. Students then research their questions, find information and sources that explain key concepts and solve problems they may encounter along the way. Inquiry-based learning is student-centred, in that students play an active and participatory role in their own learning but teacher facilitation is also extremely key and necessary to the learning process. Usually, during the inquiry learning, every student is working on a different question or topic. In this environment, teachers ask high-level questions and make research suggestions about the process rather than the content. At the end of the inquiry learnt concept, students reflect on the experience and what they learned. They also consider how the concepts learnt connects to other concepts or topics of interest, as an inquiry on one topic often results in more questions and then an inquiry into new fields. Harawati (2003) note that inquiry based instruction enhances student performance and attitudes about science and mathematics. This agrees with Borasi (1992) who also observed that the method is an important tool teachers can use to help students boost their performance in academics, critical thinking and problem solving. The greatest disadvantage of the method is that it requires a lot of time to learn a concept as a results it is rarely used in secondary schools

Students get easily bored if their teacher cannot combine teaching methods in order to make each lesson unique and intriguing. Any information can be passed over to pupils in numerous ways. Some of them are easy to understand and remember while others are difficult. The combination of different methods of teaching is something each professional teacher should not only know but also implement in their classroom. Baroody (2002) suggests that the integration of a variety of teaching methods would be the most helpful factor to improve the effectiveness of teaching and learning practices. Some novel teaching methods, such as active learning based on investigation, discovery, cooperative learning methods, animations and simulation approaches, are more effective than traditional methods where teachers just apply "chalk and talk" (Serbessa, 2006). Effective geometry teaching requires understanding of what students know and need to learn, a challenging and supportive learning environment and continually seeking improvement.

The choices of the methods used in classes vary globally. Eu (2018) noted that in most countries, a variety of teaching methods are used.  At policy level, central education authorities have some influence on the use of particular teaching methods. Across Europe, teaching methods are centrally prescribed or recommended in the majority of countries (EU, 2014).International survey data by Mullis, Martin and Foy (2008) provides some information about the methods being used in classrooms in European countries as problem-based learning. It focuses on acquiring knowledge and skills by analysing and solving representative problems. Learning often occurs in small groups under the guidance of a teacher who acts as facilitator. New information is acquired through self-directed learning and the problems encountered are used as a means to gain the required knowledge (Dochy, Segers, Bossche & Gijbels, 2003). In Germany and the Netherlands teachers or schools are only provided with central support in the form of web-based and other resources. In other countries such Italy, Hungary, the Netherlands, Sweden and Iceland teachers do not receive any guidelines and it is up to them to choose which methods to use. In Greece**,** the curriculum and teaching manuals allow teachers to choose from various methods which, depending on the circumstances, can be used exclusively or in combination with others (Scott, 2015). In Ireland at post-primary level the teachers are at liberty to choose the teaching methods that is suitable and convenient to them (Burke, 2014). Japanese teachers frequently posed mathematics problems that are new for their students and then asked them to develop a solution method on their own. After allowing time to work on the problem, Japanese teachers engaged students in presenting and discussing alternative solution methods and then teachers summarized the mathematical points of the lesson (NCTM, 2014).

Mwangi (2016) in his research found out that in many African countries, the teaching methods used are poor since they lack aspect of student-centeredness, student activities, experiments and improvisation. “Chalk and talk “, method is the practiced in many of the African countries. Most of the African countries report that the mathematics teaching is examination oriented and rote learning is the most practised method (Munyao, 2013). On the contrary North, Gal and Zewotir (2014) found out that, teachers in South Africa in KwaZulu-Natal schools, group students into small-groups to work or in extended open-ended discussions, so that they can practice, use and develop a deeper understanding of the concepts of statistics. In the Zambian case, under the Strengthening of Mathematics, Science and Technology Education (SMASTE) there was an improvement and shift from teacher centred teaching as noted by Kafataand Mbetwa(2016) after phase one of INSET trainings the targeted teachers science and mathematics to using varieties of teaching methods in classrooms. This ranges from demonstrations, discussions, practical approaches and use of ICT.

Ambuko (2008) noted that in Kenya teachers are advised to have insight and be resourceful in whatever methods they use. The teachers in Kenya are at liberty to use various methods at their disposal. SMASSE (1998) outlined the various methods used in Kenyan secondary school as practical work, investigations, group experiments cooperative learning and individual assignments among others. More frequently used method of teaching in Kenya is lecturing (Balozi & Njung’e, 2004). The Sentiments echoed by SMASSE (2011) is that in Kenyan Secondary schools some mathematics and science teachers were still using lecture methods and students were given rigidly formulated statements, which they had to memorize and regurgitate when required to do so by the teacher. The conclusion would seem to be that for professional development of teachers in a range of different methods, then teachers should be allowed to make decisions about what can be applied, when and why, is the best approach for improving teaching.

In this study several teaching and learning methods were used during the teaching. Demonstrations, discussions, Question and answer, Problems solving were used and challenges sought through misconception analyses. This agrees with Adams (2018) who observed that the most frequently used mathematics teaching methods in USA are Collaborative learning, discussions, demonstrations and worked examples in K-12 classes of an equivalent of the Kenyan Form Four classes.

### 2.7.4. Techniques of Teaching Mathematics

Teaching techniques refer to the most specific category of behaviour that teachers use in order to accomplish an immediate objective. Kiruhi *et al*. (2009) define a technique of teaching as a brief, but detailed learning activity, which a teacher uses during an instructional process to achieve intended purpose. Therefore, teaching techniques are the different teaching practices that we observe in the classroom such as explaining, demonstration and questioning among others. Ogologo and Wagbara (2013) suggested that teaching technique must involve skills and specific classroom activities. This agrees with Moore (2012) who is of the view that the technique used in classrooms presents the teacher and student with a tangible activity to make a mathematics concept understood. Orwig (2003) views technique as "an explicit procedure used to accomplish a particular learning objective or set of objectives". There are various teaching techniques that are used in classes on day-to-day bases by teachers. Each of the technique has its unique importance and purpose in teaching.

Question and answer is defined by Mtunda and Safuli (1997) as a technique both for teaching and oral testing based on the use of the questions to be answered by the pupils. Question and Answer techniques can be employed to serve various purposes, which including: to create interest and motivate participation in a class; to encourage students to express their thoughts or ideas as well as to help them clarify their thoughts or ideas and to evaluate, diagnose and check students' preparation and understanding of the material as well as the knowledge students bring into the class (Moore, 2005). By questioning, teachers may evaluate student preparedness, support conceptual development, reinforce understanding and ask students to elaborate (Wilen, 1992). A teacher can prompt students with questions at each stage of the teaching process (Maccini & Gagnon, 2000). By not accepting a response in a positive way, the teacher may discourage pupils from answering further questions (Moore, 2012) and hence the method should be used with caution.

Adekoya and Olatoye (2011) found out that demonstration techniques of teaching mathematics have the potential of raising students' achievement. This technique is one of the most effective teaching tools (Abdullahi, 1989). Effective demonstration technique is either teacher dominated or teacher/student partnership (Busari, 2004). Busari further outlined the following criteria as essential for classroom demonstration: (i) organize the demonstration to make it visible to all students. (ii) attempt to carry out the demonstration before the lesson begins. (iii) avoid having too much demonstration in a lesson not to confuse the students. (iv) be systematic, that is performing the demonstration in a scientific manner. (v) attempt to time each demonstration and space it to enable the students grasp the message. (vi) the teacher should be available in class to help students understand the concepts behind the demonstrations. Ogologo and Wagbara (2013) highlighted some of the demonstration technique's advantages as: It bridges the gap between theory and practice; It controls the rate of breakages and accidents as students watch the teacher do it before attempting to do the same; It is learning by doing method and so enables the teacher to teach manipulative and operational skills; It could be a time and material saving device because many students can observe one demonstration at the same time.

Farooq (1980) points out that a "problem" usually indicates a challenge, which requires study and investigation to get a solution. Skinner (1984) states that the term "problem-solving" is defined as the frame work or pattern within which creative thinking and learning takes place. Lester and Kehle (2003) typify problem solving as an activity that involves the students being engaged in a variety of cognitive actions including accessing and using previous knowledge and experience. The primary goal of mathematics teaching and learning is to develop the ability to solve a wide variety of simple and complex mathematics problems. To many mathematically literate people, mathematics is synonymous with solving problems, creating patterns, interpreting figures, developing geometric constructions, proving theorems, among others. On the other hand, persons not enthralled with mathematics may describe any mathematics activity as problem solving. It is a process of overcoming difficulties that appear to interfere with the attainment of a goal.

Lavy and Shriki (2010) found out that difficulty in problem solving may occur at one of the following phases, namely reading, comprehension, strategy know-how, transformation, process skill and solution. One way to teach students to problem solve is to teach the four-step processes developed by Polya (1971): i) understand the problem, ii) devise a plan, iii) carry out the plan, and iv) look back at what you have done. Lesh and Zawojewski (2007) suggested four aspects that contributed to problem-solving performance. These are the problem solvers: (1) mathematical knowledge, (2) knowledge of heuristics, (3) affective factors which affect the way the problem solver views problem solving, and (4) managerial skills connected with selecting and carrying out appropriate strategies. Problem solving helps to support core processes such as the use of representation, communication, and connection between and among mathematical concepts (Kilpatrick, Swafford & Findell, 200l). In problems solving technique students not only use their mathematical knowledge they already gained (Wyndhamn, 1997), but also improve their knowledge and understanding leading them to a better mathematical insight. Therefore, problem solving should be used as the basis for teaching mathematical concepts so that students construct their own knowledge (Peterson, Fennema & Carpenter, 1989). Teachers need to reinforce learners' intellectual curiosity, problem identification and problem-solving skills and their capacity to construct new knowledge with others (Bull and Gilbert, 2012).

Gallenstein (2005) advocated for solved through games in which children are presented with situations and activities that challenge their minds. Nisbet (2009) ascertained, using games in mathematics always played a significant role in mathematics and its learning because they encourage logical-mathematical thinking and contributed to the development of knowledge. There are three main types of games that can be used in the classroom. These include commercially made games, games made available via the internet and/or computer software, and games made by both the teacher and students. Some commercially made games, which include board games and card games (Lach & Sakshaug, 2005). Computer games or games made available via the internet can also be used in mathematics instruction. Keand Grabowski (2007) emphasized that play performs important roles in a child's psychological, social and intellectual development. Having considered the pedagogic and technological consideration (Salen & Zimmerman, 2004) ascertained that a game should also be fun to play and further as noted by (Koster, 2005) a game should be cultivating and interesting so to capture the learners' attention. Gibson, Aldrich and Prensky (2007) argues that some of the most effective lessons have been developed by writers, directors and producers of film, radio and television, who, not being instructional designers, have produced "outstanding examples of 'educational' objects." they go on to suggest that video games, as an emerging form of media, can not only be effective educational objects, but also warrant attention for their ability to engage the player's attention for thousands of hours of play.

Supervised study or practices occurs when time is allotted during the class period to do some specific questions while the teacher is present to guide the students, answer questions or help in any manner necessary (Dean, 1982). Some advantages of this method are; allows time for the student to be helped by the teacher when he especially needs it, can be used to help pupils get started on their assignments, to help them understand what they are doing and can be used for individual, small group or large group study. One of the disadvantages of this method is that it can come at a time when students think they do not have to do any work and might cause some students to depend on the teacher's help and not to work independently (Leonard and Irving, 1981).

Ogologo and Wagbara (2013) define Drill and Practice Technique as the repeated hearing; doing or use of a particular item. The method can be fun if the teacher is lively and enthusiastic about it (MIOE, 2004). Drill and practice is a poor teaching technique in mathematics, it may involve memorizing formulas and may leads to low academic performance (Moore, 2012). Drill-and-practice, like memorization, involves repetition of specific skills, such as addition and subtraction, or spelling. The technique can only be meaningful to learners if the skills built through drill-and-practice become the building blocks for more meaningful learning.

KIE (2006) notes that in programmed learning the teacher provides a sequence of activities so that the learner can reach set objectives. The role of the learner is to respond to the given instructions or questions. The learning is usually set in stages and the learner responds to each one of them at his/her own pace. Mondoh (2005) notes that materials learnt are carefully designed in a sequence of tiny units of work through which pupils work to achieve knowledge and understanding. Each unit is an effective stimulus and the correct response leads to the next unit. Kiruhi *et al*. (2009) highlighted the advantages of programmed learning as teaching units being broken into manageable chunks to ease learning and the learners progressing at their individual pace of learning where they receive feedback immediately. The limitations of the method are that the learner has no control over the units of work to be covered and their sequencing.

Howard and Frank (1979) note that the improvement of instruction is largely dependent upon the teacher. Sander (2009) noted that students have different learning styles, diverse ways of thinking, comprehending and knowing. Teachers using different pedagogical teaching techniques can support the development of new cognitive skills necessary for the transition from simple arithmetic thinking to the more abstract thinking (Johanning, 2004). This would only mean that teachers should be throughout the whole of their professional life students of teaching methods. Vashist (2007) established in her research that there is no proof that any particular teaching method is best at all time and situations. Methods need to be blended to suit a particular situation and set conditions. She further notes that teaching methods enjoy only a brief "hour" of glory and are speedily forgotten. This suggests the futility of attempting to find a fool proof method of teaching. Effective teachers demonstrate a repertoire of teaching skills that enables them to meet the different needs of their students. Good teaching is constantly experimental and methods of teaching need to be regularly improved. Sankey (2005) has pointed out that, traditional methods of teaching and learning are no longer adequate to meet the demands of higher education.

In this study Geometry and Loci concepts were computer animated from the real-life situation in PowerPoint presentation and used to demonstrate key concepts in loci. Combinations of various teaching techniques were used during instructions. Among the techniques used being demonstrations, question and answer, problem solving and supervised practice. Each of these techniques was used with a particular purpose, for instance before the students started to animate the loci concepts the teacher made some demonstrated and also engaged some students to demonstrate to their peer. This made the students to have a lot of confidence in handling the devices. To ensure that the concepts are understood and the students are attentive the teachers frequently asked questions that required students to respond instantly. At time the teachers were giving questions on a worksheet where the students worked independently as they move around marking to confirm that each student is getting the concepts correctly. They were also addressing any misconceptions that the students were holding. By the end of the lesson the students were give some problems on loci to solve either individually or as groups.

## 2.8. Mathematics Teaching-Learning Resources

One of the key teaching- learning resources is human. The understaffing of mathematics teachers is a global issue as was reported in countries such as the USA (Bajah, 1993). At the beginning of the 2016–2017 school year, the Clark County School District in Nevada USA (the nation's fifth largest district, serving more than 300,000 students) had nearly 1,000 classroom teacher vacancies (Rebora 2016). This was a serious under staffing that needed to be addressed. Falode, *et al*. (2016) observed that Cambodia, Malaysia and the Philippines are understaffed in the mathematics field. They also offer relatively low teachers' basic salaries. (Turan, 1996) noted that there is insufficient teaching force in Ankara Turkey. A World Bank report (Ottevange, Akker & Feiter 2007) indicated that in most developing countries, not enough Mathematics teachers are being produced by Universities and Colleges. Belfield, Crawford and Sibieta (2017) reported that the rising pupil numbers in England's schools and shortfalls in the number of new teacher trainees mean that retaining teachers who are already in the profession is all the more important for managing the future supply of teachers. Hungary has a serious mathematics and science teachers' shortage that needs to be addressed immediately (Andrews & Sayers, 2013).

South Africa, is still struggling with a series of socio-economic problems that are deeply entrenched in the teacher shortages in some disciplines, such as science and mathematics, poorly or under-qualified teachers, lack of infrastructure, packed classrooms, crushing poverty, social and political inequity (Davis & Krajcik, 2005).Uganda faces shortage of mathematics teachers as noted by (MES, 2017). SAAEA, (2014) observes that Malawi is equally faced with challenges of understaffing in mathematics. Many African Countries among the Zimbabwe, Tanzania, Kenya, Lesotho, Namibia and Mozambique are faced with serious understaffing in mathematics and science subjects (Attwood, 2014).

Other non-human recourses are equally important in teaching and learning. Their presences lead to students' better achievements. Mutai (2006) asserts that learning is strengthened when there are enough reference materials such as textbooks, exercise books, graph books, teaching aids, Chalkboard constructions set, a grid-board, a white board and classrooms. Davis and Krajcik (2005) observed that the availability of teaching/learning materials for mathematics in secondary schools such as text books leads with 94.1%, followed by mathematics geometrical sets (28.4%) and colored chalk (25.3%). They also noted that, charts and mathematics models contribute to 10.5% and 6.2% respectively of mathematics teaching and learning resources. Adeogun and Osifila (2008) pinpoint that textbooks are a major input for performance in examinations. This view is shared by Collopy, (2003) who observes that availability and quality of textbooks in a secondary school is strongly related to achievement among loaners at all levels of learning. Other teaching and learning tools that are vital in a mathematics class include: Geometrical set, 30 cm ruler, geo-boards, cards and probability devices among other. The tools are important for they help students understand mathematical concepts. More importantly, technological tools allow students investigate many more situations than they can explore by hand, thus helping them see patterns that leads to deeper understanding of mathematical concepts. In general using mathematical apparatus, tools and devices provides a foundation of practical experience on which students can build abstract ideas. It encourages them to be inventive, helps to develop their confidence and encourages their independence. Students are capable of solving quite difficult problems when they are free to use concrete apparatus to help them think the problem through.

Computers are teaching and learning devices that when used in classes impact students with skills useful in real life. Technology arouses students' interest and when used appropriately it makes mathematics more visual, logical and more fun. Scientific calculator has emerged as another useful tool for teaching and learning of mathematics in Kenya since 2002 (Ochanda & Indoshi, 2011) when they were introduced in the teaching and learning of mathematics. However, they further ascertain that despite the adoption of scientific calculators as a tool to aid in teaching and learning mathematics, a study carried out in Emuhaya District indicated that only 5.36 percent of the learners accessed scientific calculators during the teaching and learning of mathematics. A study by Ambuko (2008) points out that, availability of various media resources and their advantages in classroom instruction has necessitated the integration of such media in the teaching and learning process, these media may present challenges to the teachers and learners in the learning process, such as accessibility and lack of training. Wide ranges of ICT are available in the market for use in schools as resources and tools to support the teaching and learning of mathematics. This can include programmable robots, calculators, television, radio, audio tape, video, digital cameras as well as computers, software, access to the internet and inter-active whiteboards (Uloma, 2011). Technology helps to shift the responsibility of mathematics learning from the teacher to the learner.

Dayo, Olushina and Ajayi (2013) argued that availability and adequacy of teaching/learning resources promote the effectiveness of schools as these are basic things that can trigger good students' academic performance. These agree with Bulimo, Odebero and Musasia (2010) who that indicated that availability of adequate learning resources would lead to high quality education in schools hence improvement in performance of national examinations. Hanushek (1997) asserts that additional resources per se does not improve educational outcomes but teaching contexts, processes, methods and methodologies used by teachers are regarded as responsible for transforming educational resources into performance. Anghileri (2000) cautions against an overuse or overreliance on one resource materials. Hughes (1986) showed that young children were capable of solving abstract mathematical work when diverse resource materials are used. Bouck and Flanagan (2010) call upon all secondary school to ensure they have mathematics manipulatives as vital recourses for teaching and learning. These are physical objects students can manipulate to explore and develop an understanding of a mathematical concept. Manipulatives include such things as pattern blocks, base ten blocks, interlocking cubes, and many others that will subsequently be listed. Research suggests that manipulatives themselves do not magically carry mathematical understanding but rather, they provide concrete ways for students to give meaning to new knowledge (Stein & Bovalino, 2001).

Research revealed that in Sub-Sahara African countries there are a number of huge challenges in poorly resourced schools in science, mathematics and ICT education. Unless these challenges are fully addressed, successful implementation of the "well intentioned" ICT policies would be a farfetched dream. Various incentives and measures have been taken to attract young people to mathematics and science teaching but in vain (Obiaha, 2006). When the right quantity and quality of human resources is brought together, it can manipulate other resources towards realizing institutional goals and objectives (Maicibi, 2003). The implication of Maicibi's finding is that well trained teachers in mathematics if well deployed to the secondary schools will bring about well-rounded students who will perform academically well in mathematics. Consequently, every educational institution should strive to attract and retain the best of the teachers and educators available.

In this study the human resources, computer hardware, computer software, LCD projectors, geometrical sets, mathematics textbooks, excise books and past KCSE papers among others were used in teaching the experimental groups. The use of Computer animations allowed the students to visualize concepts in two and three dimensions which would have been impossible using the normal convectional teaching method. The teachers demonstrated some of the concepts and allowed students to explore other related concepts. This created a lot of fun and excitement as they practically solved the problems in the worksheets provided by the teachers. This also provided confidence and satisfaction that they can solve other related questions in loci.

## 2.9. Information and Communication Technology Use in Mathematics Education

Seyed and Sina (2013) define ICT as a set of production and service industries used for electronic storage, transfer and displaying of data and information. Over the years technology has been employed most often to furnish ways in which information could be presented and exchanged (Kitchens, 1996). ICT consists of various tools and systems that can be exploited by capable and creative teachers to improve teaching and learning situations. Roblyer, Edwards & Havriluk (1997) classification of ICT tools as: (i) Informative tools such as Internet, Network Virtual Drive, Intranet systems and Homepage among others. (ii) Hardware such as computers, laptops, LCD projects, Video cameras, Television set and radios among others are frequently used in classes. (iii) Constructive tools- these are software used in construction of presentation in various forms such as Microsoft Word, PowerPoint, FrontPage, Adobe Photoshop and Lego. Others important software include graphics software such as Geogebra and Grapes (iv) Communicative tools may include e-mail, SMS, WhatsApp Twitter and Facebook, some of which are adored in the social media. (v) Collaborative tools may discussion boards, webcam Skype and Cisco Webex among many others. Reimer and Moyer (2005) found out that junior high students benefited from using virtual pattern blocks, platonic solids and Geoboards to explore geometric concepts, using Word processors, PowerPoint, spreadsheet, Geogebra, Geometer's Sketchpad, Cabri and data analysis software

If technology is to take a leading role in the mathematics classrooms (American Mathematical Society, 1994), then research needs to be done to investigate what level of technology needs to be used as well as what technology is effective. One of the most promising opportunities for use of technology in teaching is the animation-based learning environment. A comparative study done by Idris (2005) has revealed that countries such as Malaysia, Australia, Vietnam, India, Indonesia and Philippines had developed their policies on ICT with the objective to upgrading mathematics teacher competencies to improving the quality of teaching and learning of mathematics through technology.

The South African government made a commitment in their e-Education policy whose ultimate goal is to the realization of ICT-capable managers, educators and learners (Baloyi, 2017). Malawi however, adopted its ICT policy in 2009. Though it does not specifically suggest the integration of technology in mathematics instruction, it makes commitment to use of ICTs across the Malawi education system (MIOE, 2004). Kenya produced its first National ICT Policy in 2006. Its vision is a prosperous ICT-driven Kenyan society, while its mission is to improve the livelihoods of Kenyans by ensuring the availability of accessible, efficient, reliable and affordable ICT services. One objectives of Kenya's ICT policy is to encourage the use of IT in schools, colleges, universities and other educational institutions in the country so as to improve the quality of teaching and learning (MoIC, 2006).

Muriithi (2005) points out that in Kenya like most developing countries ICT usage is still limited to computer literacy training. The Ministry of education has National ICT Strategy for Education and Training (MoE, 2006) which highlights the potential of ICT to help support implementation of Free Primary Education (FPE) and to address emerging challenges such as; overcrowded classrooms, high Pupil Teacher Ratios (PTRs) particularly in densely populated and semi-arid areas, shortage of teachers on certain subjects or areas, and relatively high cost of learning and teaching materials (Oloo, 2009). The present ICT curriculum merely deals with 'teaching about computers' and not how computers can be used to transform the teaching and learning process in our schools. "Being digital fluent" means not only knowing how to use the technological tools but also knowing how to construct things of significance with those tools. Researches in Kenya indicate that computer technology is rarely used in teaching of mathematics (Muriithi, 2005).

The most frequently used ICT computers, laptops, projection devices, recording devices and video devices have been incorporated into education as a media for information exchange making possible the delivery of information in ways other than traditional lecture and text formats (Hughes, 2005). Although ICT tools have great potential to impact the teaching and learning of mathematics, the presence of ICT hardware does not automatically produce desirable schooling outcomes in mathematics education (Li, 2004). The ICT has opened new possibilities for increasing the effectiveness of teaching and learning processes (Salomon, 2002). Knowledge of technology cannot be isolated from the content to be taught. Good mathematics teaching requires an understanding on how technology is related to the pedagogy and mathematics content (Annetta, Slykhuis & Wiebe, 2007). Successful and effective use of technology for the teaching and learning of mathematics depends upon sound teaching and learning strategies that come from a thorough understanding of the effects of technology on mathematics education (Coley *et al*. 2000; Albright and Graf, 1992). Teachers need to learn how to most appropriately and effectively integrate technology into their teaching methods (Annetta et.al, 2007). This calls for educationist to embrace technology.

Use of a computer-generated system to represent the dynamic responses and behaviour of a real or proposed system (Alakanani & Liu, 2013) is referred to as simulation. Variables in the program can be adjusted to simulate varying conditions in the system (Isaacs & Cohen, 1987). Simulations have been used in teaching and learning of chemistry with marked improvement ((Daşdemir & Doymuş, 2012) .The studies conducted by Heid (1988) suggest that instruction that integrates computer geometry systems can lead to improved student problem solving ability. Computer simulations are used to study the behaviour of objects or systems that cannot be easily or safely tested in real-life, such as weather patterns or a nuclear blast. In this study a bicycle, wall clock and a see saw were simulated to produce and predetermine motion to represent loci.

Krzysztof, Marcin, Magdalena and Jankowska (2015) define computer animation as a process of creating a series of images appearing one after another synchronised into a single whole and causing the image animation effect. Computer animations are designed to provide visualizations of processes or events and to communicate abstract concepts and theories to students (Burke, Greenbowe & Windschitl, 1998). According to Han-Chin (2005), student's prior knowledge and his or her learning strategy may affect a student's learning outcome with the use of computer animations. Animations bridge the gap between the concrete world of nature and the abstract world of concepts and models (Yair et.al, 2001,). According to Bourque and Carlson (1997) combining computer animations work with hands-on work may produce a better learning outcome than either method alone.

Students can observe and manipulate normally inaccessible objects, variables and processes in real-time. The ability of these technologies to make what is abstract and intangible to be concrete and manipulatable, suits them to the study of natural phenomena and abstract concepts. Computer manipulatives can sometimes be more powerful than concrete manipulatives; some applications offer flexibility "to explore geometric figures in ways not available with physical shape sets" (Clements & Sarama, 2009). Children learn mathematics concepts; according to Berlin and White (1986) in a more effective way if computer animations are used for they provide a smooth transition from concrete manipulation of objects to their abstract understanding.

The superiority of computer animation to other methods may be attributed to several factors, some of which are learners' ability to visualize the 3D object, receive immediate feedback; self-paced learning, reinforcement, principles of mastery learning, associate learning and step by step learning among others. Animation facilitates learner encoding process, greater self - esteem and motivation (Lin, 2001 & Kearsley, 2002).Further to that Rotbain, Marbach and Stavy (2007) sees animations as pictures in motion and analogous to a subset of visual graphics. Computer animation has a positive effect on memorizing knowledge by students. Computer animations help students to demonstrate processes in a way to model students how to connect between things. It has wide application in the processes of teaching of various technical, medical and natural science subjects.

Computer animations have been investigated as a means to help students confront and correct these misconceptions, which often involve essential learning concepts (Zietsman & Hewson, 1986).This also agrees with Anderson and Skwarecki (1986) who noted that noted that they reduce misconceptions when used during mathematics instruction. Students often hold strong misconceptions be they historical, mathematical, grammatical or scientific Studies by Jiang and Potter (1994) supported the potential of computer animations to help accomplish needed conceptual change. Animation package has been used in the field of science to assist students in the understanding of difficult topics (Yisa & Ojiaku, 2016) and found to improve student conceptual knowledge and reduce misconceptions. The use of computer animation in learning makes cognitive and abstract information clearer Yisa (2014), hence creating an aspect of reality that would be otherwise impossible to be explored within the classroom context. This agrees with Rotbain *et al*, (2007) contend that animations demonstrate concepts which are difficult to understand and visualize.

Mathematics ideas are not in the manipulatives; they are in the child's mind. In this sense, the particular medium may be less important than the fact that it could be used or manipulated to reflect and to construct new meanings and ideas (Baroody, 1989). The potential benefits of using technological tools for instruction are highlighted by Lajoie (1993) as supporting cognitive processes by reducing the memory load of a student and by encouraging awareness of the problem solving process. One of the challenges facing teacher educators is how to ensure that graduate teachers have the necessary combination of skills and pedagogical knowledge that will enable them to both effectively use today's technologies in the classroom as well as continue to develop and adapt to new technologies that emerge in the future (Gill &

Dalgarno, 2008). ICT tools share the cognitive load by reducing the time that students spend on computation, allowing them to engage in mathematics that would otherwise be out of reach, thereby stretching their opportunities.

The findings that students taught geometry using this instructional model have superiority over those taught using traditional teaching methods is in agreement to the assertion made by Abimbade (1997) who sees animations instructional model to enhance visual imagery, stimulate learning and assist the teacher to properly convey the topic content who the learners to achieve better performance score. Students are much more likely to learn and retain the learning of a new concept or skill when they are able to make meaningful mental links with previously learned concepts or experiences.

This study therefore aimed at using computer animations and finding their effects in the teaching and learning of mathematics loci topic so as to achieve the education aspirations of vision 2030 which are to reduce illiteracy by increasing access to education, improve transition rate from primary to secondary and raise the quality of education and relevance of education. It took three months to conceptualize, design, test and refine the animations used in this study. Since the animations were created by the researcher specifically for this study, it placed emphasis on both aesthetics and production techniques as well as a cognitive focus to test the stated hypotheses. As the sole designer and animator for this project, the researcher developed the animation according to his creative and aesthetic preference with the intent of creating content that would have great appeal to students. This research intended to fill the gap of teaching mathematics using Computer animation to teach the topic where students explored various mathematics concepts in the topic Loci that were concretised for students to mathematise the abstract concepts of Loci and the find effects on learning outcomes.

### 2.10. Geometry and Loci Topic

Vashist (2007), defines Geometry as that branch of mathematics in which such figures as squares, triangles, cubes, among others are studied; specifically students construct and measure the angles, length of various geometric figures and study the relationship that exist between their parts. In the modern world, geometry is a crucial branch of mathematics, both as a prerequisite knowledge to many other areas of mathematics and real-life activities. Understanding of geometric concepts and relationships is vital to the study of other branches of mathematics. Geometry is used in such fields as astronomy, survey, architecture and engineering. Knowledge geometry is also essential for interpreting, understanding and appreciating our world in which examples of geometry abound. Mugo and Kisui (2010) reaffirm that geometry strengthens one's ability to visualize, analyze and solve problems. Geometry has an important place in school mathematics curricula as it develops pupils' spatial ability, logical reasoning skills and ability to solve real world problems in which geometrical terminologies and properties occur (Presmeg, 2006).

Geometry is regarded as a problematic learning area in mathematics around the globe (Snyders, 1995). Learning geometry may not be easy and a large number of the students fail to develop an adequate understanding of geometry concepts, geometry reasoning, and geometry problem solving skills (Mitchelmore & White 2004). Geometry is built on abstract concepts and relations; it is a field of study to be offered with care to pupils and students at all levels of education (Toptaş, 2007). Geometry appears abstract and so learners experience difficulties in conceptualization, seeing relationships and making connections to real-life situations (KIE, 2002).

Jones (2002) observed that teaching geometry is difficulty in USA due to its abstract nature. He also noted that student find it very difficult to learn. To illustrate points and line segments through drawings and diagrams and yet neither object can be visible, except in our 'mind's eye' is a big challenge. Some students in Japan are successful in learning about geometry, while many have difficulties in it (Fujita, 2012). The Japanese mostly use student centred approach to teaching hence ensure that the student are able to conceptualize the geometrical concepts.

Geometry is seen as a problematic area in many of the African countries such as Senegal, Uganda, South Africa and Ghana (MIOE, 2004). Poor performance in mathematics in general and geometry topics in particular, is not a problem unique to Namibia alone but it is a global issue (Siyepu, 2005). In Nigeria teaching and learning geometry is seen as difficulty and has resulted in mass failure in mathematics examinations (Telima, 2011).

Mlodinow (2001) sees geometry is an important area in school mathematics education because geometrical thinking is a fundamental way to engage learners with mathematics, connect between the real world with mathematics or other branches of sciences and mathematics. Yang, Reys and Wu (2010) investigated geometry lessons in junior high school and reported that students considered mathematics topics important since they could felt the topics were applicable outside the class, hence the improvement of learning. Geometry, which is frequently used in real-life, is an important sub domain of Mathematics. The shapes of the rooms, buildings and structures, shapes used for decoration and ornaments are all geometric (Baykul, 2002). Duval (1998) explained that geometry instruction is often more complex than that of numerical operations or elementary algebra. It is therefore more important that geometry instructions incorporate new and tested approaches such as using visual and multimedia tools in the classroom. The integration of ideas from geometry is particularly important, and computer tools play a critical role in that integration (NCTM, 1989). From the perspective of the van Hiele model of the development of geometric thought, the student moves from observing and identifying the figure to a recognition of it properties, to understanding the interrelationships of the properties of the figures and the axiomatic system within which they are placed (Usiskin, 2003). According to Strutchens, Harris and Martin (2001) students start to express and understand the world around them, analyze and solve the problems by means of geometry and they can express the abstract symbols by shapes in order to understand them better.

The teaching of geometry starts from standard one where the learner is expected to recognize and identify straight, curved, rectangular, triangular and circular shapes (KIE, 2002). This content develops spirally from one level to the other. Geometry as a topic requires the learner to use the geometrical tools and practically learn geometrical concepts. Teachers are expected to prepare schemes of work, lesson plans, and lesson notes and organize geometry teaching/learning activities and resources for effective teaching.

Loci is one topic taught to Form Four students in Geometry among others that are studied in this branch of mathematics. Kinyua *et al*. (2005) give geometrical construction as a prerequisite knowledge to loci. Loci topic is taught to Form Four students in the Kenya's secondary schools (K.I.E, 2005). Kibui and Macrae (2005) define locus as a path, an area or volume traced out by a point, a line or an area respectively. That is a point traces out a path, a line traces out an area and an area traces out volume. Kinyua *et al*. (2005), stress the importance of understanding the language used in loci. The word Loci in the teaching and learning of mathematics at secondary school level is met for the first time in Form Four. Kimble, Garmezy and Zigler (1990) noted that many of our everyday problems are caused by unclear definitions of present circumstances or limited objectives. Locus can be expressed in two or three dimensions (MOE, 2006), which satisfy given conditions. Locus is used in day to day mathematics problem solving such as locus of points equidistant from a fixed point which represents a circle and a sphere in two a three dimensions respectively. The fixed point is the centre of the circle and the sphere while the equal distant is the radius of the circle and the sphere. It is used to describe the movement of a point on wheels of bicycles in fine art and engineering design. Lavy and Shriki (2010) found out that computer technology contributes to understanding the concepts in geometry teaching. In this study the concepts in Geometry in general were demonstrated using computer animations and simulations.

### 2.11. Theories of Learning Mathematics

Gunn and Steel (2012) define a theory as an organising framework that brings an additional layer of understanding to concrete experience by implying relationship, consistency and a degree of predictability and testability. Learning theories are commonly consulted in the instructional design process in many traditional educational setting (Mallon, 2013).Popham (2008) notes that 'learning progressions' requires the teacher to have a thorough understanding of how learning takes place and which skills and concepts are essential pre-requisites for particular learning.  Existing theories about how children learn have been classified in various categories and they have a significant bearing on how mathematics is taught (Cathcart, Pothier, Vance, & Bezuk 2011).

Siemens (2004) classifies Behaviorist, Cognitive and Constructivist as the three broad learning theories that are most often utilized in the creation of instructional environment. These theories however, were developed in a time when learning was not impacted through technology. Skinner (1984) suggests that these learning theories are not in consonants with the environment within which learners engage today. His proposal attempts to merge accepted theories of learning with the digital age into a new understanding. Over the last two decades, technology has reorganised how we live, how we communicate and how we learn. Learning needs and theories that describe learning principles and processes should be reflective of underlying social environments (Sweller, 1994).

Herawati (2003) looks at behaviourism as an approach to learning as being based on the proposition that behaviour can be researched scientifically without recourse to inner mental states. Behaviourism is associated with stimulus and responses (Skinner, 1974).  On the other hand Honebein and Sink (2012) sees behaviourism concentrating its efforts on observable behaviour and reinforcement. They believe that a student has learned something by observing their changes in behavioural responses (Baharun, 2012).Behaviorism is primarily concerned with observable behavior, as opposed to internal events like thinking and emotion. The environment shapes one's behaviour; what one learns is determined by the elements in the environment, not by the individual learner. Hartley (1998) is of the view that learning is better when the learner is active rather than passive; frequent practice and practice in varied contexts, is necessary for learning to take place. Skills are not acquired without frequent practice; and positive reinforcements like rewards and successes are preferable to negative events like punishments and failures.

Behaviourism strategies was relevant to this study in that when designing the computer animations material issues of instructional objectives, mathematics content feedback, practise as stimulus, reinforcement and were apparent. During mathematics instruction, the materials were presented in a sequentially logical order, the students were informed of explicit lessons learning outcome and were provided with feedback so that they were able to assess their performance and took corrective action if required. Therefore in this study technology was used to support the behavioural approaches to instruction.

Anderson, Reder and Simon (2002) argue that transfer between tasks is a function of the degree to which the tasks share cognitive elements. Cognitive style is seen as an individual's particular way of processing and representing information. Studies on cognitive style show that the students with analytical cognitive style of learning are very critical in their reasoning and are able to distinguish figures as discrete from their background as opposed to the non-analytical students who experience events in an undifferentiated way (Ige, 2001; Riding & Al-Salih, 2000). Students can benefit from mathematics approached in varied forms through hearing, seeing, saying, touching, manipulating, writing or drawing concepts within mathematics (Shih, Speer & Babbitt, 2011). Students who have difficulties with mathematics can benefit from lessons that include multiple models that comprise a mathematics skill or concept at different cognitive levels (Sousa, 2008), since students with learning difficulties rarely learn from only seeing or hearing mathematics (Shih *et al*, 2011).

Good and Brophy (1990) define learning from a cognitivist perspective as the acquisition or reorganisation of cognitive structures through human processes and the storage of information.

Cognitive theories focus on how learners' information (Cordeiro &Cunningham, 2013) is acquired through learners' motivation, thinking, reflection and encoding it before storage into the long term memory from where it can be retrieved (Ally, 2008). The prior knowledge and mental processes not only play a bigger role in stimuli variation but also provide orientation in behavior responses (Deubel 2003).The primary emphasis is placed on how knowledge is acquired, processed, stored, retrieved, and activated by the learner during the different phases of the learning process (Anderson, Reder, and Simon 1997). Learning happens best under conditions that are aligned with human cognitive architecture (Sobel 2001). According Cognitive theories, knowledge is a network of mental frames or cognitive constructs called schemata. Schemata organize knowledge stored in the long-term memory (Erasmus, Bishoff & Rousseau, 2010).

An understanding of the cognitive processes that drive mathematics learning and knowledge organisation is critical for the design of effective approaches to mathematics teaching. Research done by Kirschner (2002) observed that mathematical knowledge bases that are effectively organised in the form of schemas facilitate more effective activation and use of knowledge during problem solving. Baddeley and Hitch (2000) identified two key attributes on how students deal with mathematical information. First one showed connections between the processing of incoming mathematical information, reorganisation and the subsequent retrieval of that information for later use. Secondly, the drawing of attention to the types of cognitive load that student could experience as they attempt to make sense of incoming mathematical information (Owolabi, 2012). The mental resources required of working memory to learn, perform or understand a task can vary quite dramatically between tasks. Some mathematics tasks may involve little cognitive load while others may be very complex and, therefore require heavy cognitive load. If a mathematical task exceeds the mental resources available in working memory then cognitive overload will occur. Sweller (1994) observed that recalling a simple formula could be taught with little or no interaction with other elements of information. When students are asked to solve problems, a great deal of their mental effort is directed towards understanding the new problem which involves high levels of cognitive load. From a cognitive processing perspective, problem-solving consumes a high proportion of the limited working memory capacity leaving few resources for constructing schemas (Zeitman & Hewson, 1986). In this study the students were engaged cognitively as they learnt loci concepts ranging from low order cognitive involvement to high and complex cognitive involvement. This made their cognitive aspect in critical thinking and creativity to be displayed.

Vygotsky (1978) defined constructivist learning theory as the active construction of new knowledge based on a learner's previous experience. Cordeiro and Cunningham (2013) sees constructivist theory as one where students learn by actively constructing knowledge, comparing new information to previous learned information, thinking about and working through discrepancies and ultimately reaching new knowledge. Young and Collin (2003) define constructivist approach to learning as one can enable all the learners to construct valid knowledge and also enable them to transmit it in different contexts. Learning in the constructivist framework contributes to intellectual, social and psychological development of learners unlike other methods of instruction. Constructivism is based upon the premise in mathematics education that children have a mathematical reality of their own (Steffe & Wiegel, 1992). Constructivist pedagogy in mathematics believes that learner can construct knowledge by active participation rather than acquiring knowledge by watching teachers' demonstration in the classroom and, to learn to speak and act mathematically participating in mathematical discussion and solving new or unfamiliar problems (Richards, 1991).Constructivist theory proposes that humans cannot be "given" information which they immediately understand and use. Instead, humans must "construct" their own knowledge through experience (Jonassen, 1994). This agrees Okere (1996) ascertained that learners construct meaning from input, then processing it through existing cognitive structures and retaining it in their long term memory. Young children can actively construct from their everyday experiences a variety of fundamentally important informal mathematical concepts and strategies, which are surprisingly broad, complex, and sometimes sophisticated. They appear to be predisposed, perhaps innately, to attend to mathematical situations and problems (Baroody, 2000; Clements & Sarama, 2009).

Mathematics educators believe that students construct their own knowledge as they interact with their environment (Baroody & Coslick, 1998). For knowledge to be meaningful, students need to construct it themselves (Marlowe & Page, 1998). Wolfinger and Stockard (1997) noted that for older children the problem of abstractness of concepts is less intense, but some still have difficulties comprehending abstract ideas without familiar examples. Within the classroom setting, constructivist approaches to learning would have students using group work, discussions, and word problems to help create their new knowledge(Lee, 1999).It is therefore helpful to relate new concept with those familiar to children. The constructivist philosophy holds that students' learning of subject matter is the product of the interaction between what they are taught and what they bring to any learning situation (Ball, 2003). Students learn mathematics by actively reorganising their own experiences in an attempt to resolve their problems (Cobb, Yackel & Wood, 1991). In this study the students constructed new loci concepts knowledge from their prior experience on day-to-day real life.

## 2.12. Theoretical Framework of the Study

Henning, van Rensberg and Smit (2004) defines a theoretical framework is a lens on which the researcher positions his or her study. It helps with the formulation of the assumptions about the study and how it connects with the world. It is like a lens through which a researcher views the world and orients his or her study. It reflects the stance adopted by the researcher and thus frames the work, anchoring and facilitating dialogue between the literature and research.

The theoretical framework that guided the study was based on Piaget’s Constructivist Theory of Cognitive Functioning, which states that learning is attained through ‘construction’ (Piaget, 1970). Constructivist theory proposes that humans cannot be "given" information which they immediately understand and use. Instead, humans must "construct" their own knowledge through experience. Vicki and Back (2011) argued that learners have a back-ground experience and self-knowledge that they bring to the counter and that the role of the educator is to act as a guide to the learners to deepen and develop connections with the skills and content.

Jonassen (1994) summarised what he referred to as "the implications of constructivism for instructional design". The following principles illustrate how he thought knowledge construction can be facilitated: provide multiple representations of reality; represent the natural complexity of the real world; focus on knowledge construction, not reproduction; present authentic tasks (contextualising rather than abstracting instruction); provide real-world, case-based learning environments, rather than pre-determined instructional sequences; foster reflective practice; enable context-and content dependent knowledge construction; support collaborative construction of knowledge through social negotiation. Okere (1996) contend that learners construct meaning from prior knowledge and new knowledge so constructed is then process through existing cognitive structures and retain it in their long term memory. This is done in ways that leaves the input open to further processing and possible reconstruction. In this study the students were expected to construct knowledge from simulations and animated loci concepts delivered from their day –to –day life experiences.

### 2.13. Conceptual Framework of the Study

A conceptual framework is a structure which the researcher believes can best explain the natural progression of the phenomenon to be studied (Camp, 2001). It is linked with the concepts, empirical research and important theories used in promoting and systemizing the knowledge espoused by the researcher (Peshkin, 1993).

A conceptual framework is described as a set of broad ideas and principles taken from relevant fields of enquiry and used to structure a subsequent presentation (Reichel & Ramey, 1987).From a social constructivist perspective about learning (Kafai & Resnick, 1996), knowledge is personally and socially constructed. The learner centred approach is achieved by designing and making meaningful artefacts with multiple perspectives and representations of knowledge during learning. The effective use of technology encourages a move away from teacher-centred approaches and towards a more flexible and student-centred environment. A technology rich learning environment is characterized by collaborative and investigative strategies to learning, increasing integration of content across the curriculum and a significant emphasis upon concept development and understanding.

The framework shows Computer Animated Loci Teaching Technique as an intervention in the teaching and learning process of Loci a mathematics topic. The dependent variables were students' mathematics achievement and learners' misconceptions in loci. The investigation in this study was to find out whether the use of Computer Animated Teaching Loci Technique influences students' achievement and learners' misconceptions in mathematics compared to the use of conventional teaching methods. The independent variables were Computer Animated Loci Teaching Technique and the conventional teaching methods. Conventional teaching methods in this study referred to all the regular methods of teaching mathematics as opposed to use of Computer Animated Loci Teaching Technique. In an ideal classroom teaching situation where teachers use specific instructional methods we expect the students to understand what has been taught. In this study we expected the Computer Animated Loci Teaching Technique to improve students' mathematics achievement and reduce their mathematics misconceptions. This may not always be the case due to other extraneous factors.

Extraneous variables are variables that may influence the independent variables in explaining the outcome of a study. They may damage a study's validity, making it impossible to know whether the effects were caused by the independent variables. The extraneous variables in this research were teacher factors, school factors and student's factors. The teacher factors were categorised into teacher's training and experience. Teachers with more years of experience are more effective than teachers with no experience (Rice, 2010), but those with over 20 years are not much more effective than those with 5 years of experience (Ladd 2008).The teachers who participated in the research had taught Form Four class for at least two years. Owolabi (2012) opined that the teacher's academic qualification only is not enough to positively affect academic performance of secondary school students but a professional qualification in a specified field of study does. The teachers who participated in the research had a degree in education and were trained to teach mathematics.

Walklin (1982) emphasised that before using any teaching aid the teacher must be fully conversant with its operation and application. The teacher must also rehearse his presentation before confronting the class. The teachers using the Computer Animated Loci Teaching Technique were trained by the researcher for five days on the use of the Technique. To avoid Hawthorn effect the students were taught by their teachers. In cases where there was more than one stream all of them were taught the same way for ethical consideration and only one stream was included in the study for data analysis. The teaching of loci topic took three weeks as stipulated by KIE (2002).

For the school factors the researcher studied co-educational Secondary Schools. The study focused on Form Four students in the sub-county who were assumed to be of relatively the same age. Figure 2 shows the representation of the relationships among variables within the conceptual framework.

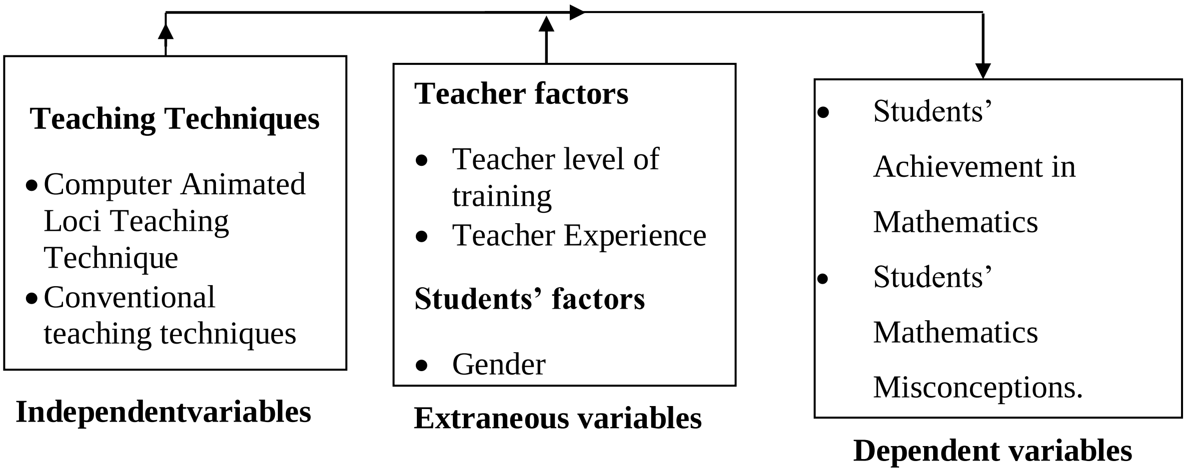



**Figure 2: The Diagrammatic Representation of the Relationship Between the independent, Intervening and dependent variables of the Study.**

# CHAPTER THREE

# RESEARCH METHODOLOGY

## 3.1. Introduction

This chapter presents at the research design; location of the study; target population, sampling procedures and sample size; instrumentation used in data collection; their validation and testing reliability; and data collection procedure; and finally data analyses.

## 3.2. Research Design

This study used Solomon Four, Non-Equivalent Control Group Design, which is quasi-experimental research. The design was preferred because secondary schools' classes once constituted exist as intact groups and the schools' authorities do not allow such classes to be broken and re-constituted for research purposes (Borg & Gall, 1989). This design contains two control groups and two experimental groups, which serves to reduce the influence of intervening variables and allow the researchers to test whether the pretest itself has an effect on the subjects (Kumari, 2013). The design helped to achieve the following purpose: to assess the effect of the experimental treatment relative to the control group; to assess the interaction and treatment conditions; to assess the effect of pre-test relative to post-test; assess the homogeneity of the groups before administration of the treatment(Borg & Gall, 1989). The non- equivalent groups, Pre-test and Post-test were used to partially eliminate the initial differences between the experimental groups and control groups.

| Group | Pre-test | Intervention | Post-test |
|---|---|---|---|
| $E_1$ | $O_1$ | X | $O_2$ |
| $C_1$ | $O_3$ | — | $O_4$ |
| $E_2$ | — | X | $O_5$ |
| $C_2$ | — | — | $O_6$ |

**Figure 3: Solomon Four, Non-Equivalent Control Group Research Design**

In Figure 3, Group $C_1$ and $C_2$ represent sampled control schools that used Conventional teaching methods. Groups $E_1$ and $E_2$ represent the sampled experimental schools that received the treatment. $O_1$ and $O_3$ denotes Pre-test while $O_2$,$O_4$, $O_5 and O_6$ indicate the Post – test for respective groups. X was used to denote Experimental treatment using Computer Animated Loci Teaching Technique. The dotted line (……) indicates the use of non-equivalent groups while (—) implies no treatment (Mugenda & Mugenda, 1999).

### 3.3. Location of the Study

The study was conducted in co-educational Secondary Schools in Kitui County, Kenya. The climatic condition varies across the county in terms of rainfall and temperature. The rainfall is usually very erratic and unreliable. The source of livelihood for majority of the people in Kitui County is subsistent farming. The absolute poverty in the county stands at 63.8% (n=648,108) which is estimated to be 0.55% of the national absolute poverty (ASDSP, 2014).

### 3.4. Population of the Study

Gall, Borg and Gall (1996), define target population as all members of a real or hypothetical set of people, events or objects from which researchers generate data for a study. According to information available at Kitui county Education office there are 380 secondary schools out of which 268 are Co-educational Secondary Schools. The target population in this study was secondary school students. According to Yount (2006) it is usually not possible to reach all the members of a target population, one must identify that portion of the population which is accessible. The accessible population was Form Four students in Co-educational schools which had enough schools for the chosen research design. There were 16,532 Form Four students in Kitui County out of which 10,630 are in Co-educational secondary schools (KCEO, 2015b & 2017b).

### 3.5. Sampling Procedures and Sample Size

According to Creswell (2010) sampling is the process used to select a portion of the population for a study. A sample is studied in an effort to understand the population from which it was drawn. As such, we are interested in describing the sample not primarily as an end in itself, but rather as a means of helping us to explain some facet of the population (Bryman (2012). McMillan and Schumacher (2010) describe sample as the group of participants from whom the data are collected. Sampling means selecting a given number of subjects from a defined population as representative of that population (Orodho, 2002).

In this study, four schools were chosen because the Solomon 4-Group Design requires four groups where each school forms a group. To ensure minimal interactions between the experimental and control groups, a simple random sampling was used to select four Sub-Counties out of sixteen Administrative Sub-Counties in Kitui County. Each group was assigned a Sub-County. According to Machaba (2013) purposive sampling means that participants are selected because of some defining characteristics that make them the holders of the data needed for the study. Sampling decisions are made for the purpose of obtaining the richest possible source of information in order to answer the research questions. A purposive random sampling was therefore used to select schools in each Sub-County that had even distribution of gender, graduate teachers teaching Form Four class and a computer laboratory with at least ten computers. A simple random sampling was used to select the streams whose results were analysed. According to Levitt and List (2007) experimental group members may feel special simply because they are in the experiment, this may reflect on their performance. To avoid this effect all streams in the two experimental groups were given the same treatment, but only the selected streams had their results analysed. The sampling was appropriate because it ensured that all schools have equal chances of being included in the study sample. Tables 7 show the number of schools in each sub-county in Kitui and the number of Co-educational secondary schools.

**Table 7: Number of Co-educational Secondary Schools in Kitui County per Sub-County**

| S/No. | Sub-County | Total Secondary Schools | Co-educations secondary |
|---|---|---|---|
| 1. | Ikutha | 23 | 17 |
| 2. | Katulani | 18 | 13 |
| 3. | Kisasi | 16 | 12 |
| 4. | Kitui Central | 31 | 25 |
| 5. | Kitui West | 29 | 24 |
| 6. | Kyuso | 20 | 17 |
| 7. | Lower Yatta | 24 | 16 |
| 8. | Matinyani | 24 | 18 |
| 9. | Migwani | 41 | 23 |
| 10. | Mumoni | 20 | 11 |
| 11. | Mutitu | 21 | 16 |
| 12. | Mutomo | 25 | 17 |
| 13. | Mwingi Central | 35 | 26 |
| 14. | Mwingi East | 27 | 14 |
| 15. | Nzambani | 14 | 11 |
| 16. | Tseikuru | 12 | 8 |
| **Total** | | **380** | **268** |

**Source: Kitui County Education Office, (KCEO, 2015b; 2017b).**

According to Mugenda and Mugenda (1999), the required size is at least 30 cases per group. Each class had more than 30 students. All the four schools where the study was done had two streams in Form Four. The streams were randomized using simple random sampling to end up with one stream whose data was used in the study. The sample size was 207 students consisting of 95 female and 112 males. The study focused on Co-educational secondary schools where the number of boys and girls were determined by their numbers in the sampled schools. The teachers using Computer Animated Loci Teaching Technique were trained by the researcher for five days on the use of the instructional method. The Technique was exhaustively discussed with mathematics teachers in the experimental groups. The mathematics teachers in the two control groups were not trained on use of the Technique and were therefore expected to use the conventional teaching methods. The Hawthorne effect can arise as a result of "researcher's demand effects" whereby experimental subjects attempt to act in ways that will please the experimenter (Levitt & List 2007). To avoid Hawthorn effect the students were taught by their teacher and in cases where there were more than one stream all of them were taught the same way. The streams were randomized using simple random sampling to end up with one stream whose data was used in the study.

### 3.6. Research Instrument

Instruments are the devices that a researcher uses to collect data; they include a pen – and – paper test, a questionnaire, or a rating scale (Fraenkel & Wallen, 2000). In this study Mathematics Achievement Test on loci (MAT), was used to collect the required data from Form Four students in Co-educational secondary schools. The misconceptions were also identified from the MAT. The items in instrument were adopted from KCSE past Examinations on Geometry and Loci. It had thirty one items that tested students' knowledge, comprehension, application to real-life situations and mathematical skills on working out questions on loci, a topic taught to Form Four students. The administration of MAT took two hours, and was supervised by the mathematics teachers. A minimum of 0 score was awarded to a student who scored all the 31 items wrong and maximum score 100 was awarded to one who scored all the items correct (See, Appendix A). Every misconception held by a student was awarded one mark. The total of all misconceptions held by the student were his or her misconception score. MAT was administered to one experimental and one control group as a Pre-test before intervention. All the four groups sat for the same MAT as a Post-test after the intervention.

### 3.6.1. Validity

Fraenkel and Wallen, (2000), defines validity as the degree to which correct inferences can be made based on results from an instrument; depends not only on the instrument itself, but also on the instrumentation process and the characteristics of the group studied. According to Munira (2010) pilot testing plays a key role in the context of surveys and is essential to ensure that the survey tool functions well before the final administration. Machaba (2013) viewed the aim of conducting a pilot study as a way of testing whether the participants would be able to answer the questions as expected and to allow the researcher to re - phrase them where necessary and also note if the participants needed further clarification. One Co-educational Secondary School was selected from 44 Co-educational secondary schools in Kibwezi Sub-County. The Sub-County was chosen for its similar characteristics to Kitui County. Kibwezi Sub-County in Makueni was part of the larger Machakos District before subdivision in 1992. The purpose of the pilot study was to enable the researcher to ascertain the validity of the instrument and to familiarise with the administration of the instrumentation and improvement of the procedures. The outcome of the pilot study indicated those questions that were not clear enough and these were paraphrased to enable the participants to answer them appropriately.

According to Maaike (2013) it is important to use relevant experts such as educationalist, developers of learning materials, teachers and researchers involved in the area of learning materials to validate the educational research instruments. According Koul (1994), face and content validity of an instrument is improved through experts' judgment. Moreover, no guidelines are presented about the minimum or maximum number of content experts. However, it is recommended to use at least two experts in order to deal with subjectivity (Maaike, 2013). Thus the instrument used in this study was validated for face and content validity by four experts in educational research from the Egerton University Curriculum, Instruction and Educational Management Department and three mathematics teachers, who are KNEC mathematics examiners. Their comments were incorporated into the instrument before being taken to the field.

### 3.6.2. Reliability

Reliability is a measure of the degree to which a research instrument yields consistent results or data after repeated trials (Mugenda & Mugenda, 2003).Reliability of the instrument was estimated using Kuder-Richardson's (K-R) 20 coefficients which require a single test administration. The items in MAT used in this study were of different difficulties and as such KR-20 was preferred (Wright & Stone, 1999). KR-20 analysis is used when the items on a test form vary in difficulty (Meagher, Tianshu, Wegner, & Miller, 2012). A threshold of 0.8826 were realised in mathematics achievements. This was above the threshold of 0.7 which is considered suitable for predictions to be sufficiently accurate (Gall, Gall and Borg, 2003). The reliability coefficient was calculated using SPSS version 21.0

### 3.7. Data Collection Procedures

The researcher sought permit from the National Commission for Science, Technology and Innovations (NACOSTI) through Graduate school of Egerton University to carry out the research. Permission was sought from the Kitui-County Commissioner to collect data from the Sub-Counties and ensure that the security of the research was guaranteed. The researcher visited the County Director of Education to seek his permission to conduct the research in the Sub-Counties. He also visited the sampled co-educational Secondary Schools to familiarise himself with the schools and to inform them of the intended study. The researcher then identified the teachers who participated in the study in the selected schools. Trained graduate teachers, who are degree holders with a teaching experience of two years and above participated in the study.

Training of the participating teachers run for five days after which the students in the experimental schools were introduced to Computer Animated Loci Teaching Technique as contained in the teachers' guide (Appendices C, D and E). The guides were made so as to indicate scope of content as follows: the concept to be demonstrated by each of the instructional approach in computer animated designs on loci; the linkage to the real-life situations; and break down of subtopics in the Loci topics; teachers and learners activities, resources and references (Appendix C). The guides assisted in having similar treatment in the experimental schools. The students in Control group C1 and experimental group E1 were given a pre- test before commencement of teaching loci. The researcher supervised the administrations of the MAT by the teachers. All the pre-test score sheets were handed over to the researcher for safe custody. The treatment ran for three weeks, the duration recommended for coverage of 'Loci' (KIE, 2002). The post- test MAT was then administered by teachers to the four groups with close supervision of the researcher. The researcher then scored the pre-test and post-test, organise and code the data for analyses.

### 3.8. Data Analysis

The purpose of data analysis is to find meaning in data (Bums, 2000). Data analysis involves the process of sorting the data, coding, cleaning and processing and results interpretation (Kamindo, 2008). The data collected using the instruments was analysed using Statistical Package for Social Sciences (SPSS) version 21.0. Descriptive and inferential statistics was used to analyse the relevant objectives. There were three variables to be considered in this study, the independent variables, the intervening variables and the dependent variables. The independent t-test was used to determine the significance of mean differences in mathematical achievement and misconception between the Experimental group $E_1$ and the control group $C_1$ on pre-test. A t-test was used because of its superior quality in detecting differences between two groups (Borg & Gall, 1989). This was to test the characteristics of the subjects before intervention. A t-test was also used to establish whether there was statistically significant gender difference in mathematics achievement and misconception when students exposed to Computer Animated Loci Teaching Techniques.

To find out the effects of Computer Animated Loci Technique during instructions on secondary school students' mathematics achievement and misconceptions in the mathematics topic "loci", the Post- test MAT was analysed. The one way ANOVA procedure was used to establish whether there was a statistically significant difference in the mean scores of achievement and misconception among the four groups. ANOVA is appropriate for use when more than two groups are involved (Fraenkel & Wallen, 2000). The inferential statistics was used to test the hypotheses at a confidence level of 95% (Mugenda & Mugenda1999), which is the same as coefficient alpha (α) level value equal to 0.05 (Gall *et al*.,1996). The study involved non-equivalent control groups. It was necessary to confirm the results by performing Analyses of Covariance (ANCOVA) using pre-test scores as the covariate. The main purpose of ANCOVA was to adjust the post-test means for differences among groups on the pre-test, because such differences are likely to occur with intact groups (Dimitrov, & Rumrill, 2003). A Summary of statistical analysis is outlined in Table 8.

**Table 8: Summary of Data Analysis**

| HYPOTHESES | INDEPENDENT VARIABLE | DEPENDENT VARIABLE | STATISTICAL TEST |
|---|---|---|---|
| **$H_O$1:** There is no statistically significant difference in the mathematics achievement scores between students exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci. | • Computer Animated Loci Teaching Technique<br>• Conventional teaching methods | Student's mathematics achievement scores. | • Independent sample t-test.<br>• One way ANOVA<br>• ANCOVA |
| **$H_O$2:** There is no statistically significant difference between the mathematics misconceptions scores committed by students exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci. | • Computer Animated Loci Teaching Technique<br>• Conventional Teaching Methods | Student's mathematics misconceptions | • Independent sample t-test.<br>• One way ANOVA<br>• ANCOVA |

**Table 8 continued…**

| | | | |
|---|---|---|---|
| **$H_O$3:** There is no statistically significant gender difference in mathematics achievement scores among secondary school students when exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci. | • Computer Animated Loci Teaching Technique<br>• Conventional Teaching Methods | Student's mathematics achievement scores. | • Independent sample t-test. |
| **$H_O$4:** There is no statistically significant difference between the misconceptions mean score of male and female students when exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci. | • Computer Animated Loci Teaching Technique<br>• Conventional Teaching Methods | Student's mathematics misconceptions. | • Independent sample t-test. |

# CHAPTER FOUR

# RESULTS AND DISCUSSIONS

## 4.1. Introduction

This chapter presents and discusses the results of the study. The research data obtained are presented using both descriptive and inferential statistics. The findings of the study are presented in tables and their implications discussed. Analysis of variance (ANOVA), analysis of covariance (ANCOVA) and t-test are used to test the four hypotheses of the study. Information in this chapter is organised in the following subsections.

i) Results of the pre-test on MAT.
ii) Effect of Computer Animated Loci Teaching Technique on students' achievement in Loci topic of mathematics.
iii) Results of the pre-test on Misconception score.
iv) Effect of Computer Animated Loci Teaching Technique on students' Mathematic misconceptions in Loci topic of mathematics.
v) Effect of the Computer Animated Loci Teaching Technique on gender difference in students' achievement in Loci topic of mathematics.
vi) Effect of the Computer Animated Loci Teaching Technique on gender difference in students' Mathematics misconceptions in Loci topic of mathematics.
vii) Discussion of the result of the study

## 4.2. Results of the pre-test on MAT

One experimental group E1 and one control group C1 sat for a pre-test MAT that was to assess the homogeneity of the groups before intervention. Table 9 shows the number of students who participated in the four schools of study by school and gender.

**Table 9: Number of Students who participated in the Research Study in Experimental and Control Schools by Gender**

| | C1 | E1 | C2 | E2 | TOTAL |
|---|---|---|---|---|---|
| FEMALE | 24 | 26 | 26 | 19 | 95 |
| MALE | 35 | 25 | 19 | 33 | 112 |
| TOTAL | 59 | 51 | 45 | 52 | 207 |

The distribution of boys and girls in the sampled schools was fair with exemption of E2 where the male students were more than 60%. Most of the classes were big enough to accommodate the students except C1 where the students were overcrowded.  Only one class C2 was within the recommended class size for secondary schools in Kenya of 45 students per class (MoEST, 2005). Table 10 shows the mean, standard deviations of pre-test scores in MAT.

**Table 10: Mean Scores on MAT for Groups E1 and C1**

| Group | N | Mean | SD | SE |
|---|---|---|---|---|
| C1 | 59 | 26.86 | 17.137 | 2.231 |
| E1 | 51 | 26.35 | 16.578 | 2.321 |
| Total | 110 | 26.63 | 16.805 | 1.602 |

The groups C1 and E1 sat for pre-test MAT, which made it possible for the study to assess the homogeneity of the groups before the treatment was applied as recommended by Gall, Borg and Gall (1996) and Kumari (2013).Table 11 shows the t-test of pre-test scores in MAT

**Table 11 : Independent Sample t-test of Pre-Test Scores on MAT Based on Groups E1 and C1**

| Variable | Group | N | Mean | SD | df | t-computed | t-critical | p-value |
|---|---|---|---|---|---|---|---|---|
| MAT | C1 | 59 | 26.86 | 17.137 | 108 | 0.158 | 1.98 | 0.719 |
| | E1 | 51 | 26.35 | 16.578 | | | | |

*Not significant at p>0.05 level

*Critical values (df= 120, t=1.98, p>0.05) Calculated values (df=108, t=0.158, p=0.719)

The independent sample t-test for MAT pre-test mean score for groups E1 and C1 were not significantly different, t (108)= 0.719 and p > 0.05 as shown in Table 11, implying that the groups had similar characteristics and were suitable for the study. This lack of pre-existing differences between treatments and controls implies that the control group yields reliable results of what would have happened to students in the absence of computer animation technique, and when these results are compared to outcomes for students exposed to computer animation technique, reliable estimates of computer animation technique impacts are obtained.

**Table 12: The Mean Score and Standard Deviation of Pre-Test Score by Gender**

| GROUP | N | Mean | SD. |
|---|---|---|---|
| FEMALE | 50 | 25.36 | 15.790 |
| MALE | 60 | 27.68 | 17.668 |
| Total | 110 | 26.63 | 16.805 |

Table 12 shows mean score of pre-test by group by gender. The overall performance of female and male in the pre-test of the two group showed that the boys performed slightly better than the female. This agrees with the reports by KNCE (2015) that boys' performance in mathematics is slightly better than girls in KCSE. Table 13 shows the results of pre-test with reference to gender.

**Table 13: Independent Sample t-Test of Pre-Test Scores on MAT Based on Groups E1 and C1by Gender**

| Variable | Group | N | Mean | SD | df | t-computed | t-critical | p-value |
|---|---|---|---|---|---|---|---|---|
| PRE-TEST | Female | 50 | 25.36 | 15.790 | 108 | -0.720 | 1.98 | 0. 323 |
| | Male | 60 | 27.68 | 17.668 | | | | |

*Not significant at p>0.05 level

*Critical values (df= 120, t =1.98, p>0.05) Calculated values (df=108, t = -0.720, p = 0.323)

The independent sample t-test of pre-test scores on MAT based on gender showed that the mean scores for male and female students were not significantly different, t(108) = 0.323 and p>0.05 as shown in Table 13, implying the groups had comparable characteristics. The use of Solomon Four-Group Design enabled the researcher to assess the presence of any interaction between pre-test and use of the Computer Animated Loci Teaching Technique to determine the effect of pre-test relative to no pre-test and generalise to groups which did not receive the pre-test. This is in line with (Borg& Gall, 1989) about control group and treatment in Solomon Four-Group Design.

### 4.3. Test Item Achievement Analysis in MAT 5b (Appendix A)

The teaching started with the students being given a pre-test to find out their entry behaviour and ascertain whether the groups are homogeneous and comparable. The students were given some times to think and put their solutions in writing. Some of the solutions that students presented for item 5b in MAT (Appendix A) are as shown in Figure 4

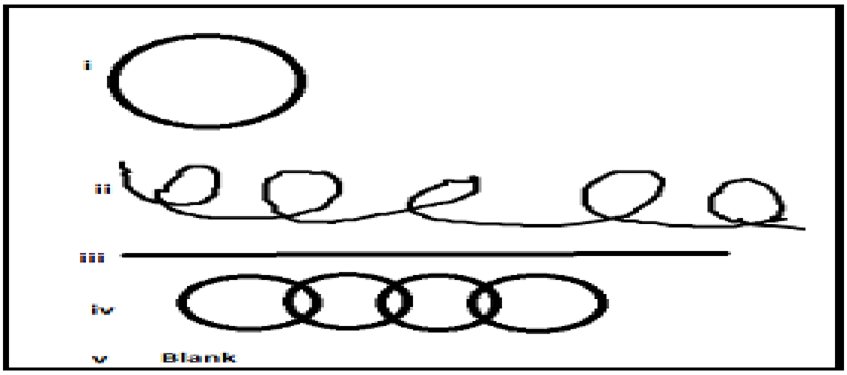



**Figure 4: Some pre-test solutions from MAT item 5b**

The question whether students were able to describe and Sketch the Loci traced by a point on the rim of a bicycle wheel as it move forward on a level ground. The question was awarded four marks. Table 14 shows the marks distribution in the test item for the pre-test indicating that majority of the students in control and experimental groups, could not get a mark in the test item.  No student got the four maximum marks in the test item. The students were of similar characteristics hence comparable.

**Table 14: The pre-test Achievement Analyses of the students' in the item 5b**

| Marks awarded to test item | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| **Control group**:% of candidates scoring the marks | 95 | 4 | 1 | 0 | 0 |
| **Experimental group**: % of candidates scoring the marks | 93 | 5 | 2 | 0 | 0 |

During instructions in the experimental group the students were presented with a computer animated moving bicycle with a point on its rare wheel's rim tracing locus. The control group was taught using the other conventional methods other than computer animated method. Figure 5 shows the locus traced by a point on the rim of a bicycle wheel as it moves forward on a level ground. The students in the experimental groups interacted with the animation where they would animate, stop and reset the animation. The expected locus of points traced by the nozzle of the bicycle as the bicycle moves forward on a level ground is demonstrated in the Figures 5. The loci represented consecutive arcs.

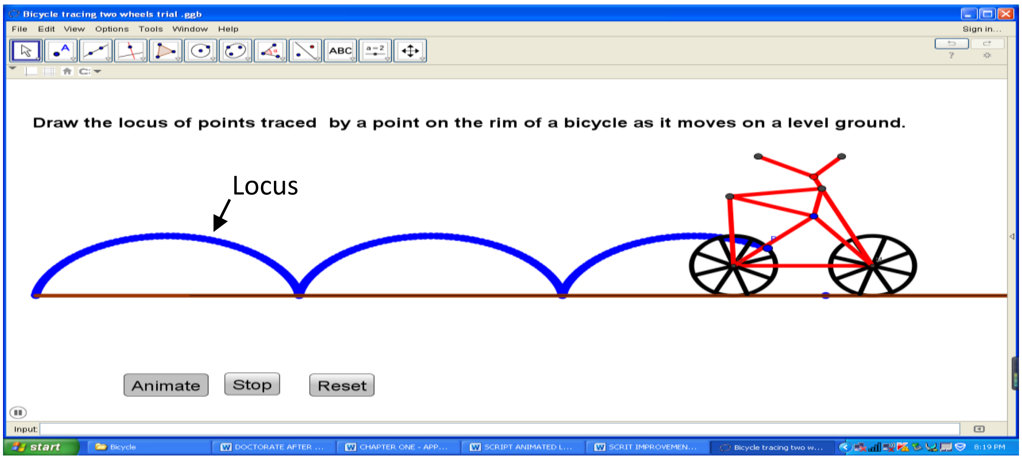



**Figure 5: Geogebra Computer animation of a point on the wheel of a bicycle as the bicycle moves on a level ground.**

After the intervention all the students sat for a post-test of the same MAT. On 5b in MAT the students were expected describe and sketch the locus of points traced by a point on the rim of a bicycle wheel as it moves on a level ground. Table 15 shows the marks distribution on the test item. From the Table the students who used Computer Animated Teaching Technique performed better than those who used the Conventional Teaching Methods.

**Table 15: The post-test Achievement Analyses of the students' Solution to the 5b in MAT**

| Marks | 0 | 1 | 2 | 3 | 4 |
|---|---|---|---|---|---|
| Control group:% of candidates scoring the marks | 56 | 22 | 20 | 1 | 1 |
| Experimental group: % of candidates scoring the marks | 30 | 19 | 17 | 18 | 16 |

## 4.4. Effects of Computer Animated Loci Teaching Technique on Students' Achievements in Mathematics

To establish the effects of Computer Animated Loci Technique on students' performance in Loci, the Post-test scores of the MAT were analysed. Hypothesis $\mathbf{H_O1}$ sought to establish whether there was a significant difference in achievement between students taught using Computer Animated Loci Technique and those taught using the conventional teaching methods. Table 16 shows the MAT mean scores obtained by the four groups.

**Table 16: The MAT Mean Scores Obtained by the Four Groups**

| | C1 | E1 | C2 | E2 | Total |
|---|---|---|---|---|---|
| N | 59 | 51 | 45 | 52 | 207 |
| Mean | 36.10 | 48.20 | 31.91 | 52.98 | 42.41 |
| Std. Deviation | 16.879 | 14.630 | 16.661 | 17.529 | 18.425 |

C1 = Control group 1 E1 = Experimental group 1

C2 = Control group 2 E2 = Experimental group 2

Table 16 reveals the mean scores and standard deviation of students taught mathematics in Experimental Groups E1 and E2 and Control Groups C1 and C2. From the Table, it was observed that the mean scores of the two experimental groups at posttest differ where control Groups had the highest mean scores of 52.98 with standard deviation of 17.529, followed by Experimental Group E1 which had mean scores of 48.20 with standard deviation of 14.630 while the Control Group had the least scores at posttest with mean scores of 31.91 with standard deviation of 16.661. This shows a higher mean score for experimental groups with Computer Animated Loci Technique compared to control groups. The results agree with research of Gambari *et al*. (2014), who found that in a post-test the experimental groups hand done better than the control groups in a mathematics achievement test where computer animations were used as a treatment. Falode *et al*. (2016) also observed that experimental groups performed better when exposed to computer animations than control groups. This is also supported by Iravani and Delfechresh (2011) who observed in physics experimental group had a mean score of 8.26 in the pretest while in the post-test a mean score of 24.85 was obtained while on the other hand, the control group had a mean score of 8.35 in the pretest while in the post-test, a mean score of 18.42 was obtained which gives a pretest. This result showed that there is a difference in the achievement means score of students taught with animation and those taught with conventional method as those taught with animation had a higher mean score than those taught with conventional method

A one- way ANOVA procedure was used to establish whether there was a statistically significant difference in mean scores among the four groups. The results are shown in Table 17

**Table 17: One- Way ANOVA of the Post-Test Scores on the MAT**

| Source of variance | Sum of squares | df | Mean square | F-computed | F-critical | P-value |
|---|---|---|---|---|---|---|
| Between groups | 14826.04 | 3 | 4942.014 | 18.204 | 2.6519 | 0.0000 |
| Within groups | 55110.05 | 203 | 271.478 | | | |
| Total | 69936.10 | 206 | | | | |

*Significant at $p \leq 0.05$ level

*Critical values (df=(3, 100),F=2.6519, p<0.05) Calculated values (df=(3,203) F=18.204, p=0.000)

F- Computed> F-Critical

Table 17 shows that differences in achievement between the four groups were statistically significant different, $F (3,203) = 18.204$ and $p < 0.05$. After establishing that there was a significant difference between mean scores in MAT achievement, it was important to carry out further test on various combinations of means to find out where the difference occurred. The post hoc test of multiple comparisons using Scheffe's method was used. The Scheffe's method is preferred since the sample sizes selected from the different populations were not equal (Githua and Nyabwa, 2008). Table 18 shows the results of Scheffe's post hoc multiple comparisons.

**Table 18: Scheffe's Post hoc Comparison of the Post-Test MAT Means for the Study Groups**

| (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | Sig. |
|---|---|---|---|---|
| C1 | E1 | -12.094* | 3.150 | .003 |
| | C2 | 4.191 | 3.261 | .648 |
| | E2 | -16.879* | 3.134 | .000 |
| E1 | C1 | 12.094* | 3.150 | .003 |
| | C2 | 16.285* | 3.370 | .000 |
| | E2 | -4.785 | 3.247 | .539 |
| C2 | C1 | -4.191 | 3.261 | .648 |
| | E1 | -16.285* | 3.370 | .000 |
| | E2 | -21.070* | 3.355 | .000 |
| E2 | C1 | 16.879* | 3.134 | .000 |
| | E1 | 4.785 | 3.247 | .539 |
| | C2 | 21.070* | 3.355 | .000 |

* The mean difference is significant at the 0.05 level.

The results in Table 18 indicated that the pairs of MAT scores of groups E1 and C1, E2 and C1, E1 and C2 and E2 and C2 are significantly different at α = 0.05 level. However, the mean scores of groups E1 and E2, and C1and C2 are not significant different at α = 0.05 level.

The main threat to internal validity of non-equivalent control group experiments is the possibility that group differences on the post-test may be due to initial or pre-existing group differences rather than to the treatment effect (Gall *et al., 1996*). This study involved non-equivalent control groups it was necessary to confirm the results by performing Analysis of Covariance (ANCOVA) using pre-test scores as the covariate. According Dimitrov and Rumrill (2003), the purpose of using the pretest scores as a covariate in ANCOVA with a pretest-posttest design is to (a) reduce the error variance and (b) eliminate systematic bias. According to Wilcox (2015) ANCOCA reduces the effects of initial group differences statistically by making compensating adjustment to post-test means of the group involved. With nonrandomized designs, the main purpose of ANCOVA is to adjust the posttest means for differences among groups on the pretest, because such differences are likely to occur with intact groups. Lyster, Quiroga and Ballinger (2013) sees Analysis of covariance (ANCOVA) as a statistical technique you can use when you want to focus on the effects of a main response variable with the effects of other interval-level variables factored out. Such a technique may be useful when: you assume that there is some external factor, such as pretest score, which will affect how your students will perform on the response variable; previous studies have shown that another variable, such as aptitude or writing scores, affects how your participants will perform on the variable of interest; you find after the fact that an unplanned variable, such as age, affected the performance of participants on the response variable.

**Table 19: Observed and Adjusted MAT post-test Mean Score for ANCOVA with pre-test MAT score as the covariate**

| Group | N | Observed MAT Mean score | Adjusted MAT mean score | SE |
|---|---|---|---|---|
| E1 | 51 | 48.20 | 48.39 | 2.049 |
| C1 | 59 | 36.10 | 35.94 | 2.197 |

ANCOVA allowed us to adjust the mathematics achievement scores based on the relationship between experimental and control groups in the post-test mathematics achievement. It was then possible to determine if experimental and control groups still had different mathematics achievement scores after making the adjustment. In this case the differences still existed after adjustment and as noted by (Leech, Barrett, & Morgan, 2005) then the differences may be attributed to treatment. The results from Table 19 and Table 20 confirmed that the differences in mean scores in the experimental group E1 and control group C1 are statistically significant. With E1 scoring better than C1. The adjustment for the pre-test score in ANCOVA has two benefits. One is to make sure that any post-test differences truly result from the treatment, and aren't some left-over effect of (usually random) pre-test differences between the groups. The other is to account for variation around the post-test means that comes from the variation in where the subjects started at pre-test (Wilcox, 2012).

**Table 20: Summary ANCOVA of the Post –test MAT scores with pre-test as covariate**

| | Sum of squares | df | Mean square | F | P |
|---|---|---|---|---|---|
| Computer Animated Loci Technique | 4236.84 | 1 | 4236.84 | 35.93 | 0.0001 |
| Pre-test | 583.34 | 1 | 583.34 | 5.14 | 0.0254 |
| adjusted error | 12616.63 | 107 | 117.91 | | |
| adjusted total | 16853.48 | 108 | | | |

*Significant at $p \leq 0.05$ level

*Critical values (df= (1, 100), F=3.936, p<0.05)

Calculated values (df= (1,107) F= 35.93, p=0.000)

F- Computed > F-Critical

Table 20 shows that there was a significant difference in the pretest scores ($F_{1,\,107} = 5.14$, $P < .05$) of the learners and the effect of this on the posttest scores was removed. After controlling for residual and previous knowledge, there was still a significant difference in the mean scores of the learners on the basis of the Computer Animated Loci Technique ($F_{1,\,107} = 35.93$, $P < .05$). The ANCOVA test results show that there is a statistically significant difference between the mean score of the experimental groups and that of the control groups. Wang, Vaughn and Liu (2011) which in their previous studies found that students taught mathematics using computer animation performed better than their counterparts taught with any other teaching methods. This also agrees with research of Haluk (2008), who found that the use of computer-animations experiments (CAE) together with a problem-solving approach has a positively effect on students' chemistry achievement. A further comparison was done to check the mean gain of the students in the pre-test and post- test for the experimental group E1and the control group C1 as shown in Table 21.

**Table 21: Comparison of mean scores and mean gain obtained by students in the MAT**

| | Overall (N= 110) | Experimental group E1 | Control group C1 |
|---|---|---|---|
| Pre –test mean | | 26.35 | 26.86 |
| Post –test mean | | 48.20 | 36.10 |
| Mean gain | | 21.85 | 9.24 |

Table 21 shows the overall mean pretest-posttest scores is 21.85% and 9.24%, for experimental and control group respectively. The experimental group E1 had a higher mean score gain as compared to control group C1. The group that was taught using Computer Animated Loci Technique had a higher mean score gain than the control group. The hypothesis that there is no statistically significant difference in mathematics achievement between students taught using Computer Animated Loci Technique and those taught through the conventional teaching methods was rejected at the 0.05α level. Therefore, using computer Animated Loci Technique improves students' achievement in the topic Loci in particular and mathematics in general more than when the students are taught using the conventional teaching methods.

When the two experimental groups (E1 and E2) are found to be similar in post-test but not similar to the two control groups (C1 and C2), the differences may be attributed to the treatment conditions (Gall *et al.*, 1996). If pre-test interacts with the treatment conditions, the difference between groups E1and E2 (4.78) should be significantly greater than that between groups C1 and C2 (4.19) (Gall *et al.*, 1996). This is because a pre-test sensitization facilitates the learning of the experimental group but not the control group (Borg and Gall, 1989). The post-test achievement scores did not indicate any interaction between pre-test and the Computer Animated Loci Technique.

The study found that students who were taught using Computer Animated Loci Technique achieved significantly higher scores in MAT than those who were taught through the conventional teaching methods. This is an indication that the use of Computer Animated Loci Technique was more effective in improving students' mathematics achievement as compared to the conventional teaching /learning methods. These findings agree with Karacop and Doymus (2013) who found that the teaching of chemical bonding via the animation techniques was more effective than the traditional teaching method in increasing academic achievement. The same is note by Ikwuka and Samuel (2017) that when computer animation is used on Chemistry there is a statistically difference in the mean academic achievement in favour of the experimental group. Gokhan (2013) note that the computer animation technique applied to the experiment group resulted in a significant difference in terms of increasing students' academic achievements concerning the topics included in the "Solar System and Beyond". The same was observed by Westhoff, Bergman and Carroll (2010) who reported that computer animations increase the performance of high school biology students. The students understood a complex signal transduction pathway better after viewing a narrated animation compared with a graphic with an equivalent legend (O'Day, 2006).

Comparing students lectured without any supplement teaching material to those who were taught chemical concepts using animation, O'Day (2007) found students using animations had significantly higher exam scores. Similarly, Wang, Vaughn, and Liu (2011) found that animation interactivity improved students′ performance in statistics. The same results was found by Gambari *et al.* (2014) that students exposed to computer animations had a better achievement score in geometry than those using traditional methods. According Mayer, Steinhoff, Bower, & Mars, (1995) ascertain that previous studies showed a tendency of effectiveness of animation-based learning on problem-solving achievements score compared with text-based learning. The findings support the earlier findings of Aboderin (1997), Gimba (2006) and Joshua (2007) who reported that the use of Pythagoras model for mathematics instruction, three dimensional instructional model for mathematics and geometrical globe instructional model for teaching mathematics at senior secondary schools enhanced students' academic performance.

However, this differs to the findings of Birgan (2010) who reported that there was no difference in achievements among students who utilized computerized animated homework and those who did not. Palmiter (1993) studied the use of animation to aid computer authoring tasks, in their findings, Animation initially assisted accuracy, speed and achievement, but after one week had elapsed, the subjects exposed to animations actually had regressed behind the non-animation subjects. Students whose teachers used technology to teach lower-order thinking skills were found to have lower achievement in mathematics (Tienken & Maher, 2008). While these findings are not surprising, it is clear that the use of technology alone is not a panacea for improved student achievement. Richtel's (2011) report on the standardized test scores of students in the Kyrene School District in Arizona detailed the lack of improvement in student achievement despite the $33 million investment in technology.

In this study the hypothesis $H_O1$ that stated that there is no statistically significant difference in the mathematics achievement mean scores between students exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci was rejected at $\alpha = 0.05$. This implied that Computer Animated Loci Technique was more effective in improving students' mathematics achievement as compared to the conventional teaching /learning methods.

### 4.5. Results of the pre-test on Loci topic Misconception scores

The MAT was presented to C1 and E1 and the misconception held by the students counted at the pre-test. Each misconception held by a student was awarded one mark and the total misconceptions for each student formed his or her misconception score. Table 22 shows the misconception mean score, the standard deviation and standard error of C1 and E1. The table shows that C1 had a slightly higher mean score than E1.

**Table 22: Mean Scores on Misconception in MAT for groups E1 and C1**

| GROUP | N | Mean | SD | SE |
|---|---|---|---|---|
| C1 | 59 | 36.02 | 10.212 | 1.330 |
| E1 | 51 | 33.55 | 9.151 | 1.281 |

There is need to assess the homogeneity of the groups before treatment application as recommended by Kumari (2013). Table 23 shows the results of t-test of the misconception, whose purpose was to show whether C and E1 were homogeneous before treatment.

**Table 23: Independent sample t-test of pre-test scores on misconceptions in MAT based on groups E1 and C1**

| Variable | Group | N | Mean | SD | df | t-computed | t-critica | p-value |
|---|---|---|---|---|---|---|---|---|
| MAT | C1 | 59 | 36.02 | 10.212 | 108 | 0.188 | 1.986 | 0.270 |
| | E1 | 51 | 33.55 | 9.151 | | | | |

*Not significant at p>0.05 level

*Critical values (df= 120, t =1.98, p<0.05)
Calculated values (df=108, t = 0.188, p = 0.270)
t- Computed < t – critical

The results indicate that the differences between misconception mean scores of groups E1 and C1 on the MAT was not statistically significant at the $\alpha$=0.05 level (t (108) = 0.188 and p > 0.05). The t-test is best suited in comparing two groups. The lack of pre-existing differences between treatments and controls implies that the control group yields reliable results of what would have happened to students in the absence of Computer Animation Teaching Technique, and when these results are compared to outcomes for students exposed to Computer Animation Teaching Technique, reliable estimates of treatment impacts was obtained. Table 24 shows the misconception scores from MAT held by students by gender and groups C1 & E1.

**Table 24: Pre-Test Misconception Score by Gender and By Group C1 and E1.**

| Group | Gender | Mean | N | SD | SE |
|---|---|---|---|---|---|
| C1 | FEMALE | 36.75 | 24 | 10.605 | 2.165 |
| | MALE | 35.51 | 35 | 10.060 | 1.700 |
| E1 | FEMALE | 33.23 | 26 | 8.076 | 1.584 |
| | MALE | 33.88 | 25 | 10.309 | 2.062 |

The misconception scores for both male and female students from the Table were almost the same with female students holding slightly more misconceptions than male students in C1. In E1 the male students made slightly more misconceptions than female counterparts. Joel *et al*. (2015) had observed in their studies that there is no difference between boys and girls in learning of sciences and mathematics. The two groups had no statistically significant difference in loci misconceptions by gender implying that they had similar characteristics and hence suitable for the study. Table 25 shows the overall pre-test students' misconception score in MAT by gender.

**Table 25: Overall Pre-Test Students' Misconception Score in MAT by Gender**

| Gender | N | Mean | SD | SE |
|---|---|---|---|---|
| FEMALE | 50 | 34.92 | 9.446 | 1.336 |
| MALE | 60 | 33.98 | 9.123 | 1.305 |

Under the pre-test the female students made slightly more misconceptions than the male student as shown in Table. The overall misconceptions held in MAT by female and male students in the pre-test of the two groups, shows that the female students made slightly more misconceptions than male students. This agrees with Asyura, Nur, Salimah, Nor, Aminatul, (2017) who also found that female students held slightly more misconceptions on calculus than male students. Table 26 shows the independent sample t-test of pre-test on misconceptions scores of MAT based on gender.

**Table 26: Independent sample t-test of pre-test scores on misconceptions in MAT based on groups E1 and C1 by gender**

| Variable | Group | N | Mean | SD | df | t-computed | t-critical | p-value |
|---|---|---|---|---|---|---|---|---|
| MAT | Female | 50 | 34.92 | 9.446 | 108 | 0.528 | 1.9864 | 0.599 |
| | Male | 60 | 33.98 | 9.123 | | | | |

* Not significant at p>0.05 level

*Critical values (df= 120, t =1.98, p<0.05) Calculated values (df=108, t = 0.528, p = 0.599)

The mean scores of misconceptions for male and female students were not significantly different, t(108) = 0.528 and p>0.05. This implied that the groups had comparable characteristics. The use of Solomon four –group design enabled the researcher to assess the presence of any interaction between pre-test and use of the Computer Animated Loci Teaching Technique to determine the effect of pre-test relative to no pre-test and generalise to groups which did not receive the pre-test (Borg & Gall, 1989; Njoroge, 2005).

### 4.6. Effects of Computer Animated Loci Teaching Technique on Students' misconception in Loci topic of Mathematics

Analyses were performed with Hypothesis $\mathbf{H_O2}$ that sought to establish whether there was a statistically significant difference between the mathematics misconceptions scores held by students exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction.

### 4.6.1. Some of the Observed Misconceptions Held by Students in MAT

Misconceptions arise in all facets of people's lives. They occur across the disciplines taught in school and across social and political realms outside of school. This thesis focused on misconceptions in the mathematics classroom, specifically misconceptions held by students in Loci a topic in Geometry. The following mathematics misconceptions observed in MAT. Some students held misconceptions on Measurements of lengths and angle, where they consistently overestimated or underestimated the length and angles. This misconception may have arisen from handling of the geometrical instruments. Sketching of the loci representing given conditions was one of the concept where misconceptions were consistently observed. Some students had challenges in construction of angles using a ruler and a pair of compasses only. Students had a greater challenge in constructing angles $75^o$ and $112.5^o$. This implies students had not understood the concepts of special angles. There were questions that required students to use the formulae $A = \frac{1}{2}bh$, $A = \frac{1}{2}ab\text{Sin}\theta$ and $A=\sqrt{s(s-a)(s-b)(s-c)}$ where $S=\frac{a+b+c}{2}$ for finding the area of a triangle. Some students had a lot of challenges in identifying which formulae to use. This was an indication of partially understood formulae. Some student could not conceptualize three dimensional figure and the consistently drew them as two dimensional. The student lacked common solids concepts. After the marking and awarding of marks the research identified the misconceptions held by the students and categorized them as shown in Table 27.

**Table 27: Some of Misconceptions Identified in MAT that are Held by the Students**

| CONCEPTS | SUB-CONCEPTS | MISCONCEPTION | MARKS AWARDED |
|---|---|---|---|
| Definition | Definition | Loci is traced not printed | 3 |
| Identification: common types of Loci | Identification | Consistently cannot identify the Loci correctly | 3 |
| Sketching | 2 –dimension | Cannot sketch loci in 2-D | 3 |
| | 3 – dimension | cannot sketch loci in 3-D | 2 |
| Construction of lines | Perpendicular lines | Cannot differentiate between perpendicular bisector and perpendicular line | 3 |
| | Parallel lines | Cannot draw parallel line | 3 |
| construction of plane figures | plane figures | consistently cannot draw the plane figures | 3 |
| Construction of Special angles using ruler and pair of compasses only | Construction of Special angles using ruler and pair of compasses only | Challenges of constructing special angles | 3 |
| Measurements | Length | Consistently over and under estimate measurement of length | 6 |
| | Angle | Consistently over and under estimate measurement of angles | 4 |
| | Scale | Linear scale factor challenges | 1 |
| Areas | Areas | Only using area as A= $\frac{1}{2}bh$ | 3 |
| Points location | Points location | Consistently cannot locate a loci point. | 2 |
| | | Total misconception | 39 |

### 4.6.2. Loci Mathematics Misconception analyses

The misconceptions held by students were analysed from the MAT which had 31 items. The Items tested a wide range of Loci concepts in accordance with Benjamin Bloom taxonomy. The application level was the most challenging to majority of the students both in Experimental and Control groups. Some of the items analysed sort to describe and sketch the Loci traced by axle of a bicycle wheel as it move forward on a level ground which was awarded 4 marks (Appendix A No. 5 (a)). Before the teaching started the students in Control and experimental (C1 & E1) were given the test to find out their entry behaviour and ascertain whether the groups were homogeneous and comparable. The students were given some times to think and put their solutions in writing. Some of the Loci misconceptions that students held are as presented in Figure 6.

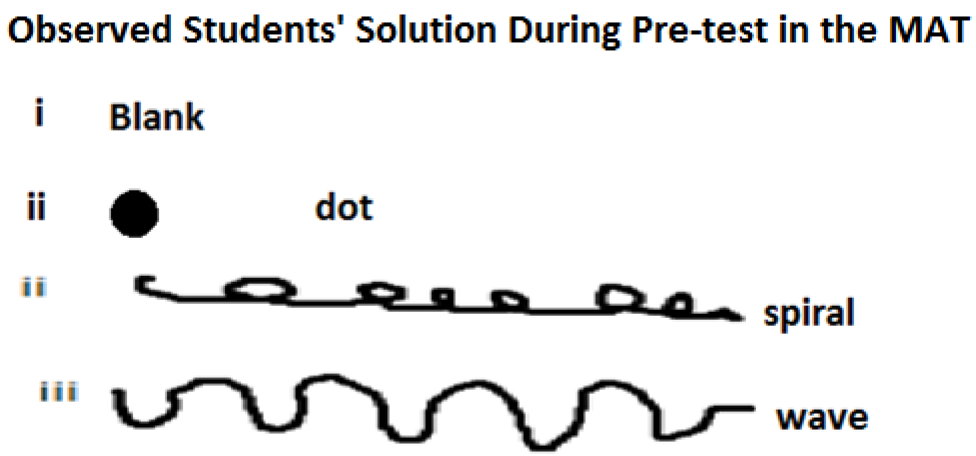



**Figure 6: Some of the Students' Solution to Item 5(a) Appendix A during Pre-test in MAT**

Majority of the students in both the control and experimental groups for pre-test never attempted the question. The solutions in the figure are all wrong and indication that students' prior knowledge on bicycle properties and relating them to loci is a challenge. This represented a misconception that students held on the locus traced by the axle of a bicycle wheel as it moves forward on a level ground. Table 25 shows the number of students who presented their solution as a dot, spiral, wave or never attempted the question (blank).

**Table 28: The number of students' who presents solutions as a dot, spiral, wave or blank**

| | Blank | Dot | Spiral | Wave | Straight line | Total |
|---|---|---|---|---|---|---|
| **Experimental group E1** | 44 | 3 | 3 | 1 | 0 | 51 |
| **Control group- C1** | 47 | 7 | 5 | 0 | 0 | 59 |

During instructions in the experimental group the students were presented with a Geogebra animated moving bicycle with it rare wheel's axle tracing locus. The control groups were taught using the other conventional methods other than Computer Animated Loci Teaching Technique. Figure 7 shows the locus traced by the axle of a bicycle wheel as it moves forward on a level ground. The students interacted with the animation where they would animate, stop and reset the animation. The locus represents a line parallel to the level ground.

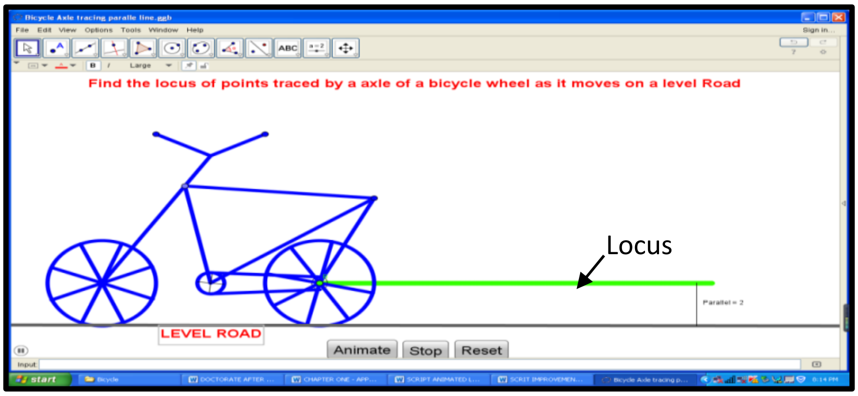



**Figure 7: Geogebra animation of an axle of a bicycle wheel as the bicycle moves on a level ground.**

After the intervention all the students sat for a post-test of the same MAT. On Test Item (5(a) Appendix A) the students were expected describe and sketch the locus traced by the axle of a bicycle as it moves on a level ground. Figure 7 shows the observed student's solutions to item after the intervention

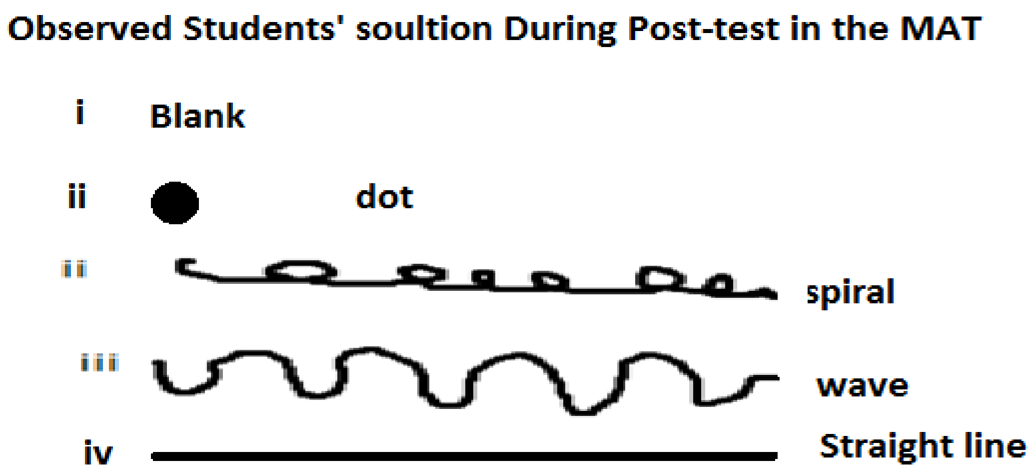



**Figure 8: Some of the Students' Solution to Item 5(a) Appendix A during Pro-test in MAT**

After the intervention the post- test results shows that fewer students in the E1 never attempted the question compared to C1. The students who were taught loci using Computer Animated Loci Teaching Technique had an opportunity of seeing an animated bicycle tracing the loci. The locus traced was supposed to be a straight line parallel to the level ground. Table 29 shows the distribution of solutions in the categories blank, dot, spiral, wave and a straight line. From the table the students who used Computer Animated Teaching Technique performed better than those who used the conventional teaching methods. 48 out of 59 representing 81.35 % of the students in experimental (E1) getting the question correctly while 11 out 51 representing 21.57% of the students in control (C1) getting the question correctly. The results agrees with Ayşen (2012) who found that students taught Geometry using Computer animation outperformed their counterpart taught using conventional teaching methods.

**Table 29: The number of students' who presents solutions as a blank, dot, spiral, wave or a straight line**

| | Blank | Dot | Spiral | Wave | Straight line | Total |
|---|---|---|---|---|---|---|
| **Control group- C1** | 22 | 11 | 9 | 6 | 11 | 59 |
| **Experimental group E1** | 4 | 2 | 1 | 2 | 43 | 51 |

Technology enables both students and teachers to access wide range of tools to use in mathematics. Perkins (1995) computer technology can be used to offer students explanations; make relational knowledge available and students can possess extensive conceptual understanding. Carefully selected demonstrations are one way of helping students overcome misconceptions, and there are a variety of resources available (Katz, 1991). In this study the demonstration of Computer Animated Loci Teaching Technique concepts were carefully selected to address the challenges in Loci topic that is taught to Form Four students.

### 4.6.3. Testing the Hypnosis $H_O2$ to find out whether Computer Animated Loci Teaching Technique as Effects on Misconceptions

Table 30 shows the misconception scores of the post-test of the four groups that participated in the research.

**Table 30: Post –test misconception mean scores obtained by the students in the study groups**

| | E1 | C1 | C2 | E2 |
|---|---|---|---|---|
| Mean | 27.94 | 33.32 | 36.73 | 27.10 |
| N | 51 | 59 | 45 | 52 |
| SD | 8.327 | 8.961 | 7.557 | 8.865 |
| SE | 1.166 | 1.167 | 1.127 | 1.229 |

The experimental groups E1 and E2 had scores of 27.94 and 27.10 respectively. The scores were less than that of the control groups C1 and C2 who scored 33.32 and 36.73 respectively. On the overall there we fewer misconception held by the students in experimental groups where Computer Animated Loci Teaching Technique were used compared to control groups who were taught using the conventional teaching methods. The agrees with Haluk (2004), who found that students who used animations to learn chemical bonding in chemistry had less misconceptions compared with their counterpart who used other conventional methods of teaching/learning. A one- way ANOVA procedure was used to establish whether there was a statistically significant difference in mean scores among the four groups. Table 31 shows the results a one- way ANOVA test of the post-test mean scores of loci misconception in the MAT.

**Table 31: One- way ANOVA of the post-test scores of Misconceptions on MAT**

| Source of variance | Sum of squares | df | Mean square | F-computed | F-critical | P-value |
|---|---|---|---|---|---|---|
| Between groups | 3068.89 | 3 | 1022.96 | 14.180 | 2.68 | 0.00 |
| Within groups | 14644.20 | 203 | 72.139 | | | 00 |
| Total | 17713.08 | 206 | | | | |

*Significant at p≤0.05 level

*Critical values {(df=3,120), F=2.68, p<0.05)}

Calculated values {df= (3,203), F= 14.18, p=0.000}

F-calculated >F-critical

The results indicates that differences in misconception scores between the four groups were statistically significant different, $F(3,203) = 14.180$ and $p < 0.05$. After establishing that there was a significant difference between misconceptions scores in MAT, it was important to carry out further test on various combinations of means to find out where the difference occurred. The post hoc test of multiple comparisons using Scheffe's method was used. The Scheffe's method is preferred since the sample sizes selected from the different populations were not equal (Githua and Nyabwa, 2008). Table 32 shows the results of Scheffe's post hoc multiple comparisons.

**Table 32: Scheffe's post hoc comparison of the post-test misconception mean scores on MAT for the study groups**

| (I) GROUP | (J) GROUP | Mean Difference (I-J) | Std. Error | Sig. |
|---|---|---|---|---|
| E1 | C1 | -5.381* | 1.624 | .013 |
| | C2 | -8.792* | 1.737 | .000 |
| | E2 | .864 | 1.674 | .966 |
| C1 | E1 | 5.381* | 1.624 | .013 |
| | C2 | -3.411 | 1.681 | .252 |
| | E2 | 6.245* | 1.616 | .002 |
| C2 | E1 | 8.792* | 1.737 | .000 |
| | C1 | 3.411 | 1.681 | .252 |
| | E2 | 9.656* | 1.729 | .000 |
| E2 | E1 | -.864 | 1.674 | .966 |
| | C1 | -6.245* | 1.616 | .002 |
| | C2 | -9.656* | 1.729 | .000 |

* The mean difference is significant at the 0.05 level.

The results indicated that the pairs of misconception scores of groups E1 and C1; E2 and C1; E1 and C2; and E2 and C2 are significantly different at $\alpha = 0.05$ level. However, the mean scores of groups E1 and E2, and C1and C2 are not significant different at $\alpha = 0.05$ level. This study involved non-equivalent control groups it was necessary to confirm the results by performing Analysis of Covariance (ANCOVA) using pre-test scores as the covariate.

According to Campbell and Stanley (2015), the threat to internal validity of non-equivalent control group experiments is the possibility that group differences on the post-test may be due to initial or pre-existing group differences rather than to the treatment effect. According to Wilcox, (2015), ANCOCA reduces the effects of initial group differences statistically by making compensating adjustment to post-test means of the group involved. With nonrandomized designs, the main purpose of ANCOVA is to adjust the posttest means for differences among groups on the pretest, because such differences are likely to occur with intact groups. Table 33 shows the observed and adjusted MAT post-test Misconceptions mean Score for ANCOVA with pre-test Misconceptions mean Score as the covariate.

**Table 33: Observed and Adjusted MAT post-test Misconceptions mean Score for ANCOVA with pre-test Misconceptions mean Score as the covariate**

| Group | N | Observed MAT Mean score | Adjusted MAT mean score | Standard error |
|---|---|---|---|---|
| E1 | 59 | 33.55 | 34.98 | 1.964 |
| C1 | 51 | 36.02 | 35.26 | 2.009 |

The results from Table 33 and Table 34 confirmed that the differences in mean scores in the experimental group E1 and control group C1 are statistically significant.

**Table 34: Summary ANCOVA of the Post –test Misconception mean scores with pre-test Misconception mean scores as covariate**

| | Sum of squares | df | Mean square | F | P |
|---|---|---|---|---|---|
| Computer Animated Loci Technique | 558.51 | 1 | 558.51 | 8.56 | 0.0042 |
| Between regressions | 5.16 | 1 | 5.16 | 0.08 | 0.7778 |
| adjusted error | 6978.1 | 107 | 65.22 | | |
| adjusted total | 7536.61 | 108 | | | |

*Significant at $p< 0.05$ level

*Critical values (df= (1, 100), F=3.936, $p<0.05$)

Calculated values (df= (1,107) F= 8.56, p=0.0042)

F- Computed > F-Critical

A further comparison was done to check the mean gain of the students in the pre-test and post-test for the experimental group E1and the control group C1 as shown in Table 35

**Table 35: Comparison of misconception mean scores in pre-test and misconception mean score gain obtained by students in the MAT**

| Overall (N= 110) | Experimental group E1 | Control group C1 |
|---|---|---|
| Pre –test mean | 33.55 | 36.02 |
| Post –test mean | 27.94 | 33.32 |
| Mean gain | 5.61 | 2.70 |

Table35 shows that the experimental group E1 had a higher drop misconception mean score of 5.61 as compared to mean score drop of 2.70 of the control group C1. By using a diagnostic test at the beginning or upon completion of a specified mathematics topic, a mathematics teacher can obtain clearer ideas about the nature of the students' knowledge and misconceptions in the topic (Treagust, 1988). The pre-test and posttest made it possible for the researcher to obtain clear idea on misconceptions. The group that was taught using Computer Animated Teaching Loci Technique had lower misconceptions mean score drop than the control group. The hypothesis that there is no statistically significant difference in mathematics misconception mean score between students taught using Computer Animated Teaching Loci Technique and those taught through the conventional teaching methods was rejected at the 0.05α level. Therefore, using computer Animated Loci Teaching Technique improves students' misconception in the topic Loci in particular and mathematics in general more than when the students are taught using the conventional teaching methods.

Kara and Yesilyurt (2007) noted in their research on use of computer animations that the misconceptions about genes in biology before the treatment were 25% and 20.8% in the experimental and control groups respectively. There was no statistically significant difference between the two groups in the pre-test. After the treatment, the students' responses indicated that the misconceptions, decreased to 8.3% and 12.5% in both experimental group and control group respectively. There was a significant difference in the academic achievement in favour of the experimental group. The significant academic achievement of the students in the experimental groups could be explained by the fact that the instructional animation software programs created a learning environment in which students can learn at their own pace.

Kara and Yesilyurt's results agrees with research by Salih, Erol and Kose (2006) who studies misconception related to photosynthesis and respiration in plants, the pre-test results showed that students had misconception at the rate of 46% and 27% in the experiment group and 37% and 26% in the control group. After treatment, the rate of misconceptions decreased to15% and 4% in the experiment group; 29% and 15% in the control group, respectively. This implied that computer animation reduced the misconceptions. This agrees with Ramazan and Osman (2012) who found out that the results of the computer Animations help remediate misconception in probability examinations more effectively than traditional teaching methods. Han-Chin (2005) investigated students' misconceptions and understanding of electrochemistry and found that student who used computer animation had less misconceptions compared to those who used convectional teaching method. According to Green *et al*. (2008) the students who use computer animation to learn geometry are less likely to make misconceptions as compared to those who learn geometry using convectional teaching methods. However the mere presence of computer animation programmes does not reduce the misconceptions that students have in Geometry. The effectiveness of animations depends on competence of the designer. When professional are involved in making the animations then the animations are likely to be more reliable as indicated by Ramazan and Osman (2012).

In this study the hypothesis $H_O2$ that stated that was there is no statistically significant difference between the mathematics misconceptions mean scores held by students exposed Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction of the topic Loci was rejected at $\alpha = 0.05$. This implied that Computer Animated Loci Technique was more effective in improving reducing learner's mathematics misconception as compared to the conventional teaching /learning methods.

### 4.7. Effect of the use of Computer Animated Loci Teaching Technique on gender difference in students' achievements in Loci topic of mathematics

Analysis was performed with Hypothesis $\mathbf{H_O3}$ that sought to establish whether there was a statistically significant gender difference in mathematics achievement scores among secondary school students when exposed to Computer Animated Loci Technique. Table 36 shows the results of post-test MAT score based on gender.

### 4.7.1. Test Item Achievement Analysis in MAT Question 8(a) (Appendix A) by gender

The teaching started with the students being given a pre-test to find out their entry behaviour and ascertain whether the groups are homogeneous and comparable. The students were given some times to think and put their solutions in writing. The question statement was that a solid 30 cm ruler which lies on a flat surface is rotated about one of its shorter edge until it is flat on the surface again. The students were to state and sketch the loci traced by the ruler. The question was testing on Three–Dimensional locus and was awarded four marks. Table 36 shows the results of pre-test by gender.

**Table 36: Pre-Test results Result for MAT Question 8(a) by Gender**

| | Gender | Blank | 0 Marks | 1 Marks | 2 Marks | 3 Marks | 4 Marks | Mean Mark | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Control** | M | 10 | 12 | 5 | 4 | 3 | 1 | 1.040 | 35 |
| **group- C1** | **F** | 8 | 9 | 4 | 1 | 2 | 0 | 0.750 | 24 |
| **Experiment** | **M** | 6 | 8 | 6 | 4 | 2 | 0 | 1.000 | 26 |
| **al group E1** | **F** | 7 | 7 | 8 | 2 | 1 | 0 | 0.833 | 25 |

The Table 36 shows that both the male and female students performed relatively the same with male students' overall achievement in the item 8 (a) being slightly higher than the female. This implies that both male and female students' were comparable for both control and experimental groups. After the intervention where E1 was exposed to Computer Animation Teaching technique and C1 was taught using the conventional teaching methods, all the students sat for post-test MAT. Table 37 shows the results post-test for item 8(a) by gender.

**Table 37: Pro-Test results Result for MAT Question 8(a) by Gender**

| | Gender | Blank | 0 Marks | 1 Marks | 2 Marks | 3 Marks | 4 Marks | Mean Mark | Total |
|---|---|---|---|---|---|---|---|---|---|
| **Control** | M | 2 | 6 | 6 | 6 | 6 | 9 | 2.182 | 35 |
| **group- C1** | **F** | 2 | 5 | 4 | 2 | 5 | 6 | 2.137 | 24 |
| **Experiment** | **M** | 1 | 2 | 2 | 4 | 7 | 10 | 2.840 | 26 |
| **al group E1** | **F** | 0 | 2 | 2 | 3 | 7 | 11 | 2.920 | 25 |

The Table 37 shows that both male and female students performed relatively the same within the group but on overall the students in experimental group outperformed their counterparts in the control group. On this item the female students in the experimental group be formed better than the male students in the same group. This agrees with the findings of Hunter and Greever (2007) who found that when computer animation are used, the female students outperformed the male students in mathematics indicating that female students experienced a greater benefit from exposure to technology in the classroom than male students.

### 4.7.2. Testing the Hypnosis $H_O3$ to find out whether Computer Animated Loci Teaching Technique has Effects on mathematics Achievement by gender

After the intervention was done all the four groups sat for the Post-test MAT, where achievement was analysed by gender. Table 38 shows the results of the Post-test per group by gender.

**Table 38: Post-Test Achievement Result for MAT by Gender per group**

| POST TEST | C1 | | E1 | | C2 | | E2 | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Gender | F | M | F | M | F | M | F | M | |
| Mean | 34.71 | 37.06 | 47.58 | 48.84 | 30.58 | 33.74 | 53.16 | 52.88 | 42.41 |
| N | 24 | 35 | 26 | 25 | 26 | 19 | 19 | 33 | 207 |
| Std. Deviation | 16.91 | 17.04 | 12.72 | 16.63 | 15.30 | 18.64 | 15.82 | 18.68 | 18.43 |

The post- test results show that Male students performed better than their female counterparts in all the groups except one. Over all boys performed slightly better than girls in MAT. Table 39 shows the overall results of post-test MAT score based on gender.

**Table 39: Overall posttest Achievement Result for MAT by Gender**

| | GENDER | N | Mean | SD | SE |
|---|---|---|---|---|---|
| | Female | 95 | 40.79 | 17.47 | 1.792 |
| POSTTEST | Male | 112 | 43.79 | 19.17 | 1.812 |
| | Total | 207 | 42.41 | 18.43 | 1.281 |

From the table it is evident that the male students performed than their female counterpart. This result agrees with the findings of WAEC (2011) which revealed that boys performed better than girls in Geometry when computer animations are used. On the contrary Gimba (2006) reported that female students performed better than male students when exposed to geometry animations.

Table 40 shows the independent sample t-test of posttest scores on MAT based on gender. A total of 95 girls and 112 boys did the posttest.

**Table 40: Independent sample t-test of post-test scores on MAT based on gender**

| Variable | Group | N | Mean | SD | df | t-computed | t-critical | p-value |
|---|---|---|---|---|---|---|---|---|
| MAT | Female | 95 | 40.79 | 17.47 | 205 | -1.167 | 1.9842 | 0.257 |
| | Male | 112 | 43.79 | 19.17 | | | | |

* Not significant at p>0.05 level

*Critical values (df= 120, t =1.98, p≤0.05) Calculated values (df=205, t = -1.167, p = 0.257)

The t-test revealed no significant gender difference in mathematics achievement score between the female and male students, t (205) =-1.167, p > 0.05. Both male and female students performed relatively the same. There was no statistically significant difference between the 95 girls and 112 boys exposed to the Computer Animated Loci Technique and those not exposed to it. Table 41 shows Comparison of mean gain of students' pre-test and post-test scores in MAT by gender.

**Table 41: Comparison of mean gain of students' pre-test and post-test scores in MAT by gender**

| Test | Male | Female |
|---|---|---|
| Pre-test | 27.68 | 25.36 |
| Post-test | 43.79 | 40.79 |
| Mean gain | 16.1 | 15.43 |

Table 41 shows that the boys did slightly better than girls in both pre-test and post-test. The mean gain in post-test over pre-test for male students 'achievement score was slightly higher than that of girls. The results agrees with Van Dijk (2005) who found that although the gap exist between male and female students in mathematics achievement test, when computer animations are used the difference is not significant. However he ascertain that more research into the outcomes of female students using technology in mathematics is necessary to identify instructional practices that eliminate, rather than exacerbate, this disparity. According to Milagros and Jacquelynne (2012), there is no significant difference between male and female students in achievement when they are taught algebra using computer animations. The results also agrees with Abdulrasaq, Ganiyu and Olakanmi (2017) who noted that there was no significant difference in the academic achievement of male and female students taught practical biology using computer animation instructional package. This result is in agreement with the findings of Ayotola and Abiodun (2010), Gambari *et al*. (2014), Salisu (2015) and Akpoghol, Ezeudu, Adzape and Otor (2016) who found that there is no significant difference in the academic achievement of male and female students taught science using computer animation.

On the contrary Ikwuka and Samuel (2017) noted in their research on effects of computer animation on Chemistry academic achievement by gender in Nigeria that there is a significant mean difference in the academic achievement of the male and the female students in favour of the males. The findings of Hunter and Greever (2007) was that when computer animation and simulations are used, the female students outperformed the male students in mathematics indicating that female students experienced a greater benefit from exposure to technology in the classroom than male students.

## 4.8. Effect of the use of Computer Animated Teaching Loci Teaching Technique on Gender Difference in Students' Misconceptions in Loci Topic of Mathematics

Analysis was performed with Hypothesis $\mathbf{H_O4}$ that sought to establish whether there was statistically significant gender difference between the misconceptions mean score of male and female students when exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction.

### 4.8.1. Test Item Misconception Analysis in MAT Question 5(a) (Appendix A) by gender

The students in C1 and E1 were given a pre-test to find whether the two groups are homogeneous and comparable. Item 5 (a) ( Appendix A) sort to the description and sketching the Loci traced by axle of a bicycle wheel as it move forward on a level ground which was awarded 4 marks. Some of the solutions in the students' working were categories blank, dot, spiral, wave and a straight line. Table 42 shows the pre-test mathematics misconceptions in MAT held by gender per group.

**Table 42: Pre-test Mathematics Misconceptions in MAT Held by gender per group**

| Pre-test | Gender | Blank | Dot | Spiral | Wave | Straight line | Total |
|---|---|---|---|---|---|---|---|
| **Control group- C1** | M | 29 | 3 | 3 | 0 | 0 | 35 |
| | F | 18 | 4 | 2 | 0 | 0 | 24 |
| **Experimental group E1** | M | 23 | 1 | 1 | 1 | 0 | 26 |
| | F | 21 | 2 | 2 | 0 | 0 | 25 |

From Table 42 it is observed that majority of both male and female students in the two groups never attempted item 5(a) during the pre-test. The misconceptions held by the students which were observed in the MAT were dot, spiral and wave. In C1 the students who attempted the item held a total of six mathematics misconceptions for both male and female, while in E1 three and four mathematics misconceptions were held by male and female students respectively. They indicated that both groups held the same mathematics misconception on the test item.

After the intervention both groups sat for post-test MAT on loci. Table 43 shows the pro-test mathematics misconceptions in MAT held by gender per group.

**Table 43: Pro-test Mathematics Misconceptions in MAT Held by gender per group**

| Post-Test | Gender | Blank | Dot | Spiral | Wave | Straight line | Total |
|---|---|---|---|---|---|---|---|
| **Control group- C1** | M | 12 | 5 | 6 | 4 | 7 | 34 |
| | F | 10 | 6 | 3 | 2 | 4 | 25 |
| **Experimental group E1** | M | 1 | 1 | 1 | 1 | 22 | 26 |
| | F | 3 | 0 | 0 | 1 | 21 | 25 |

From Table 43 it is observed that after the intervention the number of students who never attempted the test item reduced drastically. Only a total of four students in E1 avoided the question in the Pre – test down from forty four during the pre-test. Twenty two students avoided the test item in C1 down from forty seven during the pre-test. A total of fifteen mathematics misconceptions were held by male student in C1 while the female students held a total of eleven mathematics misconceptions. A total of three mathematics misconceptions were held by male students and only one was held by the female student. On overall C1 group held more misconceptions than E1. Computer Animated Teaching Technique reduces mathematics misconceptions held by both the male and female students.

### 4.8.2. Testing the Hypnosis $H_O4$ to find out whether Computer Animated Loci Teaching Technique has Effects on mathematics misconception by gender

After interventions all the four groups sat for Post-test MAT. Table 44 shows the mean score of the mathematics misconceptions held by the students by gender per group.

**Table 44: Post-Test Misconceptions Mean Score Result for MAT by Gender per group**

| POST TEST | C1 | | E1 | | C2 | | E2 | | Total |
|---|---|---|---|---|---|---|---|---|---|
| Gender | F | M | F | M | F | M | F | M | |
| Mean | 32.25 | 34.06 | 28.73 | 27.12 | 36.27 | 37.37 | 27.00 | 27.15 | 31.17 |
| N | 24 | 35 | 26 | 25 | 26 | 19 | 19 | 33 | 207 |
| Std. Deviation | 9.892 | 8.331 | 8.234 | 8.511 | 8.12 | 6.865 | 9.171 | 8.827 | 9.273 |

The post- test results on mathematics misconception mean score show that female students performed better than their male counterparts in all the groups except E1 where the male students outperformed the female student. All the students held misconceptions in Loci which agree with Adesoji and Babatunde (2008) observed that both male and female chemistry students held misconceptions in inorganic chemistry. Table 45 shows the overall post-test misconception result for MAT by gender.

**Table45: Overall posttest Achievement Result for MAT by Gender**

| | GENDER | N | Mean | Std. Deviation | Std. Error Mean |
|---|---|---|---|---|---|
| POSTTEST | Female | 95 | 31.34 | 9.395 | 0.964 |
| | Male | 112 | 31.03 | 9.208 | 0.870 |
| | Total | 207 | 31.17 | 9.273 | 0.645 |

On the overall the male students made fewer misconceptions than female in MAT as shown Table 45. This agrees with Adesoji and Babatunde (2008) who observed that female students held more misconceptions than their male counterparts in inorganic chemistry. This also agrees

Ahmed, Tariq and Tahseen (2012) who observed that on overall there are higher proportions of gender misconceptions held by girls than by boys at secondary level in Pakistan. Table 46 shows the independent sample t-test of posttest scores on MAT based on gender.

**Table 46: Independent sample t-test of post-test scores on MAT based on gender**

| Variable | Group | N | Mean | SD | df | t-computed | t-critical | p-value |
|---|---|---|---|---|---|---|---|---|
| MAT | Female | 95 | 31.34 | 9.395 | 205 | 0.239 | 1.984 | 0.811 |
| | Male | 112 | 31.03 | 9.208 | | | | |

A total of 95 girls and 112 boys did the posttest. The t-test revealed no significant gender difference in misconception mean score between the female and male students, t (205) = 0.239, p > 0.05. Both male and female students performed relatively the same. There was no significant difference between the 95 girls and 112 boys exposed to the Computer Animated Loci Technique though the boys had a slightly lower misconception mean score in MAT. On the contrary Ahmed *et al*. (2012) observed that 82% of girls and 96% of boys held that the solution 'oil in water' was mostly termed as 'chemical solution'. This implies that boys held more misconceptions than girls. Table 47 shows the comparison of misconception mean score gain of student's pre-test and post-test score in MAT.

**Table 47: Comparison of misconception mean score gain of students' pre-test and post-test scores in MAT**

| Test | Male | Female |
|---|---|---|
| Pre-test | 34.83 | 34.92 |
| Post-test | 31.17 | 30.42 |
| Mean gain | 3.66 | 4.50 |

Table 47 shows that the boys made slightly few misconceptions than girls in both pre-test and post- test MAT. The mean gain in post-test over pre-test for male students is slightly lower than that of girls. The gain is not significant. This agrees with Booth, Koedinger and Siegler, (2007) who found that misconceptions made by both male and female students in algebra are not statistically significant. On the contrary gender differences were observed in the misconceptions concerning force and motion concepts when computer animations were used as noted by Erylmaz (2002). Female students' misconceptions in mathematics are more likely in basic mathematics rules compared to male (Asyura *et al*., 2017). The male students had fewer misconceptions than female students. The results of this study generally supported the findings of the literature that the female students held slightly more misconceptions than the male students in loci a topic of geometry. However, the statistical analysis done also indicated that on the overall gender differences observed in the misconception scores was not significant.

# CHAPTER FIVE

# SUMMARY OF FINDINGS CONCLUSIONS, IMPLICATIONS AND RECOMMEDATIONS

## 5.1. Introduction

This chapter presents the summary of findings, conclusions, implications and recommendations emanating from the study. Suggestions on possible areas for further research are made.

## 5.2. Summary of Research Findings

The research sought to investigate and establish:

(i) The effects of Computer Animated Loci Teaching Technique during instruction on secondary school students' mathematics achievement**,** in "Loci". To achieve the objective of the research a null hypothesis was formulated and tested. The hypothesis stated that there was no statistically significant difference in the mathematics achievement scores between students exposed to Computer Animated Loci Teaching Technique and those not exposed to it during mathematics instruction. It was found that the use of Computer Animated Loci Teaching Technique made students achieve better scores. The results of hypothesis reveal that there is significant difference in the students achievements in favour of the group taught the geometrical concepts with computer animation.

(ii) To establish the effects of Computer Animated Loci Teaching Technique during instruction on secondary school students' mathematics misconceptions**,** in "Loci". To achieve the objective, a null hypothesis was formulated and tested. The hypothesis stated that there was no statistically significant difference between the mathematics misconceptions scores committed by students exposed to Computer Animated Loci Technique and those not exposed to it during mathematics instruction. It was found that the using Computer Animated Loci Teaching Technique made students reduced the misconceptions they made in mathematics in general and in particular Geometry.

(iii) To determine whether there is gender difference in Student's Mathematics achievement when they are taught "Loci" using Computer Animated Loci Technique during mathematics instruction. To achieve the objective a null hypothesis was formulated and tested. The hypothesis stated that there was no statistically significant gender difference in mathematics achievement scores among secondary school students when exposed to Computer Animated Loci Technique and those not exposed to it during mathematics instruction. It was also found that the mathematics achievement scores of both male and female students exposed to Computer Animated Loci Technique and those not exposed to it were not significant different.

(iv) To determine whether there is gender difference in Student's Mathematics Misconceptions score in the topic "Loci" when they are exposed to Computer Animated Loci Technique during mathematics instruction. To test the objective a null hypothesis was formulated and tested. It stated that there was no statistically significant difference between the misconceptions mean score of male and female students when exposed to Computer Animated Loci Technique and those not exposed to it during mathematics instruction. It was also found that the mathematics misconceptions scores of both male and female students exposed to Computer Animated Loci Technique and those not exposed to it were not significant different.

## 5.3. Conclusions

The study has examined the poor performance in mathematics education especially within the secondary school level in a rapidly technology changing world. The innovative technology using computer animation package for teaching mathematics seems to be the answer to the students' poor mathematics performance problem. Computer Animations were found to reduce students' misconceptions in mathematics and sciences. Using Computer animation package is more effective in teaching the mathematical concepts of geometry, improves learners' performance and enhances their conceptual understanding. It is also gender friendly.

Based on this study the following conclusions have been arrived at, with regard to co-educational Secondary Schools.

i) Computer Animated Loci Teaching Technique enhances students' achievement in mathematics better than the conventional teaching methods in secondary schools.
ii) Computer Animated Loci Teaching Technique reduces the mathematics misconceptions held by students in Loci which is a sub-set of Geometry. Reduction in misconception in geometry will lead to increase in mathematics achievement.

iii) Neither male nor female students are disadvantaged by use of Computer Animated Loci Teaching Technique during mathematics instructions. The mathematics achievement in loci for both male and female students is the same.

iv) When Computer Animated Loci Teaching Technique both male and female students reduces the mathematics misconceptions the hold. The differences in mathematics misconception held by both after intervention are not significant.

## 5.4. Implications of the Findings

Computer Animated Loci Teaching Technique resulted in higher mathematics achievements and reduced mathematics misconceptions in Co-educational Secondary Schools in Kitui County. Since majority of students in the county is in Co-educational Secondary Schools (KCEO, 2014; 2015) the use of Computer Animated Loci Teaching Technique in teaching of the topic "Loci" in mathematics can improve the current trend of dismal performance in mathematics and further reduce the mathematics misconceptions held by students resulting further to better performance. Both gender are affected positively Computer Animated Loci Teaching Technique since both boys and girls improved in mathematics achievement and reduced mathematics misconceptions. The stakeholders such as mathematics teachers, CEMASTEA, KICD, MoEST and Mathematics Educators have an additional teaching technique to consider as continually entrench ICT integration in our mathematics classrooms

## 5.5. Recommendations of the study

(i) Computer Animated Loci Techniquewas found to be effective as a teaching strategy for geometry instruction when compared with traditional method of instruction. Therefore, mathematics teachers should be encouraged to use it.

(ii) Male and female students were affected positively and evenly by the use of computer animation package. Therefore, mathematics teachers should employ this strategy to improve male and female students' achievement in mathematics at secondary school level in particular and other levels in general.

(iii) Teacher education institutions should introduce a mathematics education unit where student teachers make Computer animations for mathematics concepts on ICT that will warrant the mathematics teachers' use of modern ICT and computer animation during teaching and learning process. The problem of dismal performance in mathematics may be addressed by use of computer animations

(iv) Mathematics Education stakeholders such as QASO and KICD should encourage teachers to use Computer animations in their teaching. This should be done with caution, because the success depends on how the animations are effectively used. Computer animations are more effective when they are used to supplement but not to entirely replace other methods of instruction.

(v) In service courses organised by the Ministry of Education, such as CEMASTEA, TSC and KICD, should incorporate Computer animations in their teaching programmes. This is because the quality of teachers and the kind of training they have is a major determinant of the quality of education in any country. Teacher training programmes should equip the teachers with the knowledge and skills necessary to achieve the educational goals and objectives.

### 5.5.1. Areas for Further Research

This study suggests that Computer Animated Loci Technique can effectively improve mathematics instruction in Co-educational Secondary Schools. However there are areas that warrant further research.

(i) A study to determine the topics and concepts that can be taught using computer animation and develop the computer animation.

(ii) A study to determine the effects of using computer animations in other mathematics topics with respect to mathematics achievement, misconception, motivation and self-confidence.

(iii) The relationship of anxiety, misconceptions, interest and mathematics achievements when students are exposed to Computer animations.

(iv) Mathematics teacher’s use of Computer animation during mathematics instruction in secondary schools in Kenya.

## REFERENCES


Abdullah, A.M. (1989). A *Survey of resources and their utilization in school.* Ibadan: University Press.

Abdulrasaq, H., Ganiyu, B. and Olakanmi, I. A.(2017).Effects of Computer Animation Instructional Package on Secondary School Students' Achievement in Practical Biology. *Cypriot Journal of Educational Sciences Volume 12, Issue 4, (2017) 218-227 www.cjes.eu Effects.*

Aberdein, A. (2013). Mathematical wit and mathematical cognition. Topics in Cognitive Science, 5(2):231–250.

Abiam, P. O. & Odok, J. K. (2006).Factors in Students' Achievement in Different Branches of Secondary School Mathematics. *Journal of Education and Technology, 1(1), 161-168.*

Abimbade, A (1997). *Principle and practice of educational technology*. Ibadan: International Publishers Ltd.

Aboderin, G. S. (1997). Construction of Pythagoras model for mathematics instruction in secondary schools. Unpublished B.Tech Project, Department of Science Education, FUT Minna.

Aburime, F. E. (2009). Harnessing Geometric Manipulatives as a Revitalization Strategy for Mathematics Education in Nigeria Sutra. *International Journal of Mathematical Science Education. 2,(1) , 22-28.*

Acharya, B. R. (2017). Diversity in mathematics education, Kathmandu: Pinnacle publication Pvt. Ltd.

Ackman, M.L., & Mysak, T.M., (2009). Structuring an early clinical experience for pharmacy students: lessons learned from the hospital perspective. *Can J Hosp Pharm 2009;62(4):320-325*

ACME.(2011). Mathematical Needs, Mathematics in the workplace and in Higher Education. London.

Adams, C. (2018). Essential Strategies and methods in Teaching Mathematics.https://www.weareteachers.com/strategies-methods-in-teaching-mathematics/accessed (2/2/2018)

Adekoya, Y.M. & Olatoye, R.A. (2011).Effect of Demonstration, Peer-Tutoring, and Lecture Teaching Strategies on Senior Secondary School Students' Achievement in an Aspect of Agricultural Science. *The Pacific Journal of Science and Technology.12 (1). 320 – 332.*

Adeogun, A. A and Osifila G.I (2008): Relationship between educational resources and students' academic performance in Lagos state Nigeria, *International journal of Educational management (IJEM), 5 &6:144-153*

Adesoji, F. A. & Babatunde, A.G.(2008). Investigating Gender Difficulties and Misconceptions In Inorganic Chemistry At The Senior Secondary International Journal of African & African American Studies Vol. VII, No. 1, Jan 2008

Adetunde, A. I. & Asare, B. (2009). Comparative Performance of Day and Boarding Students in Secondary School Certificate Mathematics Examinations: A Case Study of Kasena-Nankana and Asuogyaman Districts of Ghana. *Academia Arena, 1(4).*

Adler, J. (2001) *Teaching Mathematics in Multilingual Classrooms.* Dordrecht: Kluwer Academic Publishers.

Aguele, L.I. & Agwugah, N.V. (2007).Female Participation in Science, Technology and Mathematics (STM) Education in Nigeria and National Development. *Journal of Social Science, 15 (2), 121-126.*

Agwagah, (1993).Instructions in mathematics reading as a factor in students' achievement and interest in word problem-solving. Unpublished Doctoral thesis, University of Nigeria, Nsukka.

Ahmed, S. A., Tariq, M. K. & Tahseen, M. A. (2012). Disparity in Misconceptions about the Concept of Solution at Secondary Level Students in Pakistan. Journal of Elementary Education Vol.22, No. 1 pp.65-79

Ainley, J., Pratt, D. & Hansen, A. (2006). Connecting engagement and focus in pedagogic task design. *British Educational Research Journal, 32(1), 23–38.*

Ainsworth, S. E. (2006). DeFT: A conceptual framework for considering learning with multiple representations. *Learning and Instruction, 16(3), 183-198.*

Ajaja, O.P. (2009). *Teaching methods across disciplines.* Ibadan: Bomn Prints.

Ajaja, O.P. (2013). Which strategy best suits biology teaching? Lecturing, concept mapping, cooperative learning or learning cycle? *Electronic. Journal of Science Education Vol. 17, No. 1 pg.1 – 37.*

Ajisuksmo, C. R.P., & Saputri, G. R. (2017). The Influence of Attitudes towards Mathematics, and Meta-cognitive Awareness on Mathematics Achievements. *Journal of Scientific Research Publishing Creative Education. 8, 486-497*

Akanmu, M. A. & Fajemidagba, M. O. (2013).guided-discovery learning strategy and senior school students Performance in mathematics in ejigbo, Nigeria. *Journal of Education and Practice* Vol.4, No.12.

Akpoghol, T.V., Ezeudu, F.O., Adzape, J.N., & Otor, E.E. (2016). Effects of Lecture Method Supplemented with Music and Computer Animation on Senior Secondary School Students' Academic Achievement in Electrochemistry. *Journal of Education and Practice.Vol.7,* No.4, 2016, ISSN 2222-1735 (Paper) ISSN 2222-288X (Online).

Alakanani, A. N., Liu Y. (2013). Using Technology to Teach Mathematical Concepts through Cultural Designs and Natural Phenomena. *Asian Journal of Management Sciences and Education* 2(2), 25 – 35.

Albright, M. & Graf, D. (1992).*Teaching in the Information Age*: The Role of Educational Technology. San Francisco, Jossey-Bass Publishers.

Alio, B. C. & Harbor-Peters, V. F. (2000).The effect of Polya's Problem-Solving Technique on Secondary School Students' Achievement in Mathematics. *ABACUS, Journal of Mathematical Association Nigeria, 25(1), 26-38.*

Alkhateeb, H. M. (2001). Gender Differences in mathematics achievement Among High School Students in the United Arab Emirates, 1991-2000, *School Science and Mathematics, Vol.101.*

Allen, G. D. (2007). Student Thinking: Misconceptions in mathematics Texas A & M University College Station, TX 77843-3368

Ally, M. (2008). Foundation of education Theories for online learning. In T Anderson (Ed.), The Theories and Practices of online learning (2nd Ed.), Canada AU press Athabasca University, 15-44.

Alro, H. & Skovsmose, O. (1996) Students' Good Reasons in For the Learning of Mathematics, FLM Publishing association, Canada.

Altun, T., Yiğit, N. & Alev, N. (2007). The Effects of Computer Supported Materials on Student Achievements and Perceptions in Science Education, Conference IMCL2007, April 18 -20, Amman, Jordan.

Ambuko, B.S. (2008). *Media selection and use in teaching and learning Kiswahili*. Unpublished Thesis M.Ed Thesis, Maseno University

American Mathematical Society. (1994). National policy statement. Retrieved fromhttp://www.ams.org 15/6/2016

Anderson, I. (1989). Constructing tournament designs. *Mathematical Gazette, 73 (1989) 284-292.*

Anderson, J. A., Reder L. M., and Simon, H. A.( 1997). Situative versus cognitive perspectives: Form versus substance. *Educational Researcher. 26 (1): 18–21.*

Anderson, J.R., Reder, L.M., & Simon, H.A. (2002).Applications and misapplications of cognitive psychology to mathematics education. http://act-r.psy.cmu.edu/papers/misapplied.html visited on 13/1/2014.

Anderson, J. R., & Skwarecki, E. (1986).The automated tutoring of introductory computer programming. *Communications of the ACM*, 29, 842-849.

Anderson, L. W. & Krathwohl, D. (2001) *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. Allyn & Bacon. Boston, MA (Pearson Education Group).

Andrews, P., & Sayers, J. (2013). Comparative studies of mathematics teaching: Does the means of analysis determine the outcome? ZDM: The International Journal on Mathematics Education, 45(1), 133-144.

Anghileri, J. (2001). *Principles and practices in arithmetic teaching. Innovative approaches for the primary classroom.* Buckingham: Open University Press.

Anika. D, Sebastian. K & Lerman. S. (2015) Why Use Multiple Representations in the Mathematics Classroom? Views of English and German Pre-service Teachers. *Article in International Journal of Science and Mathematics Education · March 2015 DOI: 10.1007/s10763-015-9633-6*

Annetta, L. A., Slykhuis, D. & Wiebe, E. (2007). Evaluating Gender Differences of Attitudes and Perceptions Toward PowerPointTM for Pre-service Science Teachers. *Eurasia Journal of Mathematics, Science & Technology Education, 2007, 3(4), 297-304.*

Anyagh, I.P. (2006). Effect of Formula Approach on Students' Achievement and Retention in Algebra. Unpublished Master's Thesis. Benue State University.

Apple, M. (1999). Rhetorical reforms: Markets, standards, and inequality. *Current Issues in Comparative Education, 1(2), 6-17.*

Aremu, O. A & Sokan, B. O. (2003). *A multi-causal evaluation of academic performance of Nigerian learners:* Issues and implications for national development. Department of Guidance and Counseling, University of Ibadan, Ibadan.

Arends, RI. 1990. Learning to Teach. McGraw-Hill, Inc

Aronson, J., Fried, C. B., & Good, C. (2002).Reducing the Effects of Stereotype Threat on African American College Students by Shaping Theories of Intelligence. *Journal of Experimental Social Psychology, 38,* 113-125.

ASDSP (2014) Agricultural Sector Development Support Programme (ASDSP) www.asdsp.co.ke visited 2.1.2016

Askew, M. (2002).The changing primary mathematics classroom—the challenge of the National Numeracy Strategy. In L. Haggerty (Ed.), Aspects of Teaching Secondary Mathematics: Perspectives on Practice. London: Routledge Falmer.

Asyura, A. N., Nur, H. M. A., Salimah, A, Nor H. T, &Aminatul, S. I. (2017).Mathematical misconception in calculus 1: Identification and gender difference. AIP Conference Proceedings 1870, 070001 (2017); accessed on 18/1/2018: https://doi.org/10.1063/1.4995944

Atengogwel, J.C., Odhiabo. J. & Kibe, S. (2008). Impact of SMASSE. INSET on students capacity through improved teachings & learning in the classroom.

Attwood, T. (2014). Why are Some Students so Poor at Maths? Retrieved on 19th October 2017 from https://www.senmagazine.co.uk/articles/articles/senarticles/why-are-some-people-so-poor-at-maths.

Ayşen, Ö. (2012) Misconceptions in Geometry And Suggested Solutions For Seventh Grade Students. *Procedia – Journalon Social and Behavioral Sciences 55 pg 720 – 729*

Ayotola, A., & Abiodun, S. (2010). Computer Animation and the Academic Achievement of Nigerian Senior Secondary School Students in Biology. *Journal of the Research Center for Education Technology (RCET),* 6 (2), 148-161.

Azuka, B. F. (2000). Mathematics in technological development, focus on the next millennium-implications of secondary education. *Journal of Mathematical Association of Nigeria. 25(1) 74-82.*

Azuka, B. F. (2013).Activity -Based Learning Strategies in the Mathematics Classrooms. *Journal of Education and Practice www.iiste.org Vol.4, No.13, 8-15*

Baddeley, A. D. & Hitch, G. J. (2000). Development of working memory: Should the Pascual-Leone and the Baddeley and Hitch models be merged? *Journal of Experimental Child Psychology, 77, 128–137*

Baer, J. (2003). Grouping and achievement in cooperative learning. College teaching, 51 (4), 169-174.

Baharun, N. (2012). Improving students learning of statistics: the impact of web-based learning support on student’s outcomes. Unpublished PhD thesis, university of Wollongong, Australia

Bajah, S. T. (1993). Shortage of Science and Mathematics Teachers: A Nigerian Case Study. Abstract in ERIC Documents. ED389688. http://www.bids.ac.uk/ovidweb/ovidweb.cgi visited on 22/8/2013

Ball, D. L. (2003).*What Mathematical Knowledge is Needed for Teaching Mathematics.* Secretary's Summit on Mathematics, US Department of Education.

Baloyi, V. M. (2017), influence of guided inquiry-based laboratory activities on outcomes achieved by first year physics. Unpublished PhD Thesis University of Pretoria.

Balozi, C. C. & Njung'e, J. (2004, August 24th ). "Trends in Teaching Approaches and Methods in Sciences and Mathematics Education. SMASSE Project p.3 & 11.

Bandura, A. (1977). Social Learning Theory. New York: General Learning Press.

Baroody, A. J. (1989). Manipulatives don't come with guarantees. *Arithmetic Teacher, 37(2), 4-5.*

Baroody, A. J. (2000). Research in review: Does mathematics instruction for three- to five-year-olds really make sense? *Young Children, 55(4), 61-67.*

Baroody, A.T. & Coslick, R.T.(1998). *Fostering children's mathematics power: An investigative to K-8 Mathematics instruction,* Malwah, N.J., Lawrence Erlbaum.

Barton, B. (1996). Making sense of ethno mathematics: Ethno-mathematics is making sense. "Educational Studies in Mathematics," 31, 201-33.

Bas, I., and Boyaci, I. S. (2007) Modelling and optimization I: Usability of response surface methodology. *Journal of Food Engineering, 78, 836–845.*

Bautista, R. G. (2008). "The Effects of Personalized Instruction on the Academic Achievement of Students in Physics"

Bautista, R,G. (2012). Students' Attitude and Performance Towards Algebraic Word Problem Solving Through Personalized Instruction. Proceedings of EDULEARN12 Conference.2nd-4th July 2012, Barcelona, Spain. ISBN: 978-84-695-3491-5., pg 3294 – 3301

Baykul, Y. (2002). İlköğretimde Matematik Öğretimi (1–5 Sınıfları için), 6. Baskı, Pegem.

Belfield, C., Crawford, C. and Sibieta, L. (2017). Long-Run Comparisons of Spending Per Pupil Across Different Stages of Education. London: The Institute for Fiscal Studies [online]. Available: https://www.ifs.org.uk/uploads/publications/comms/R126.pdf [28 April, 2017].

Bell, A. (2005). *Introduce Diagnostic Teaching. Alan Bell and the Toolkit Team*. A Strategy in the Toolkit for Change Agents. MARS, Michigan State University.

Bell, A., & Swan, M. (2006).*Mathematics Assessment Resource Service (MARS Project).*Collaborative project with Michigan State University, Funded by the National Science Foundation. Washington, DC.

Berlin, D., & White, A. (1986).Computer simulations and the transition from concrete manipulation of objects to abstract thinking in elementary school mathematics. *School Science and Mathematics, 86(6), 468-479.*

Bettina, R. & Katrin R. (2007). Integrating Intuition The Role of Concept Image and Concept Definition for Students' Learning of Integral Calculus: *TMME Monograph 3, 181-204.*

Birgan, L. J. (2010). The effects of multimedia technology on students' perceptions and retention rates in mathematics at a community college. Dissertation, North central University.

Bishop, J. (2000). Linear Geometric Number Patterns: Middle School Students' Strategies. Mathematics Education Research Journal, Vol. 12, No. 2, 107-126.

Black, P., & Wiliam, D. (1998). Inside the Black Box: Raising Standards through Classroom Assessment. *Phi Delta Kappan, 80 (2).*

Blasjo, V. (2012).A definition of mathematical beauty and its history. Journal of Humanistic Mathematics, 2(2):8.

Bodner, G. (1986). Constructivism: A theory of knowledge. *Journal of Chemical Education 63: 873–878.*

Borg, W.R. & Gall, M.D. (1989).*Educational Research: An Introduction, 5$^{th}$ Edn.* New York .Longman, White Plains.

Boonen, A. J. H., van Wesel, F., Jolles, J., & van der Schoot, M. (2014). The role of visual representation type, spatial ability, and reading comprehension in world problem solving: An item-analysis in elementary school children. *International Journal of Educational Research*, 68, 15–26.

Booth, L. R. (1988). Children's difficulties in beginning algebra. In A. F. Coxford & A.P. Shulte (Eds.), *The ideas of algebra, K-12* (pp. 20-32). Reston, VA: NCTM.

Booth, J.L., Koedinger, K.R., & Siegler, R.S. (2007).The effect of prior conceptual knowledge on procedural performance and learning in algebra. In D.S. McNamara & J.G. Trafton (Eds.), Proceedings of the 29th Annual Cognitive Science Society. Austin, TX: Cognitive Science Society.

Borasi, R. (1992). *Learning mathematics through inquiry*. Portsmouth, NH: Heinemann.

Borich, G. D. (2004). *Effective Teaching Methods.* Upper Saddle River, New Jersey: Pearson Prentice Hall.

Bosco, J. (2004). Is it possible to reform schools: Toward keeping the promise of ICT in our schools, presented at Ireland's Presidency of the European Union Conference on ICT in Education: New futures for learning in the digital age. Dublin.

Bouck, E. & Flanagan, S. (2010). Virtual manipulatives: What they are and how teachers can use them. *Intervention in School and Clinic, 45 (3), 186-191.*

Bourque, D. R., & Carlson, G. R. (1987). Hands-on versus computer simulation methods in chemistry. *Journal of Chemical Education, 64(3), 232-234.*

Boydm R. & Richerson, P. J. (2009). Culture and the evolution of human cooperation. *Journal philosophical transaction of the royal society. 364, 3281–3288*

Briggs, E.E. (1968). Mathematics laboratories and teacher centres – the mathematics revolution in Britain. *The Arithmetic Teacher 15 (5).*

Briskorn, D.(2009) Combinatorial properties of strength groups in round robin tournaments, *European Journal of Operational Research 192 (2009) 744-754.*

Briskorn, D. and S Knust (2010). Constructing fair sports league schedules with regard to strength groups, *Discrete Applied Mathematics 158:123-135.*

British Academy. (2012). Society Counts: Quantitative Skills in the Social Sciences (A Position Paper) (pp. 1–12). London.

Brown, D.L.,(2006). Can you do the math? Mathematical competencies of baccalaureate degree nursing students. *Nurse Educator 31 (3), 98–100.*

Brown, G., Bull, J. & Pendlebury M. (1997): *Assessing Student Learning in Higher Education,* London: Routledge.

Bryman, A. (2012). *Social research methods* 4th Ed. New York: Oxford University Press.

Buckner, B.R (2011). The Impact of Using Technology on Student Achievement: Teaching Functions with the Ti-Nspire to 9th Grade Algebra Students. Unpublished thesis for Doctor of Philosophy in Mathematics Education. Department of Teaching and Learning University of Louisville Kentucky

Bulimo, W. A., Odebero, S. O. & Musasia, M. M. (2010). Equity in Access to Secondary Schools by Type of Primary Schools Attended in Kakamega South District. *In Organization for Social Science Research in Eastern and Southern Africa (OSSREA); Kenya Chapter. 1(1) 97-107*

Bull, A. &Gilbert, J. (2012). Swimming Out of Our Depth: Leading Learning in 21st Century Schools. Wellington, New Zealand Council for Educational Research.www.nzcer.org.nz/system/files/Swimming%20out%20of%20our%20depth%20final.pdf (Accessed 21 May 2016).

Burke, D. (2014). Audit of Mathematics Curriculum Policy across 12 Jurisdictions. National Council for Curriculum and Assessment, Dublin.

Burke, K. A., Greenbowe, T. J., & Windschitl, M. A. (1998). Developing and using conceptual computer animations for chemistry instruction. *Journal of Chemical Education, 75(12), 1658-1661.*

Burns, R. B. (2000). *Introduction to Research Methods (4th Ed.)* London: Sage publication.

Burton, D. M. (1999).*The History of Mathematics: An Introduction (4th Ed.).* Boston: WCB McGraw-Hill.

Burton, L. (1989). Images of Mathematics. In P. Ernest (Ed.), Mathematics Teaching: the State of the Art (pp.180-187). New York: The Falmer Press.

Busari, O. O. (2004). Sustaining students' interest in science: influence of cognitive and teacher variables. *Journal of science teachers Association of Nigeria: 27 (1), 7-13.*

Carey, S. 2000. Science Education as conceptual change. *Journal of Applied Developmental Psychology 21: (1) 13-19*

Cathcart, W.G., Pothier, Y.M., Vance, J.H. & Bezuk, N.S. (2011). Leaving Mathematics in Elementary and Middle School: A Learner-Centered Approach, 5th Edition, Boston, and Pearson.

Cattell, R. B. (1944). Psychological Measurement: Normative, Ipsative, Interactive. *Psychological Review (51), 291-302.*

CEMASTEA, (2009).Situational Analysis Report. Unpublished SMASSE Reports.

CEMASTEA (2012).Secondary Inset Programme: Training Manual for National Inset-2012. CEMASTEA

Chapparo, C. & Lane, S. J.(2012), "Learning disabilities and intellectual disabilities: why is this so hard for me?" in Kids Can Be Kids: A Childhood Occupations Approach, S. J. Lane and A. C. Bundy, Eds., pp. 525–548, F.A. Davis Company, Philadelphia, Pa, USA.

Clarkson, P. C. (1992). Language and mathematics: A comparison of bilingual and monolingual learners of mathematics. Educational *Studies in Mathematics, 23, 417-429.*

Clawson, C. C. (2004), *Mathematical Sorcery,* Viva Books, India.

Clements, D., & Sarama, J. (2009*).Learning and teaching early mathematics:* The learning trajectories approach. New York: Routledge.

Clements, D. H., & Sarama, J. (2007). Early childhood mathematics learning. In J.F.K. Lester (Ed.), Second handbook of research on mathematics teaching and learning (pp. 461-555). New York: Information Age Publishing.

Cobb, P., Yackel, E., & Wood, T. (1991). Curriculum and teacher development: Psychological and anthropological perspectives. In E. Fennema, T. P. Carpenter, & S. J. Lamon

(Eds), *Integrating research on teaching and learning mathematics* (pp. 83–120). Albany, NY: SUNY Press.

Cockcroft Report. (1982). Mathematics counts: Report of the Committee of Inquiry into the Teaching of Mathematics in Schools under the Chairmanship of W. H. Cockcroft (pp. 273-287). London: HMSO.

Cole, N. S. (1997). The ETS gender study: How females and males perform in educational settings. Princeton, NJ: Educational Testing Service.

Coley, R. J., Cradler, J., & Engel, P. K. (2000).*Computers and the classroom:* the status of technology in U.S. schools .Princeton, NJ: Policy Information Center, Educational Testing Service.

Colgan, L. (2014). Making math children will love: Building positive attitudes to improve student achievement in mathematics. What Works? Research into Practice Research Monograph 56.Student Achievement Division, Ontario Ministry of Education. Retrieved from http://www.edu.gov.on.ca/eng/literacynumeracy/inspire/research/ WW_ MakingMath.pdf.

Collopy, R. (2003). Curriculum materials as a professional development tool: How a mathematics textbook affected two teachers' learning. *Elementary School Journal, 103, 287–311.*

Colwell, R. (2000). *NSF Director's Statement.* Initial Findings from the Third International Mathematics and Science Study.

Cordeiro, P.A., &Cunningham, G.W. (2013). Educational leadership: a bridge to improved practice, Boston: Pearson c2013

Creswell, J.W. (2010). Qualitative inquiry and research design: Choosing among five traditions. Thousand Oaks: Sage.

Croark, C.J, Mehaffie, K.E, McCall, R.B &Greenberg, M.T. (2007).*Evidence-Based Practices and Programs for early childhood*. United Kingdom: Sage.

Cross, S. B. (2009). Project-based curriculum: Two teachers' use of standards-based mathematics curriculum materials from an enactment perspective. Presentation at the Annual Meeting of the North American Chapter of the International Group for the Psychology of Mathematics Education, Atlanta, GA.

D'Ambrosio, U. (1984). "The intercultural transmission of mathematical knowledge: Effects on mathematical education." Campinas: UNICAMP.

Dale, D. C., & Cuevas, G. J. (1987) Integrating language and mathematics learning, In C Joann (Ed ), ESL through content-area instruction. Regents, New Jersey: Prentice Hall.

Daşdemir, İ. & Doymuş, K. (2012).The effect of using animation on primary science and technology course students' academic achievement, retention of knowledge and scientific process skills. *Pegem Education and Training Journal, 2(3),33-42.*

Davis, E. A., & Krajcik, J. S. (2005).Designing educative curriculum materials to promote teacher learning. *Educational Researcher, 34(3), 3–14*

Daymude, K., (2010). Test Error Analysis in Mathematics Education: A Mixed Method Study. Unpublished PhD Thesis in Mathematics Education of University of ATHENS, GEORGIA

Dayo, M. O., Olushina, O. A., &Ajayi, I. A., (2013), Empirical Nexus between Teaching/Learning Resources and Academic Performance in Mathematics among Pre-University Students in Ile-Ife, South-West Nigeria. *International Journal of Scientific and Research Publications, Volume 3, (3), 1-6.*

Dean, P.G. (1982). *Teaching and Learning Mathematics.* Great Britain: The Woburn Press.

Deubel, P. 2003. An investigation of behaviorist and cognitive approaches to instructional multimedia design. *Journal of Educational Multimedia and Hypermedia 12 (1): 63–90.*

Dewey, J. (1915). *The School and Society (Rev. Ed.).* Chicago, IL: The University Press.

Dienes, Z. 1960. *Building Up Mathematics (4th edition).* London: Hutchinson Educational Ltd.

Dickson, L., Brown, M., &Gibson , O. (1984). *Children Learning Mathematics*. Eastbourne, East Sussex : Holt, Rinehart and Winston.

Dimitrov, D. M. & Rumrill, P. D. (2003).Pretest-Posttest Designs and Measurement of Change. *Work 20 (2003) 159–165.*

Ding, C., S: Song, K. & Richardson ,L. I; (2007). Do mathematical gender differences continue? *Educational Studies in Mathematics, 58(2),9-14.*

Dochy, F., Segers, M., Van den Bossche, P. & Gijbels, D., (2003). Effects of problem-based learning: ameta-analysis. *Learning and Instruction, 13, pp. 533-568.*

Dowker, A.D (2005). *Early identification and intervention for students with mathematics difficulties.* University of Oxford, Vol. 38, No 4 July/August 2005, 324 – 332.

Dreher, A., & Kuntze, S. (2015). Teachers' professional knowledge and noticing: The case of multiple representations in the mathematics classroom. *Educational Studies in Mathematics, 88(1), 89-114.*

Driscoll, M., Carliner, S. (2005) Advanced Web-Based Training: Adapting Real World Strategies in Your Online Learning, Pfeiffer. ISBN 0787969796

Duncan, W. (1989).Engendering School Learning: Science Attitudes and Achievement among Girls and Boys in Botswana. *Studies in Comparative and International Education Journal, 6, 12-21.*

Dunleavy, J., & Milton, P. (2008).Student engagement for effective teaching and deep learning. *Education Canada, 48(5), 4-8.*

Dumitru, I. A. (2000) .Developing the critical thinking and efficient learning. Timișoara: West. Pp. 93-95

Duval, R. (1998).Geometry from a cognitive point of view. In C. Mammana & V. Villani (Eds.), Perspectives on the Teaching of Geometry for the 21st Century: An ICMI study (pp. 37-52), Dordrecht: Kluwer.

Duval, R. (2006).A cognitive analysis of problems of comprehension in a learning of mathematics. *Educational Studies in Mathematics, 61, 103-131.*

Echesa, A. C. (2003). Error Analysis; a Second Look. A Paper presented at the National SMASSE In-service for SMASSE District Trainers – August 2003.

Eggen P.D; Kauchak D.P.(2006) *Strategies and Models for Teachers, Teaching Content and Thinking Skills*, New Jersey: Pearson Prentice Hall.

Ellison, G. & Swanson, A. (2010). The Gender Gap in Secondary School mathematics at High Achievement levels: Evidence from the American mathematics Competitions. *Journal of Economic Perspectives 24(2): 109 -128.*

Eluwa, O. I, Akubuike N. E., & Bekom K. A. (2011) Evaluation of Mathematics Achievement Test: A Comparison Between Classical Test Theory (CTT) and Item Response Theory (IRT) *Journal of Educational and Social Research Vol. 1 (4) 99-106.*

Englert, P., (2010). Ipsative Tests: Psychometric Properties https://oprablog.wordpress.com/2010/10/27/ipsativetestspsychometric-properties/. visited on 18/1/2018

English, L. (2002). Priority Themes and Issues in International Research In Mathematics Education. In L. English (Ed.), Handbook of International Research in Mathematics Education (pp. 3-15). New Jersey: Lawrence Erlbaum Associates.

Ericikan, K., McCreith, T., & Lapointe, V. (2005). Factors Associated With Mathematics Achievement and Participation in Advanced Mathematics Courses: An Examination of Gender Difference from an International Perspective. *School and Mathematics, 105, 5.*

Ernest, P. (1998) Images of mathematics, values, and gender: a philosophical perspective. Social justice and mathematics education: proceedings of the 25thConference of the International Group for the Psychology of Mathematics Education. Utrecht, The Netherlands: *Springer-Verlag, 1998, p.45-58.*

Eryılmaz, A. (2002). Effects of Conceptual Assignments and Conceptual Change Discussion on Students' Misconceptions and Achievement Regarding Force and Motion. *Journal of Research in Science Teaching, 39(10), 1001-1015.*

Erasmus, A. C, E. Bishoff, G.& Rousseau, G. (2010). The potential of using script theory in consumer behaviour research. *Journal of Family Ecology and Consumer Sciences14, no. 4: 367-381.*

Etukudo, U. E. (2002).The Effect of Computer–Assisted Instruction on Gender and Performance of Junior Secondary School Students in Mathematics. *ABACUS, Journal of Mathematical Association Nigeria, 27(1), 1-8.*

European Commission, (2011).Commission Staff working Document. Progress Towards the Common European Objectives in Education and Training. Indicators and Benchmarks – 2010/2011.Brussels: European Commission.

European Commission, (2014).Proposal for key principles of a Quality Framework for Early Childhood Education and Care. Report of the Working Group on Early Childhood Education and Care under the auspices of the European Commission. [pdf] Available at:http://ec.europa.eu/education/policy/strategic-framework/archive/documents/ecec_ quality framework_en.pdf [Accessed 12 October 2017].

European Union, (2018). Education and Training MONITOR 2018: Luxembourg: Publications Office of the European Union, 2018http://www.ec.europa.eu/ education/monitor. Accessed on 18/10/2018

Even, R. (1990).Subject Matter Knowledge for Teaching and the Case of Functions. *Educational Studies in Mathematics, 21(6), 521-544.*

Examination Council of Zambia.(2014). School Certificate and GCE Mathematics Examiners Report, Lusaka.

Falode O. C., Ojoye B. T., Ilobeneke S. C. & Falode M. E. (2016). Effectiveness of Interactive Hypermedia Instructions When Used Alone and When Combined With Lecture Method on Secondary School Students' Achievement and Interest Towards Physics in Minna, Nigeria. *Nigerian Journal of Educational Technology, Vol. 1 No. 2, pp 1-12*

Farrell, L., Cochrane, A., & McHugh, L. (2015). Exploring attitudes towards gender and science: The advantages of an IRAP approach versus the IAT. *Journal of Contextual Behavioral Science,4(2), 121–128.*

Farlex,(2017).Dictionary, Encyclopedia and Thesaurus: The Free Dictionary. http://www. thefreedictionary.com/ accessed Nov 20, 2017

Farooq, R.A. (1980). *A Comparative Study of Effectiveness of Problem Solving Approach and Traditional Approach of Teaching Social Studies to Secondary Schools Students* (Unpublished PhD. thesis) University of Punjab Lahore, (Pakistan).

Fasasi, F.M. (2009). Institutional impediments associated with students‟‟ failure in secondary school in Adamawa state *Journal of Educational studies 14(1) 93 – 98.*

Fennema, E. (2000). Gender and Mathematics. What is Known and What I Wish was Known? Unpublished Manuscript. Madison, Wisconsin: Wisconsin Centre for Educational Research.

Finn, J. D. (1980). Sex Differences in Educational Outcomes. A Cross National Study. Studies in Comparative. *International Education Journal, 16, 35-44.*

Fischbein, E. (1987). *Intuition in Science and Mathematics. An Educational Approach.* Dordrecht: Kluwer.

Fleischman, H.L., Hopstock, P.J., Pelczar, M.P., Shelley, B.E. (2010). Highlights from PISA 2009: Performance of US 15-Year-Old Students in Reading, Mathematics, and Science Literacy in an International Context (NCES 2011-004). US Department of Education, National Center for Education Statistics. Washington, D.C: U.S. Government Printing Office; 2010.

Forbes,(2014). Ipsative vs. Normative Personality Tests: Which is the Right Tool for Hiring?http://www.forbes.com/sites/theemploymentbeat/2014/10/30/employers-singpersonality-tests-to-vet-applicants-need-cautious-personalities-of-theirown/#3c88a2211a b2visited on18/1/2018

Fountain, S. & Amaya G. (2003) *Assessment Strategies for Skills-Based Health Education* UNICEF Education Section, New York.

Fox, L.H. & Soller, J.F.(2001). Psychological dimensions of gender differences in mathematics. In J.E. Jacobs, J.R. Becker and G.F. Gilmer(Eds), Changing the faces of mathematics: Perspective on gender, pp. 9-24, Peston, National Council of Teachers of Mathematics.

Fraenkel, J. R., & Wallen N, E.(2000*). How to Design & Evaluate Research in Education,* - New York: McGraw – Hill High Education.

Freeman, R. & Lewis R. (2002): *Planning and Implementing Assessment*, London, Routledge.

Frigo, T. (1999). Resources and Teaching Strategies to Support Aboriginal Children's Numeracy Learning: A Review of the Literature. Sydney: NSW Board of Studies

Fujita, T. (2012).Learners’ level of understanding of the inclusion relations of quadrilaterals and prototype phenomenon. *Journal of Mathematical Behavior, 31(1), 60-72.*

Furner, J. M., & Duffy, M. L. (2002).Equity for all students in the new millennium: Disabling math anxiety. *Intervention in School and Clinic, 38(2), 67–74.*

Fuson, K. (1992) “Issues in Place-Value and Multi-Digit Addition and Subtraction Learning and Teaching.” *Journal for Research in Mathematics Education*, 21:273–280.

Gagliardi, R. (1997). Technical Advisor: Multicultural Education. International Bureau Education Pretoria

Gagne, R.M., Wager W.W., Golas K.C. & Keller J.M.(2005).*Principles of Instructional Design,* Thomson Wadsworth.

Gainsburg, J. (2005). School mathematics in work and life: what we know and how we can learn more. *Journal Elsevier of Technology in Society 27 (1–22)*

Galadima, I. & Yusha’u M.A. (2007).An Investigation into Mathematics Performance of Senior Secondary School Students in Sokoto State. *Abacus: The Journal of Mathematical Association of Nigeria Vol.2 (1) (Mathematics Education series).*

Gale, A. W. & Davidson, M. J. (Eds.) (2006).*Managing Diversity and Equality in Construction: Initiatives and Practice.* London: Taylor and Francis.

Gall, M. D., Borg, W. R., & Gall, J. P. (1996).*Education research an introduction (6th Ed.).* White plains N.Y: Longman.

Gallenstein, N. (2005). Engaging Young Children in Science and Mathematics. *Journal of Elementary Science Education, 17 (2), 27-41.*

Gall, M.D., Gall, J.P., & Borg, W.R. (2003).*Educational Research: An Introduction (7th Ed.).* Boston: Allyn and Bacon.

Gambari, A.I., Falode, C.O. & Adegbenro, D.A. (2014).Effectiveness of computer animation and geometrical instructional model on mathematics achievement and retention among junior secondary school students. *European Journal of Science and Mathematics Education Vol. 2, No. 2, pp 127-146*

Ganeshini, S. (2010). Msc (Science Communication)Faculty of Science National University of Singapore Mw5200 Msc Science Communication Project Report Strengthening student engagement in the classroom.www.math.nus.edu.sg/.../Ganeshini.pdf visited on 8/8/2014

George, M. & Kutty, P. G. T. (2015).Mathematics and Civil Society. Mar Ivanios College, Trivandrum, India-695 015.

Gerdes, P. (1995). *Women and Geometry in Southern Africa*. Universidade Pedagogica, Ethno-mathematics Project.

Gerdes, P. (1999). Geometry from Africa: Mathematical and Educational Explorations. The Mathematical Association of America.

Gibson, D., Aldrich, C. & Prensky, M. (2007). Games and Simulations in Online Learning: Research and Development Frameworks. Information Science Publishing (an imprint of Idea Group Inc.). London

Gimba, R. W. (2006). Effects of 3-dimensional instructional materials on the teaching and learning of mathematics among senior secondary schools in Minna metropolis.2nd SSSE Annual National Conference, Federal University of Technology, Minna. Held between 19th – 2nd November, 2006.

Ginsburg, H. P. (1997*). Entering the child's mind: The clinical interview in psychological research and practice.* New York: Cambridge University Press.

Githua, B.N. (2002). *Factors Related to the Motivation of Learning Mathematics Among Secondary School Students in Kenya in Nairobi Province and Three Districts in Rift Valley Province* – Unpublished Thesis, Njoro: Egerton University Kenya.

Githua, B.N, & Nyabwa, R.A. (2008). Effect of Advance Organizer Strategy During Instruction on Secondary School Students' Mathematics Achievement in Kenya's Nakuru District. *International Journal of Science and Mathematics Education 6, 439-457.*

Girard, M. (1987) Interactive Design of 3D Computer-Animated Legged Animal Motion, *IEEE Computer Graphics and Applications, Vol. 7, No6, pp.39-51.*

Gill, L. & Dalgarno, B. (2008).Influences on pre-service teachers' preparedness to use ICTs in the classroom. In Hello! Where are you in the landscape of educational technology? Proceedings ASCILITE Melbourne 2008.

Goddard, R. D., Sweetland, S.R. & Hoy, W.K. (2000). Academic Emphasis of Urban Elementary Schools and Student Achievement in Reading and Mathematics: A Multilevel Analysis. *Educational Administration Quarterly Vol. 36, No. 5 pp 683-702.*

Goldin, G.A.: 2003, Developing complex understandings: On the relation of mathematics education research to mathematics, *Educational Studies in Mathematics, 54, 171-202.*

GOK, (2007).*Kenya Vision 2030,* Nairobi: Government Printers.

Gokhan, A.(2013) Effect of Computer Animation Technique on Students' Comprehension of the "Solar System and Beyond" Unit in the Science and Technology Course. *Mevlana International Journal of Education (MIJE)Vol.3(1),pp.40-46,1April, 2013* Available online at http://mije.mevlana.edu.tr/

Golden, S., McCrone, T. & Ruud, P. (2006). Impact of e-learning in further education: Survey of scale and breadth. (Online).Available: http://www.dfes.giv.uk/ research/data/uploadfiles/RR745.pdf

Goldin, G.A. (2003). Representational Systems, Learning, and Problem Solving in Mathematics. *Journal of Mathematical Behaviour, 17(2), 137-165.*

Golding, J. (2017) Mathematics teachers' capacity for change: *Journal Taylor Francis online Oxford Review of Education, Volume 43, 2017 - Issue 4 Article Published Online: 27 Jul 2017.*

Gonca, E. (2014*) Effects of Physical Modeling and Computer Animation Implemented With Social Constructivist Instruction on Understanding of Human Reproductive System.* Unpublished Doctoral Thesis in Secondary Science and Mathematics Education: Middle East Technical University.

Good, T.L. & Brophy, J.E. (1990). *Educational Psychology: a realistic approach (4$^{th}$ed).*White Plains, NY, Longman.

Gould, B. (1991) on proof and progress in mathematics. *Bulletin of the American mathematical society.30 (2), 10-15.*

Granström, K. (2006). *Group phenomena and classroom management.* A Swedish perspective. Handbook for Classroom Management: Research, Practice, and Contemporary Issues (pp. 1141-1160). New York: Erlbaum.

Green, M., Piel, J., &Flowers, C. (2008).*Reversing Education Majors 'Arithmetic* Misconceptions with Short-Term Instruction Using Manipulatives. North Carolina at Charlotte: Heldref Publications.

Greene, J. C. (2007). *Mixed methods in social inquiry.* San Francisco, CA: Jossey-Bass.

Gronlund, N. E. (2004). Writing instructional objectives for teaching and Assessment (7th Ed.).Upper Saddle River, NJ: Pearson.

Gunn, C. &Steel, C (2012).Linking theory to practice in learning technology research. Research in learning technology

Gustafson, K. L., & Branch, R. M. (2002). What is instructional design. Trends and issues in instructional design and technology, 16-25.

Gutbezahl, J. (1995). How Negative Expectancies and Attitudes Undermine Females' Math Confidence and Performance: A Review of the Literature. Abstract in ERIC documents. ED380279. http://www.bids.ac.uk/ovidweb/ovidweb.cgi visited on 10/9/2010.

Haluk, O (2004). Some Student Misconceptions in Chemistry: Chemical Bonding, *Journal of Science Education and Technology, Vol. 13, No. 2, 147-159 June 2004*

Han-Chin, L. (2005).Examining the use of computer simulations and animations top remote learning of electrochemistry among college students. Unpublished Master's Thesis, Iowa State University

Hanushek, E. A. (1997). *Assessing the Effects of School Resources on Student Performance:* An update Education Evaluation and Policy Analysis.

Harbor, P. (2001) *Unmasking Some Aversive Aspect of School Mathematics and Strategies for Averting them.* Inaugural Lecture: 5th , July.

Harel, G. & Sowder, L. (2005). Advanced Mathematical-Thinking at Any Age: Its Nature and Its Development. *Mathematical Thinking and Learning, 7 (1), 27-50*

Hartley, J. (1998) *Learning and Studying. A research perspective,* London: Routledge.

Haynes, C. (2007). Experiential learning: Learning by doing. http://adulteducation.wikibook.us/index.php?title=Experiential_Learning_-_Learning_by_Doing.

Heid, M.K. (1988). Re-sequencing skills and concepts in applied calculus using the computer as a tool. *Journal for Research in Mathematics Education. 19, 3-25.*

Henning, E., Van Rensberg &Smith (2004).Finding your way in qualitative research. 2nd Ed. Pretoria: Van Schaik.

Herawati, S. (2003). FINAL REPORT: *Improvement of Secondary School Education*, IMSTEP-JICA Project.

Hicks, L. E. (1970).Some Properties of Ipsative, Normative and Forced-Choice Normative Measures. *Psychological Bulletin, 74*(3), 167-184.

Hill, H. C., Rowan, B., & Ball, D. L. (2005).Effects of Teachers' Mathematical Knowledge for Teaching on Student Achievement. *American Educational Research Journal, 42(2), 371-406.*

Hodgen, J., & Marks, R. (2013).The Employment Equation: Why our young people need more maths for today's jobs. London

Hodgen, J., Pepper, D., Sturman, L. & Ruddock, G., (2010). Is the UK an Outlier? An international comparison of upper secondary mathematics education. London: Nuffield Foundation.at:http://www.nuffieldfoundation.org/sites/default/files/files/Is%20the%20UK%20an%20Outlier_nuffield%20Foundation_v_FINAL.pdf[Accessed 5 April 2017].

Honebein, P. C &Sink, D. L. (2012). The practice of eclectic instructional design. *Performance improvement 51(10), 26-31*

Howard, B. L. & Frank, H. K. (1997), *Teacher Education & National Development*, Washington D.C: ICET.

House. J.D., (2006). Mathematics beliefs and achievement of elementary school students in Japan and United States: Results from the third international mathematics and science study. *The Journal of Genetic Psychology 11(5), 226-231.*

Hughes, J. (2005), The role of teacher knowledge and learning experiences in forming technology- integrated pedagogy. *Journal of Technology and Teacher Education, 13(2), 277–302.*

Hung, D. & Khine, M.S (2006). Engaged learning with Emerging Technologies. Springer, Dordrecht.

Hunter, L., & Greever-Rice, T. (2007). Analysis of 2005 MAP results for eMINTS students. Columbia, MO: Office of Social and Economic Data Analysis.

Hunter, S. M. R. & McCurry, M. K. (2013). Effective pedagogies for teaching math to nursing students: A literature review. *Nurse Education Today 33: 1352–1356*

Hyde, J.S., Lindberg, S. M., Linn, M. C., Ellis, A. B. &Williams, C. C. (2008), Gender Similarities Characterize Math Performance. *Education Forum 25 July 2008 Vol 321 494-495*

Idris, N. (2005). Comparative Studies on ICT among Australia, Vietnam, India, Indonesia, and Malaysia. Proceeding of icmi-earcome.

Ige, T.A. (2001). Concept of Mapping and Problem-Solving Teaching Strategies as Determinants of Achievement in Secondary School Ecology. *Ibadan Journal of Educational Studies 1(1), 290-301.*

Ikwuka, O. I. &Samuel, N.N.C (2017).Effect of Computer Animation on Chemistry Academic Achievement of Secondary School Students in Anambra State, Nigeria. *Journal of Emerging Trends in Educational Research and Policy Studies (JETERAPS) 8(2): 98-102*

IMU, (2014). (International Mathematics Union) Union *Mathematics in Africa 2014 A Summary Report Prepared for the International Congress of Mathematicians (ICM)* In Seoul, Korea August 13-21, 2014 by the International Mathematics Union (IMU)

Ingram, S. (2011). What is a strategy: Fundamentals of strategic planning. Actionable Strategic Planning. December 8, 2013. Retrieved from http://www.Actionablestrategicplanning.com/?p=61.

Iravani, M.R. and Delfechresh H. (2011) Effect of Computer Aided Instruction (CAI) on Science Achievement of Higher Primary Students. *International Journal of Business and Social Science (Special Issue), 2(19), 170-172.*

Isaacs, P.M. & Cohen M.F. (1987) Controlling Dynamic Simulation with Kinematic Constraints, Behavior Functions and Inverse Dynamics, Proc. SIGGRAPH'87. *Computer Graphics, Vol.21, No4, pp.215-224.*

JAB, (2013) Joint Admission Board. The 2013 KCSE Cluster Points. online and download http://publicebooklibrary.com/manual/new-method-to-calculate-the-2013-kcse-cluster-points.pdf.visited on 15/12/2014

Jahun, I. U., & Momoh, J. S. (2001).The Effects of Sex and Environment on the Mathematics Achievement of JSS III Students in Kwara State. *ABACUS, Journal of Mathematical Association Nigeria, 26(1), 53-58.*

Jarvis, P. (1994) 'Learning', *ICE301 Lifelong Learning*, Unit 1(1), London: YMCA George Williams College.

Jasmin, A. C. (2005) "*The Effect of Personalized System of Instruction* (PSI) on the Achievement of Students in College Algebra at Quirino State College."

Jebson, S. J. (2012). Impact of Cooperative Learning Approach on Senior Secondary School Students Performance in Mathematics. *Journal Ife Psychology, 20(2), 107-112*

Jiang, Z., & Potter, W. D. (1994).A computer micro world to introduce students to probability. *Journal of Computers in Mathematics and Science Teaching, 13(2), 197-222.*

Jinfa, C., Kaiser .G., Perry B., & Ngai. W. (2009).*Effective Mathematics Teaching From Teachers' Perspectives.* Sense Publishers Rotterdam/Boston/Taipei

Joel, D., Berman, Z., Tavor, I., Wexler, N., Gaber, O., Stein, Y., & Margulies, D. S. (2015). Sex beyond the genitalia: The human brain mosaic. Proceedings of the National Academy of Sciences, 112 ( 50 ), 15468–15473.

Joensen, J. S. & Nielsen, H. S. (2013) Math and Gender: Is Math a Route to a High-Powered Career? Discussion Paper No.7164 January 2013, Denmark

Johanning, D. I. (2004). Supporting the Development of Algebraic Thinking in Middle School: A Closer Look at Students' Informal Strategies. *Journal of Mathematical Behavior, 23, 371-388.*

Jonassen, D. (1994). Thinking Technology. *Educational Technology, 34(4), 34-37.*

Jones, K. (2002). Issues in the Teaching and Learning of Geometry.www.fisica.ru/.../teacher /.../Issues-in/the-teaching/and-learning-ofge.

Joshua, F. (2007).*Design and construction of geometrical model for learning mathematics in the senior secondary schools.* Unpublished B. Tech. project, Science Education Department, Federal University of Technology, Minna.

Jukes, I. (2008). Understanding digital kids (Dks): Teaching and learning in the new digital landscape. Retrieved November 19, 2016, from http://www.hmleague.org/Digital%20Kids.pdf

Kadiri, S.A. (2004). *The Effectiveness of the Personalized System of Instruction Among Secondary School Students in Osun State.* Unpublished PhD Thesis, Obafemi Awolowo University, Ile-life, Nigeria.

Kafai, Y. B., & Resnick, M. (1996).*Constructionism in practice: Designing, thinking, and learning in a digital world.* Mahwah, NJ: Lawrence Erlbaum Associates.

Kafata, F., &Mbetwa, S. K. (2016). An Investigation Into The Failure Rate In Mathematics And Science At Grade Twelve (12) Examinations And Its Impact To The School Of Engineering: A Case Study of Kitwe District Of Zambia. *International Journal of Scientific & Technology Research Volume 5, Issue 08, 71-93.*

Kagan, S. (1989).The structural approach to cooperative leaning. *Educational leadership. 47(4), 12-16*

Kagume, D.W. (2010). *A Multiple Case Study of Social Cognitive Influences on Career Choice in Science, Mathematics and Technology among Kenyan Women.* Unpublished Doctoral Thesis. Department of Counseling. Oregon State University, United States.

Kakoma, L. & Makonye, P. J. (2010), Learner Errors And Misconceptions In Elementary Analysis: A Case Study of A Grade 12 Class In South Africa. *Acta Didactica Napocensia* 3(3), 35-46.

Kamindo, M. C. (2008). *Instructional Supervision in an Era of Change: Policy and Practice in Primary Education in Kenya*: Unpublished PhD Thesis Durham University school of Education United Kingdom.

Kara, Y. & Yesilyurt, S. (2007). Assessing the effects of tutorial and edutainment software programs on students' achievements, misconceptions and attitudes towards biology**.** Asia Pacific Forumon Science Learning and Teaching, Volume 8,Issue 2, Article1,p.161 (Dec., 2007)

Karacop, A. & Doymus, K. (2013).Effects of jigsaw cooperative learning and animation techniques on students' understanding of chemical bonding and their conceptions of the particulate nature of matter. *Journal of Science Education and Technology, 22(2), 186-203.*

Katrin, S. & Äli, L. (2014). Distinguishing Self-Directed and Self-Regulated Learning and Measuring them in the E-learning Context. International Conference on Education &

Educational Psychology 2013 (ICEEPSY 2013). *Procedia - Social and Behavioral Sciences 112 ( 2014 ) 190 – 198*

Kaur, B. (2005) Schools in Singapore with High Performance in Mathematics at the Eighth Grade Level: *The Mathematics Educator Vol. 9, No.1, 29-38*.

KCEO,(2015a). Kitui County Education Office-Kitui County KCSE Analyses Report. County Director of Education Kitui March 2015.

KCEO, (2015b). Kitui County Education Office: -Kitui County TSC-Staff Return for August 2015, KCEO Kitui.

KCEO, (2018a) Kitui County Education Office:- Kitui County KCSE Analyses Report. County Director of Education Kitui August 2017.

KCEO, (2017b). Kitui County Education Office;- Kitui County TSC-Staff Return for March 2017, KCEO Kitui.

Ke, F., & Grabowski, B. (2007). Game playing for math's learning: Cooperative or not? *British Journal of Education Technology, 38 (2), 249-259.*

Kearsley, G. (2002). *Exploration in learning & instruction:* The theory into practice. Database (Online).

Kelly, F, (2013) Measuring the Economic Benefits of Mathematics Science Research in the UK. Engineering and Physical Sciences Research Council (EPSR).https://www.lms.ac.uk/sites /lms.ac.uk/files/Report%20EconomicBenefits.pdf Accessed on 2/1/2018

Kiamanesh, A. R. (2006, November). Gender differences in mathematics achievement among Iranian eighth graders in two consecutive international studies (TIMSS 99 & TIMSS 2003).IRC 2006 Conference, Washington, DC. Retrieved from http://www.iea.nl/fileadmin/user_upload/IRC/IRC_2008/Papers/IRC2008_Kiamanesh_Mahdavi-Hezaveh.pdf

Kibui, P. & Macrae, M.F. (2005).*Explore Mathematics*, Nairobi: Longman Kenya,.

KIE, (2002).*Secondary Education Syllabus Vol.2.*Nairobi: KIE.

KIE, (2005).*Secondary Mathematics Students Book Four*, Nairobi: KLB.

KIE, (2006).*Secondary Mathematics Teacher's Handbook*, Nairobi: KIE.

Kilpatrick, J., Swafford, J., & Findell, B. (Eds.). (2001). Adding it up: Helping children learn mathematics. Retrieved March 20, 2008, from the National Academies Press Web site: http://www.nap.edu/catalog.php?record_id=9822

Kimble, A. G., Garmezy, N., & Zigler, E. (1990). *Principles of Psychology (3rd ed).* New Delhi: V.R. Demodaran for Wiley Eastern Ltd.

King, D. (2012), *A Report Card on Education in Jamaica*: (CAPRI) Caribbean policy research institutes

Kinyua, M., Maina, L. & Ondera J. (2005).*Advancing in Mathematics Teacher's Guide Form 4,* Nairobi: Longhorn Publishers.

Kiptum, J.K., Rono, P. K., Too, J.K, Bii, B. K. & Too, B. (2013). Effects of Students Gender on Mathematics Performance in Primary Schools in Keiyo South District, Kenya: *International Journal of Scientific & Technology Research Volume: 2 (6), 247 – 252.*

Kirkey, T. (2005). Differentiated instruction and enrichment opportunities: An action research report. *Ontario Action Researcher, 8* (3), 10-13.

Kirschner, P. A. (2002). Cognitive load theory: implications of cognitive load theory on the design of learning. *Learning and Instruction, 12(1), 1–10.*

Kiruhi, M. Githua, B. & Mboroki, G. (2009).*Methods of Instructions*, Ongata Rongai: Gugno Books & Allied.

Kitchens, L. (1996). Teaching, technology and transformation: Integrating technology into the curriculum. *The Texas Technology Connection*, 3 (2), 7 - 13.127.

Kloosterman, P. & Ruddy, M. (2011).*National and International Assessments*: Center for Evaluation & Education Policy Indiana University

KCSE, (2003-20012). *Mathematics Past Papers.* Nairobi: KNEC.

KNEC, (2010).*Examination Regulations and Syllabuses*, Nairobi: KNEC

KNEC, (1993 – 1995, 2004 - 2015). *The KCSE Examination Report,* Nairobi: KNEC.

KNEC, (2013).*The KCSE Examination Report, volume 2: Mathematics & Sciences.* Nairobi: KNEC.

Koech, P.L. (2006). *Influence of Gender Stereotype on Girls and Performance in Mathematics in Secondary Schools in Butere – Mumias Districts.* Unpublished M.Phil. Thesis, Moi University, Eldoret, Kenya.

Koedinger, K. R & Booth, J. L (2017). *Key Misconceptions in Algebraic Problem Solving.* Human Computer Interaction Institute, Carnegie Mellon University Pittsburgh, PA 15213 USA

Kolawole, E. B. (2007). Effects of competitive and cooperative learning strategies on academic performance of Nigerian students in Mathematics. *Educational research Review, 3 (1) , 33-37.*

Kolen, M. J., & Brennan, R. L. (2004).Test equating, scaling, and linking (2nd ed.). New York: Springer.

Koshy, V. & Murray, J. (2002).*Unlocking Numeracy.* London: Fulton.

Koster, R. (2005).*A theory of fun for game design*. Scottsdale, AZ: Paraglyph Press.

Koul, K. (1994).*Methodology of Educational Research* New Delhi Van Educational Books.

Kumari, P.L. (2013) Significance of Solomon four group pretest-posttest method in True Experimental Research-A Study. *IOSR Journal of Agriculture and Veterinary Science (IOSR-JAVS) 5,( 2) 51-58*

Kuntaa, D.D. (2012). *The Museum in Ghana: Their Role and Importance in Ghana's Social and Economic Development*. Unpublished Master of Arts in African Art and Culture Thesis: Kwame Nkrumah University of Science and Technology, Kumasi.

Kurumeh, M.S. & Opara. M. F. (2008). *Innovative Teaching Approaches of Mathematics Education in the 21st century.* Makurdi: Azaben Publishers.

Kyriacou, C., (1992). Active Learning in Secondary School Mathematics. *British Educational Research Journal, (18)3, pp. 309-319.*

Krzysztof, D., Marcin, B. Magdalena, P. &Jankowska, A. (2015).The Role of Computer Animation in Teaching Technical Subjects. *Advances in Science and Technology Research Journal Volume 9, No. 28, Dec. 2015, pages 134–138*

Lach, T., & Sakshaug, L. (2005). Let's do math: Wanna play?. *Mathematics teaching in the middle school, 11 (4), 172-176.*

Ladd, H. F. (2008). "Value-Added Modeling of Teacher Credentials: Policy Implications." Paper presented at the second annual CALDER research conference, "The Ins and Outs of Value-Added Measures in Education: What Research Says," Washington, D.C., November 21. http://www.caldercenter.org/upload/Sunny_Ladd_presentation.pdf.

Lajoie, S. (1993).Computing environments as cognitive tools for enhancing learning. In S. Lajoie & S. Derry (Eds.), *Computers as cognitive tools*, (Vol. 1, pp. 261-288). Hillsdale, NJ: Lawrence Erlbaum Associates.

Lakoff, G., & N´u˜nez, R. E. (2000).*Where mathematics comes from: How the embodied mind brings mathematics into being.* New York: Basic Books.

Laura D.T.M., Mendolia, S. & Contini, D.(2016). The Gender Gap in Mathematics Achievement: Evidence from Italian Data. IZA Discussion Paper No. 10053

Lave, J. (1988). *Cognition in practice: Mind, mathematics and culture in everyday life*. Cambridge: Cambridge University Press.

Lavy, I., & Shriki, A. (2010).Engaging in problem posing activities in a dynamic geometry setting and the development of prospective teachers' mathematical knowledge. *Journal of Mathematical Behavior, 29, 11–24.*

Leder, G. (1996). Gender Equity: A Reappraisal. In Hanna, G. (Ed.). (1996).Towards Gender Equity in Mathematics Education: An ICMI Study.

Lee, C. (2006). *Language for learning mathematics: Assessment for learning in practice.* Maidenhead, Berkshire England: Open University Press.

Lee, V. S. (1999). Creating a blueprint for the constructivist classroom. The National Teaching and Learning Forum Newsletter, 8(4).

Leech, N. L., Barrett, K. C., & Morgan, G. A. (2005). SPSS for Intermediate Statistics: Use and Interpretation (2nd ed.). Mahwah, NJ: Lawrence Erlbaum Associates.

Leo, R. (2011). Geometry: A History from Practice to Abstraction. https://nrich.maths.org/6352 accessed on 17/6/2019

Leonard, H. C., & Irving, S. S. (1981). *Secondary and Middle School Teaching Methods (*4Th Ed.). New York: Macmillan publishes.

Lesh, R., & Zawojewski, J. S. (2007).Problem solving and modeling. In F. Lester (Ed.), Second handbook of research on mathematics teaching and learning (pp. 763–804). Greenwich, CT: Information Age Publishing.

Lester, F. K., & Kehle, P. E. (2003). From problem solving to modeling: the evolution of thinking about research on complex mathematical activity. In: R. Lesh, & H. Doer (Eds.), Beyond constructivism. Models and modeling perspectives on mathematics problem solving, learning, and teaching (pp. 501–517). Mahwah, NJ: Lawrence Erlbaum Associates, Publishers.

Levitt, S. D., & List, J. A. (2007). "What do Laboratory Experiments Measuring Social Preferences Reveal About the Real World," *Journal of Economic Perspectives, 21(2): 153–174.*

Li, Q. (2004). *Technology and mathematics education: Any impact?* The Eleventh International Literacy and Education Research Network Conference on Learning, La Havana.

Lim, T. H. (2000). *The teaching and learning of algebraic equations and factorisation in O-Level mathematics: A case study.* Unpublished MEd Dissertation. Universities of Brunei Darussalam.

Lin (2011). Facilitating Learning from Animated Instruction: Effectiveness of Questions and Feedback as Attention- directing Strategies. *Educational Technology& Society,* 14, 31-42.

Lin, C.H. (2001). *The effect of varied enhancements to animated instruction on test measuring different educational objectives.* Unpublished Doctoral Dissertation, The Pennsylvania State University.

Lochead, J., & Mestre, J. (1988). From words to algebra: Mending misconceptions. In A. Coxford & A. Shulte (Eds.), The Ideas of Algebra, K-12 (1988 Yearbook of the National Council of Teachers of Mathematics, pp. 127-135). Reston, VA: National Council of Teachers of Mathematics.

Lubienski, S. T., Robinson, J. P., Crane, C. C., & Ganley, C. M., (2013). Girls' and boys' mathematics achievement, affect, and experience: Findings from ECLS-K. *Journal for Research in Mathematics Education, 44, 634–645.*

Lyke, J. A., & Young, J. K. (2006). Cognition in context: Students' perceptions of classroom goal and structures and reported cognitive strategy use in the college classroom. *Research in Higher Education, 47*(4), 477-490.

Lyster, R., Quiroga, J., & Ballinger, S. (2013). The effects of Bi-literacy instruction on morphological awareness. *Journal of Immersion and Content-Based Language Education, 1* (2), 169–197.

Maag, J. W. (2004). *Behavior management: From theoretical implications to practical applications*. Belmont, CA: Thomson Learning.

Maaike, C. E. (2013 ). *Research report validation procedure*. CLU-Utrecht University

Maccini, P., & Gagnon, J. C. (2000). Best practices for teaching mathematics to secondary students with special needs. *Focus on Exceptional Children , 32,* 1–22.

Machaba, M.M. (2013). *Teacher Challenges in the Teaching Of Mathematics at Foundation Phase.* Unpublished Doctoral Thesis of Education in Early Childhood Education of University of South Africa.

Madona, G.& Marine, D. (2017) Interactive Teaching Methods: Challenges And Perspectives .IJAEDU- *International E-Journal of Advances in Education, Vol. III, Issue 9, 544-548*

Magliaro, J. (2007). Mathematics teachers' preparedness to integrate computer technology into the curriculum. *Canadian Journal of Learning Technology Vol.33 (3)*

Mahlabela, P.T. (2012). Learner *Errors and Misconceptions in Ratio and Proportion. A Case Study of Grade 9 Learners from a Rural Kwazulu-Natal School.* Theses Submitted in Part of Fulfillment of the Requirement of A Masters Degree in Mathematics Education of the University Of Kwazulu-Natal

Maicibi, N. A. (2003). *Human Resource Management Success.*Kampala.Net Media Publication. Ltd. Uganda.

Maiyo. J. A. & Ashioya, L. A. (2009). *Poverty Alleviation*: The Educational Planning Perspective. Department of Educational Planning and Management, Masinde Muliro University of Science and Technology.

Makueni, (2007). *Makueni Baseline Study Report by Makueni SMASSE Coordinator*. Unpublished Report Presented to Mathematics and Science Teachers in the District April 2008 In-Service of Teachers.

Maliki, A. E Ngban, A. N &Ibu, J. E. (2017. Analysis of Students' Performance in Junior Secondary School Mathematics Examination in Bayelsa State of Nigeria *Studies: Journal on Home and Community Science Pages 131-134 Published online: 01 Sep 2017*

Malkevitch, L. (2013). Finite Geometry? Feature column monthly essays on mathematical topics. American mathematical society. Retrieved May 2, 2013, from http://www.ams.org/samplings/feature-column//fcarc-finitegeometries.

Mallet, D. G.(2007) Multiple Representations For Systems Of Linear Equations Via The Computer Algebra System Maple. *International Electronic Journal of Mathematics Education 2, ( 1), 16-31*

Mallon, M. N (2013). Extending the learning process: using the theory of Connectivism to inspire student's collaboration. *Kansas library association and university libraries of proceedings 3, 18-27*

Marlowe, B. A., & Page, M. L. (1998).*Creating and sustaining the constructivist classroom*. Thousand Oaks, CA: Sage.

Mashile, E.O. (2001). Science Achievement Determinants: Factorial Structure of Family Variables. *South African Journal of Education, 21:335-338.*

Mathematics Navigator (2016) Misconceptions and Errors. American Choice https://www.westada. org/cms/lib/ID01904074/.../Misconceptions_Error%202.pdf

Matias, L. R., (2017). "Tell me and I forget, teach me and I may remember, involve me and I learn": changing the approach of teaching Computer Organization. Departamento de Computacion, Facultad de Ciencias Exactas y Naturales ´ Universidad de Buenos Aires and ICC, CONICET Buenos Aires, Argentina mlopez@dc.uba.ar article Xiv:1703.02944v1 [cs.CY] 8 Mar 2017

Max, A. S. (1988).*Teaching mathematics. A source book of aids, activities and strategies (2nd Ed). USA: Prentice Hall*

Mayer, R. E., Steinhoff, K., Bower, G.,& Mars, R. (1995). A generative theory of textbook design: Using annotated illustrations to foster meaningful learning of science text. *Educational Technology Research and Development, 43, 31-44*

Mbugua Z.K. (2012). Factors Contributing to Students' Performance in Mathematics at Kenya Certificate of Secondary education. A case of Baringo County, Kenya. *Am. J. Contemp. Res. 2(6):87-91.*

McDermott, L. (1984). Research on Conceptual Understanding of Physics. *Physics Today, 37, 24-32.*

McMillan, J.H., &Schumacher, S. (2010). *Research in education. (Evidence based inquiry) 7th Ed.* United States of America: Library of Congress Cataloguing in Publication Data.

Meagher, D. G., Tianshu P., Wegner, R. and Miller, J. R. (2012). *Miller Analogies Test: Reliability and Validity.* Pearson Executive Office 5601 Green Valley Drive Bloomington, MN 55437

Meissner, H.: (2002), Einstellung, Vorstellung, and Darstellung, in: Cockburn and Nardi (Eds.) PME26. Proceedings of the 26th Annual Conference, University of East Anglia, Norwich, vol. 1, 156-161.

MES,(2017) Ministry of Education and Sports Uganda. The Education and Sports sector annual performance report. Financial year 2016/2017. Available at http://www.education.go.ug/file/downloads/ ESSAPR%20%202016-17.PFD

Mestre, J. (1986). Teaching problem solving strategies to bilingual students: What do research results tell us? International *Journal of Mathematics Education in Science and Technology, 17, 393-401.*

Miheso, K .M. (2012).`Factors affecting mathematics performance among secondary school students in Nairobi province Kenya` unpublished PhD thesis Kenyatta University http://ir-iblary.ku.ac.ke/etd.handle/123456789/2485

Milagros, S. &Jacquelynne, E.(2012) Self-concept of computer and math ability: Gender implications across time and within ICT studies. *Journal of Vocational Behaviour Volume 80, Issue 2, Pages 486-499*

MIOE, (2004). The Malawi Institute of Education *Participatory Teaching and Learning: A Guide to Methods and Techniques.* Published Malawi Institute of Education

Mitchelmore, M. C., & White, P. (2004).Teaching mathematical concepts: Instruction for abstraction. Invited regular lecture presented at the 10th International Congress on Mathematical Education, Copenhagen, Denmark.

Mlodinow, L. (2001). Euclid's Window: *The story of geometry from parallel lines to hyperspace.* London: The Penguin Press

MOE, (2006).The Ministry of Education *Secondary mathematics teacher's handbook,* Nairobi, Kenya Institute of Education.

MoEST (2005).Education sector report. Nairobi: Ministry of Education, Science and Technology. Retrieved May 11, 2016 from http://siteresources.worldbank.org/INTKENYA/Resources/gok_eduction_sector_rpt.pdf

Mohyuddin, R. G., & Khalil, U. (2016).Misconceptions of students in learning mathematics at primary level. *Bulletin of Education and Research, 38(1), pp.133-162.*

MoIC (2006), Ministry of Information and Communication: National Information and Communication Technology (ICT) Policy, Nairobi

Mondoh, H.O. (2001). Cognitive Differences in a Mathematics class. Paper presented during a workshop on in-Servicing Science and Mathematics Teachers of Nakuru District, 9-12 April, Nakuru High School, Kenya

Mondoh, H.O. (2005). *Methods of Teaching Mathematics*. Njoro: Egerton University press.

Monica, G.M &Ferguson, H. (1996).Types and quality of knowledge. *Journal of Educational psychologist, 31 (2), 105 – 113.*

Moore, K. D.( 2005). *Effective instructional strategies.* London: Sage Publications.

Moore, N. D (2012)."Alternative Strategies for Teaching Mathematics". Education and Human Development Master's Theses. http://digitalcommons.brockport.edu/ehd_theses visited on 13/12/2013.

Mtunda, F.G. & Safuli S.D.D. (1997).*Theory and practice of teaching*. Blantyre: Dzuka. Mzumara PS, In-service course materials for teacher educators. (Unpublished)

Mugenda, M.O. & Mugenda, A.G. (1999).*Research Methods, Qualitative and Quantitative Approaches.* Nairobi: CTS Press.

Mugenda, O.M. & Mugenda, A.G. (2003).*Research methods: Quantitative and Qualitative approaches*, Acts press, Nairobi Kenya.

Mugo, P. & Kisui R. (2010).*Mastering PTE mathematics***.** Oxford University press. East Africa Ltd.

Mullis, I.V.S., Martin, M.O. & Foy, P.,( 2008). TIMSS 2007 International Mathematics Report: Findings from IEA's Trends in International Mathematics and Science Study at the Fourth and Eighth Grades. Chestnut Hill, MA: Boston College, TIMSS and PIRLS International Study Center.

Munira, A. (2010) Students' Conceptions of the Nature of Mathematics and Attitudes towards Mathematics Learning. *Journal of Research and Reflections in Education .Vol.4, No.1, pp 27 -41. Available at: http://www.ue.edu.pk/jrre accessed on 15/8/20*16.

Munyao, H.T. (2013). *Impact of SMASSE on teaching mathematics in secondary schools in Mwingi West District.* Unpublished thesis. Kitui County. Kenya.

Muriithi, P. (2005). *A framework for integrating ICT in the teaching and learning process in secondary schools in Kenya MSc.* Thesis submitted at the University of Nairobi, School of Computing and Informatics.

Murphy, P. & Moon, B. (2004).*Developments in Learning and Assessment*. London: Holdder & Stougton.

Mustafa B., Aslıhan K. T., & Turgay .A (2011). The Effect of Computer Assisted Instruction with Simulation in Science and Physics Activities on the Success of Student: Electric Current. *Eurasian Journal of Physics and Chemistry Education. Jan (Special Issue):34-42, 2011*

Mutai, B.K. (2006). *How to write quality research proposal: a complete and simplified recipe.* New York: Talley Publications.

Mwangi, P. G., (2016) *Influence of Practical Approach of Teaching on Student Achievement in Geometry in Public Primary Schools in Thogoto Zone, Kiambu County, Kenya.* Unpublished Thesis of Master in Education in School of Education: Department of Educational Communication & Technology of Kenyatta University

National Council of Teachers of Mathematics [NCTM].(1989). *Curriculum and evaluation standards for school mathematics.* Reston, VA.: The National Council of Teachers of Mathematics.

National Council of Teachers of Mathematics [NCTM] (2000).*Principles and Standards for School Mathematics.* Reston, VA., Author

National Council of Teachers of Mathematics [NCTM] (2014).*Principles to actions, ensuring mathematical success for all*.. Reston, VA., Author

Ng'eno, J., Githua B., & Changeiywo J. (2013).Teachers' Perceptions of Their Preparedness to Integrate Information Communication and Technology in Secondary School Mathematics Instruction in Rift Valley Region, Kenya. *Journal of Education and Practice. 4,(12), 51-57.*

Niederle, M., & L. Vesterlund (2010)."Explaining the Gender Gap in Math Test Scores: The Role of Competition." *Journal of Economic Perspectives 24(2): 129-144.*

Nisbet, S., & Williams, A. (2009).Improving students' attitudes to chance with games and activities. *Australian Mathematics Teacher, 65 (3), 25-37*

Njoroge, J.N (2005). *Effects of Cooperative Learning on Secondary School Students' Achievement and Attitudes Towards Mathematics: A Case of Nakuru District, Kenya.* Unpublished, Master's Thesis, Egerton University, Njoro Kenya.

Noraini, I. (2006). Exploring the Effects of Ti-84 Plus on Achievement and Anxiety in Mathematics. *Eurasia Journal of Mathematics, Science and Technology Education 2, (3), 66-78*

Norris, E. (2012). *Solving the math's problem:* international perspectives on mathematics education. London.

North D, Gal, I.& Zewotir, T., (2014). Building capacity for developing statistical literacy in a developing country: Lessons learned from an intervention. *Statistics Education Research Journal, 13(2):15–27.*

Novak, E. & Tassell, J. L.(2017) Studying pre-service teacher math anxiety and mathematics performance in geometry, word, and non-word problem solving. *Learn Individual Differerence.54, 20–29 (2017).*

Nunes, T., Light, P. & Mason, J. (1993). Tools for thought: the measurement of length and area. *Learning and Instruction, 3, 1, 39-54.*

Obiaha, N. E., (2006). *STAN Physics for Senior Secondary Schools.* Heinemann Education Bool Publishers, Nageria

Obimba, F.U. (1989). *Fundamental of Measurement and Evaluation in Education and Psychology*. Abuja, Ibadan, Lagos, Owerri: Totan Publishers Ltd.

Ochanda .,J. P. & Indoshi, F. C. (2011). Challenges and benefits of using scientific calculators in the teaching and learning of Mathematics in secondary school education. *Journal of Media and Communication Studies Vol. 3(3), pp.l02-111, March 201IISSN 2141-2545 Academic Journals.*

O'Connor, M. (2000).*The open-ended approach in mathematics Education.* Nairobi; Kenya SMASSE Project.

O'Connor, M.M. Kanja, C.G & Baba, T. (Ed) (2000).*The open ended Approach in Mathematics Education:* A first step toward classroom practice in Kenyan setting. Nairobi: SMASSE project JICA-MOEST.

O'Day, D. H. (2007). The Value of Animations in Biology Teaching: A Study of Long-Term Memory Retention. *Journal CBE Life Sci. Educ 6(3) 217–223.*

O'Day, D. H. (2006). Animated cell biology: a quick and easy method for making effective high-quality teaching animations. *Journal CBE Life Sci. Educ 255–263.*

Odili G. A., (2006). *Mathematics in Nigeria Secondary Schools. A Teaching Perspective*. Port-Harcourt – Rex – Charles and Patrick Ltd.

Odhiambo E.O.S, Maito.T. L. & Ooko J. K. (2013).Teachers and Students Attitude towards Mathematics in Secondary Schools in Siaya County, Kenya. *Asian Journal Of Management Sciences And Education Vol. 2 ( 3) 116-123.*

Odom, W, E. (1998) Report of the Senior Assessment Panel of the International Assessment of the U.S.A Mathematical Sciences https://www.nsf.gov/pubs/1998/nsf9895/math.htm. *accessed on 15/12/2017*

OECD, (2003) (Organisation for Economic Co-operation and Development).Mathematics Teaching and Learning Strategies in PISA. Paris: OECD Publishing.

Ofoegbu, F.I. (2004). Teacher Motivation: A Factor for Classroom Effectiveness and School Improvement in Nigeria. Gale Group. Retrieved August 15 2005, from http://www.findArticles.com accessed 10/5/2012.

Ogologo, G. A. & Wagbara, S. (2013). Effect of demonstration, strategy on senior secondary school students' achievement in separate ion techniques in chemistry in Obio/Akpor Local Government Area, Rivers State. *Journal Vocational Education & Technology (2013) Vol. 10,Nos. 1&2. 15 – 29.*

Ohuche, R.O. & Akeju, S.A. (1977). *Testing and Evaluation in Education*. Lagos: Africana Educational Resources.

Okafor, C. F., & Anaduaka, U. S.(2013). Nigerian School Children and Mathematics Phobia: How the Mathematics Teacher Can Help. *American Journal of Educational Research, 2013, Vol. 1, No. 7, 247-251*Available online at http://pubs.sciepub.com/ education /1/7/5

Okere, M. (1996).*Physics Education*, Nairobi: Lectern Publication Limited.

Olajengbesim (2006).*Effect of concept mapping and problem-solving instructional strategies in students' learning outcomes in chemistry.* An Unpublished M.Ed Project. University of Ibadan.

Oloo, L. M. (2009). *Baseline Survey Report for ICT in Secondary Schools in Selected Parts of Kenya.* Developing Partnership for Higher Education.

Ontario Ministry of Education. (2005). The Ontario curriculum grades 1-8 mathematics. Retrieved from http://www.edu.gov.on.ca/eng/curriculum/elementary/math18curr.pdf

Ottevanger, W., van den Akker, J. & Feiter de, L. (2009).*Developing Science, Mathematics, and ICT Education in Sub-Saharan Africa:* Patterns and Promising Practices. World Bank Working paper 101, Washington.

Orodho, J. A. (2002). *Techniques of Writing Research Proposals and Reports in Education and Social Sciences.* Nairobi: Masola Publishers Paris: UNESCO.

Örs, E., F. Palomino & E. Peyrache (2013), “Performance Gender-Gap: Does Competition Matter?”*Forthcoming in Journal of Labor Economics 31(3).*

Orwig, C. (2003). Prepare for language learning. InLinguaLinks library 5.0 plus. n.p. Dallas: SIL International Digital Resources.www.sil.org/lingualinksLANGUAGELEARNING PrepareForLanguageLearning/PrepareForLanguageLearning.htmRetrieved from on 15/3/2014

Oser, F. & Baeriswyl, F. J. (2001). Choreographies of Teaching: Bridging Instruction to Learning. In: V. Richardson (Ed.): *Handbook of research on teaching*. Washington D.C.: American Educational Research Association, pp. 1031–1065.

Owolabi, O. T. (2012) Effect of Teacher’s Qualification on the Performance of Senior Secondary School Physics Students: Implication on Technology in Nigeria. *Journal Canadian Center of Science and Education. Vol. 5, No. 6; 72-77.*

Oxford, R.I. (1990). *Language Learning Strategies: What Every Teacher Should Know.* New York: Newbury House Publisher.

Palmiter, S. (1993). The effectiveness of animated demonstrations for computer-based tasks: A summary, model, and future research. *Journal of Visual Languages and Computing, 4(1), 71-89.*

Patel, N.M, & Patel, G. A. (2005).*Mathematics for Kenya Schools,* Nairobi: Malimu Publication.

Perveen ,K.(2009) *Comparative Effectiveness of Expository Strategy and Problem Solving Approach of Teaching Mathematics at Secondary Level university.* Institute of Education and Research Arid agriculture university Pakistan.

Peterson, P. L.; Fennema, E. &Carpenter, T., (1989). Using Knowledge of How Students Think About Mathematics. *Educational Leadership, 46*(4), 42-46.

Pew Research Centre(2018) Social & Demographic Trends. Changes in the American workplace.http://www.pewsocialtrends.org/2016/10/06/1-changes-in-the-american workplace/ accessed on 2/2/2018

Piaget, J. (1970). *Structuralism*. New York: Basic Books.

Piasta, S. B., Pelatti, C. Y., &Miller, H. L (2014).Mathematics and Science Learning Opportunities in Preschool Classrooms. *Journal of Early Education Development ; 25(4): 445–468.*

Picciano, A.G. (1994). *Computers in the schools: A guide to planning and administration*. New York, NY: Merrill/Macmillian.

Popham, J., (2008). *Transformative Assessment.* Alexandria, VA: Association for Supervision & Curriculum Development (ASCD).

Pourmoslemi, A., Erfani, N. & Firoozfar, I (2013). Mathematics Anxiety, Mathematics Performance and Gender differences among Undergraduate Students: *International Journal of Scientific and Research Publications, Volume 3, Issue 7,1-6.*

Polya, G. (1971). *How to Solve It*. Princeton, NJ: Princeton University Press.

Presmeg, N. (2006). Research on visualization in learning and teaching mathematics. In A. Gutiérrez, p. Boero (Eds.), Handbook of Research on the Psychology of Mathematics Education: Past, Present and Future (pp. 205-235). Rotterdam, Taipei: Sense Publishers.

Putwain, D. (2009). Predicting Examination Performance Using an Expanded Integrated Hierarchical Model of Test Emotions and Achievement Goals. *Psychology Teaching Review, 15 (1): 18-31.*

QCA, (2003).(Qualifications and Curriculum Authority):*Assessment For Learning Using Assessment to Raise Achievement in Mathematics.* Qualifications and Curriculum Authority 83 Piccadilly London W1J 8QA www.qca.org.uk/

Ramazan, G. &Osman, B. (2012).The effect of computer-assisted teaching on remedying misconceptions: The case of the subject “probability”. Journal Computers & Education 58: 931–941.

Rebora, Anthony.( 2016), “Faced with Deep Teacher Shortages, Clark County, Nev., District Looks for Answers.” Education Week 35 (19): S2

Reichel, M., & Ramey, M. A. (Eds.) (1987*). Conceptual Frameworks for Bibliographic Education: Theory to Practice.* Littleton Colorado: Libraries Unlimited Inc.

Resnick, L. (1983). Mathematics and science learning: A new conception. *Science, 220, 477-478.*

Reimer, K. & Moyer, P. S. (2005). "Third-Graders Learn About Fractions Using Virtual Manipulatives: A Classroom Study." *Journal of Computers in Mathematics and Science Teaching* 24(1): 5-25.

Riasat, A. (2010). Effect of Using Problem Solving Method in Teaching Mathematics on the Achievement of Mathematics Students. *Asian Social Science journal vol 6 No. 2: 76-71*

Riccomini, P. J. (2014). Identifying and using error patterns to inform instruction for students struggling in mathematics. Webinar series, Region 14 State Support Team. Retrieved from http://www.ohioregion14.org/perspectives/?p=1005.

Riccomini, P. J. (2005). Identification and remediation of systematic error patterns in subtraction. *Learning Disability Quarterly, 28(3), 233-242.*

Rice. J. K. (2010) *The Impact of Teacher Experience Examining the Evidence and Policy Implications.* National centre for analyses of longitudinal data in educational research. Urban institute.

Richards. J. (1991).Mathematical discussions.in E.von glaserfeld (ED), Radical constructivism in Mathematics Education. pp 13-51.Dordrecht, The Netherlands.

Richardson, V. (1996).The role of attitudes and beliefs in learning to teach. In J. Sikula (Ed.), Handbook of research on teacher education (2nd edn., pp. 102-119). New York: Macmillan.

Richtel, M. (2011,).In classroom of the future, stagnant scores. *The New York Times*, p. 1:16.

Riding, R.I & Al-Salih, N (2000).Cognitive Style and Motor Skill and Sports *Performance. Educational Studies 26 (1), 19-32.*

Rising, G.N &. Johnson D.A. (1972). *Guidelines for Teaching Mathematics (2nd Ed.).* California: Wadsworth Publishing Company.

Robberts, A. S. (2016). The influence of South Africa teachers' qualifications and experience on the mathematics performance of learners: Pretoria University online line library Theses and Dissertations (Science, Mathematics and Technology Educationhttps://repository.up.ac.za/ handle/2263/32289 accessed on 16/12/2017

Robert C. J. & Glenn, J. (1992).*Mathematics dictionary*, Springer.

Roblyer, M.D., Edwards, J., & Havriluk, M.A. (1997).*Integrating educational technology into teaching.* Upper Saddle River, NJ: Merrill.

Roets, HE. 1995. *Psychology of Andragogy*. UNISA Pretoria

Roohi,F.(2017). *Role of Mathematics in the Development of Society*.www.ncert.nic.in /.../Final-Article-Role%20of%20Mathematics%20in%20the%20Deve accessed on 18/11/2017

Roschelle, J., Pea, R., Hoadley, C., Gordin, D., & Means, B. (2001). Changing How and What Children Learn in School With Computer-Based Technologies. *The Future of Children, 10(2), 76-101.*

Ross, K., Saito, M., Dolata, S., & Ikeda, M. (2004).*Southern Africa Consortium for Monitoring Educational Quality ( SACMEQ ) data archive*. Paris: IIEP.

Rossi, Cesare, Flavio, Russo& Ferruccio (2009). Ancient Engineers' Inventions: Precursors of the Present. *History of Mechanism and Machine Science. ISBN 978-9048122523.*

Rotbain, Y., Marbach-Ad, G. &Stavy, R. (2007).Using a Computer Animation to Teach High School Molecular Biology. *Journal of Science Education and Technology*. 17, 49-58.

Roy Hollands (1990).*Development of Mathematical Skills:* Blackwell Publishers, Oxford, London

Rubenstein, R., & Thompson, D. (2002).Understanding and supporting children's mathematical vocabulary development. *Teaching Children Mathematics, 9, 107–112.*

Ruthven, K., Hennessy, S., & Brindley. S., (2004). Teacher representations of the successful use of computer-based tools and resources in secondary-school English, Mathematics and Science *Teaching & Teacher Education 20 (3) 259-275*

Ruzic, R. & O'Conell, K. (2001)."Manipulatives."Enhancement literature review. https://www.cast.org/ncac/Manipulatives1666.cfm accessed on 18/4/2019

SAAEA, (2014).*The Southern Africa Association for Educational Assessment:* A Comparative Report on the Education Landscape of the Countries in the Southern Africa Association for Educational Assessment.

Safro, S.( 2009) *Factors That Impede The Formation Of Basic Scientific Concepts During Teacher Training In Ghana.* Unpublished Master of Education Degree Thesis in the Subject Didactics: University of South Africa, February 2009.

Saitis (2000): *Baseline Studies:* Determinants and Impact of ICT use for African SMEs: Implications for Rural South Africa

Salen, K., & Zimmerman, E. (2004).*Rules of play: Game design fundamentals*. Cambridge, MA: The MIT Press.

Salih, C., Erol, T. & Kose, S. (2006). The effects of computer-assisted material on students cognitive levels, misconceptions and attitudes towards science. *Journal Computers & Education 46 (2006) 192–205*

Salisu, A. (2015). *Impact of Animated-Media Strategy on Achievement, Retention and Interest Among Secondary School Geography Students in Weather Concepts, Kastina State, Nigeria*. Unpublished Masters thesis of Department of Science Education, Ahmadu Bello University, Zaria.

Salman, M.F. (2004). Analysis of Gender Influence and Performance of JJJs Students' Technique in Solving Simultaneous Linear Equations by Graphical Methods, *Gender Discuss 1 (1) 87-99*

Salman, M.F. (2005). Teachers Identification of Difficulty Level of Topics in the Primary School Mathematics Curriculum in Kwara state abacus. *Journal of Mathematics Association of Nigeria, 30(1), 20-29.*

Salomon, G. (2002). Technology and pedagogy: Why don't we see the promised revolution? *Educational Technology, 42(2),71-75.*

Sankey, M.D. (2005). Multimodal design and the neo-millennial learner. In Proceedings from OLT 2005 Conference, *QUT, Brisbane, 251-259.*

Sander, P. (2009).Current Developments in Measuring Academic Behavioural Confidence. *Psychology Teaching Review, 15 (1): 31-44.*

Sanger, M. J., & Greenbowe, T. J. (1997a). Common student misconceptions in electrochemistry: Galvanic, electrolytic, and concentration cells. *Journal of Research in Science Teaching, 34(A), 377-398.*

Sarafian, H.(2000) "*The Magic Angles of Projectile Motion.*" Mathematics in Edu. Res.9,20-26,

Schneck, C. M. (2009), "A frame of reference for visual perception," in Frame of Reference for Pediatric Occupational Therapy, P. Kramer and J. Hinojosa, Eds., pp. 349–389, Lippincott Williams & Wilkins, Philadelphia, Pa, USA, 3rd edition, 2009.

Schunk, D.H. (2004). *Learning Theories*. 4th Ed. United States of America: Library of Congress Cataloguing in Publication Data.

Seah, W.T.(2003) *The professional socialization of teachers in transition: A values perspective.* In: INTERNATIONAL EDUCATION RESEARCH CONFERENCE AARE-NZARE, 29th Nov. to 3rd Dec., 2003, Auckland, New Zealand. Proceedings...Auckland, New Zealand: AARE, 2003. p. 1-11. Available at: http://www.aare.edu.au/03pap/sea03594.pdh. Accessed at: 13 June 2017.

Senthamarai, S. (2018).Interactive teaching strategies. Proceedings of the Conference on "Recent Trend of Teaching Methods in Education" Organised by Sri Sai Bharath College of Education Dindigul-624710, Tamil Nadu, India. *Journal of Applied and Advanced Research, 2018: 3(Suppl. 1) S36 – S38).*https://dx.doi.org/10.21839/jaar. accesses on 2/3/2019

Serbessa, D.D.(2006). Tension between traditional and modern teaching-learning approaches in Ethiopian primary schools. *Journal of International Cooperation in Education, 9(1):123–140.Availableathttp://home.hiroshima-u.ac.jp/cice/wp-content/uploads/2014/03/9-1-10.pdf. Accessed 19 March 2017.*

Seyed, A. J. & Sina, Z. (2013) Impact of Information and Communications Technology on Growth of Agriculture Sector. *Asian Journal of Management Sciences and Education 2 (2) 182-191.*

Shih, J., Speer, W. R., & Babbitt, B. C. (2011). Instruction: Yesterday, I learned to add; today I forgot. In F. Fennell (Ed.), *Achieving fluency: Special education and mathematics* (pp. 59-83). Reston, VA: National Council of Teachers of Mathematics.

Shinwha C. & Noss, R. (2001).*Investigating Students' Understanding of Locus with Dynamic Geometry*. Proceedings of the British Society for Research into Learning Mathematics 21(3) November 200. Institute of Education, University of London

Shuard, H. B. (1982). Differences in Mathematical Performance Between Girls and Boys. In Cockcroft Report.(1982). Mathematics counts: Report of the Committee of Inquiry into the Teaching of Mathematics in Schools under the Chairmanship of W. H. Cockcroft (pp. 273-287). London: HMSO.

Sidhu, K. S. (1995), *The Teaching of Mathematics, (Fourth Edition),* Sterling Publishers, New Delhi, India,

Siemens, G. (2004). Connectivism: A Learning Theory for the Digital Age, published on http://www.elearningspace.org/Articles/connectivism.htmm

Sierpinska, A. (1994). *Understanding in mathematics.* London: The Falmer Press.

Sifuna D.N,.(2006). A review of major obstacles to women's participation in higher education in Kenya.*Res. Post-Compulsory Educ. 11(1):85-105.*

Simonson, M.R., & Thompson, A. (1997*).Educational computing foundations*. Upper Saddle River, NJ: Prentice-Hall.

Sinnes A.T. (2004). *Approaches to Gender Equity in Science Education.* Doctoral Dissertation.University of Oslo. Oslo, Norway

Siyepu, S. W. (2005). *The Use of Van Hiele Theory to explore Problems Encountered in Circle Geometry: A grade 11 Case Study*. Unpublished Master's Thesis, Rhodes University Grahamstown.

Sjögren J. (2011). *Concept Formation in Mathematics* Printed by Geson, Göteborg. SE-405 30 Göteborg Sweden also available at http://hdl.handle.net/2077/25299 visited on 12/9/2013.

Skemp, R. (1982). Communicating mathematics: surface structures and deep structure, Visible *Language, 16(3), 281–288.*

Skinner, B. N. (1974). *About Behaviourism.* New York: Knopf

Skinner, C.E.1984. *Educational Psychology fourth edition Prentice Hall of India* (Pvt.).Ltd.New Delhi India. P-529

Slavin, R. E. (2010). Instruction based on cooperative learning. In Mayer, R. E. & Alexander, P. A. (Ed.), Handbook of research on learning and instruction (pp. 344-360). New York, NY: Routledge.

Sloyer, C. W. (2003). Mathematical insight: Changing perspective. *Mathematics Teacher, 96, 238–242.*

SMASSE,(1998).*Baseline Studies Document*. An Unpublished paper presented during National INSET at KSTC, Nairobi.

SMASE, (2011).*Baseline survey report*. Nairobi: Kenya. CEMASTEA.

SMASE Project (2012).*Training Manual for NationalINSET-2012*:CEMASTEA

Smith, J.P., diSessa A. A., & Roschelle, J. (1993). Misconceptions Reconceived: A Constructivist analysis of Knowledge in Transition. *The Journal of Learning Sciences 3(2), 115- 163.*

Smith, W. C.,(2014). *The Global Expansion of the Testing Culture: National Testing Policies and the Reconstruction of Education.* Unpublished Thesis for Degree of Doctor of Philosophy in Educational Theory and Policy. The Pennsylvania State University

Snyders, M. (1995).*Geometry in Senior Secondary Class.* Proceedings of the 4th Amesa Conference (pp 5–13). Port Elizabeth: University of Port Elizabeth.

Sobel, C. P. 2001. *The cognitive sciences: An interdisciplinary approach*. Mountain View, CA: Mayfield.

Sottilare, R. & Gilbert, S. (2011). Considerations for tutoring, cognitive modeling, authoring and interaction design in serious games. Authoring Simulation and Game-based Intelligent Tutoring workshop at the Artificial Intelligence in Education Conference (AIED) 2011, Auckland, New Zealand, June 2011.

Sousa, D. A. (2008).*How the brain learns mathematics*. Thousand Oaks, CA: Corwin Press.

Spooner, M. (2002).*Errors and misconceptions in math's at key stage 2. working towards a successful SATs.* London: David Fulton Publishers.

Stacey, K., & Flynn, P. (2007).Principles to Guide Assessment with Technology. In Noraini Idris (Ed.), Classroom Assessment in Mathematics Education, pp. 1-16. Kuala Lumpur: McGraw Hill Education.

Steen L. A. (Ed.) (2001).*Mathematics and Democracy*: The Case for Quantitative Literacy. New Jersey: The Woodrow Wilson National Fellowship Foundation.

Steffe, L. P., & Wiegel, H. G. (1992).On reforming practice in mathematics education. *Educational Studies in Mathematics, 23, 445-465.*

Stein, J.K., & Bovalino, J. (2001). Manipulatives: One piece of the puzzle. Mathematics Teaching in the Middle School, 6 (6), 356–359.

Stenmark, J, (Ed.). (1991). *Mathematics assessment*: Myths, models, good questions, and practical suggestions. Reston, VA: National Council of Teachers of Mathematics.

Stigler, J.W., and Hiebert, J. (1999).*The Teaching Gap: Best Ideas from the World's Teachers for Improving Education in the Classroom.* New York: Free Press.

Stigler, J. W., & Perry, M. (1988).*Cross cultural studies of mathematics teaching and learning: Recent findings and new directions.* Reston, VA: National Council of Teachers of Mathematics.

Stoblein, M.(2009). Activity-based learning experiences in quantitative research methodology for young scholars, Retrieved September 19, 2016 from www.pomsmeetings.org/...../011-0782.pdf

Strutchens, M. E., Harris, K. A., & Martin, W. G. (2001).Assessing geometric and measurement understanding using manipulatives. Mathematics Teaching in the Middle School, 6, 402-405.

Sun, J., Anderson, R. C., Lin, T.-J., & Morris, J. (2015).*Social and cognitive development during collaborative reasoning.* Washington, DC: American Educational Research Association.

Sunzuma, G., Masocha M. & Zezekwa N. (2013). Secondary School Students' Attitudes towards Their Learning of Geometry: A Survey of Bindura Urban Secondary Schools: *Greener Journal of Educational Research. 3 (8), Pp. 402-410,*

Sutherland, R. (1993). Connecting theory and practice: Results from the teaching of Logo. *Educational Studies in Mathematics, 24, 95–113.*

Swan, M. (2005). Improving Learning in Mathematics: Challenges and Strategies (Standards Unit). Department for Education and Skills Standards Unit. University of Nottingham.

Sweller, J. (1994).Cognitive load theory, learning difficulty and instructional design. *Learning and Instruction, 4, 295–312.*

Tachie, S.A, & Chireshe (2013). High Failure Rate in Mathematics Examinations in Rural Senior Secondary Schools in Mthatha District, Eastern Cape: *Learners' Attributions Stud Tribes Tribals,11(1):67-73*

Tait, K. (2009). Understanding tertiary student learning: Are they independent thinkers or simply consumers and reactors? *International Journal of Teaching and Learning in Higher Education, 21(1), 97-207.*

Tata, U. S, Abba, A. Abdullahi M. S. (2014). The Causes of Poor Performance in Mathematics among Public Senior Secondary School Students in Azare Metropolis of Bauchi State, Nigeria. *IOSR Journal of Research & Method in Education (IOSR-JRME) e-ISSN: 2320–7388,p-ISSN: 2320–737X Volume 4, Issue 6 Ver. III.*

Telima, A., (2011). Problems of Teaching and Learning of Geometry in Secondary Schools in Rivers State, Nigeria.*Int. J. Emerg. Sci., 1(2), 143-152*

Thompson, K. M. (1993*). Geometry Students' Attitudes toward Mathematics: An Empirical Investigation of Two Specific Curricular Approaches.* Unpublished Master's Thesis, California State University Dominguez Hills, USA.

Thorpe, M. (1993).*Evaluating open and Distance learning.* Longman. Essex.

Tienken, C. H., & Maher, J. A. (2008).*The influence of computer-assisted instruction on eighth grade mathematics achievement.* Research in Middle Level Education Online, 32(3). Retrieved from http://nmsa.org

Too, K. (2007). Challenges of Teaching Mathematics in Secondary Schools in Kenya: A Case study of Nandi and Uasin Gishu Districts. The Educator, 1(2) 17-26. *Journal of the school of education, Moi University.*

Toptaş, V. (2007).Classroom Teacher's Opinions about the Skills in Elementary School Mathematics Curriculum (1-5).*Elementary Education Online, 9(1), 136-149, 2010.lkö retim Online, 9(1), 136-149, 2010*. [Online]: http://ilkogretim-online.org.tr.

Treagust, D. F. (1988). Development and use of Diagnostic Tests to Evaluate Students' Misconceptions in Science, *International Journal of Science Education, 10:2, 159-169.*

Trevisan, A. J. B. and Areas, J. A. G. (2012) Development of corn and flaxseed snacks with high-fibre content using response surface methodology (RSM). *International Journal of Food Sciences and Nutrition, 63(3), 362–367.*

Tripathi, P. N. (2008). Developing mathematical understanding through multiple representations. *Mathematics Teaching in the Middle School, 13, 438–445.*

Turan, E. (1996). *The problems of teaching biology in high schools.* Unpublished master thesis. Dokuz Eylul University, Izmir.UK: Society for Research into Higher Education and Open University Press.

Tutty, J. I., & Klein, J. D. (2008). Computer-mediated instruction: a comparison of online and face-to-face collaboration. *Educational Technology Research and Development, 56(2), 101-124.*

Udousoro, U.J.(2011). The effect of gender and mathematics ability on academic performance of students in Chemistry. *African Research Review, International Multidisciplinary Journal, Ethiopia, 5(4) 201-213.*

Uloma, O. (2011), Challenges to Effective Management and Utilization of Teaching Resources in Nigerian Schools. *ABSU Journal of Arts, Management, Education, Law and Social Sciences (Jamelss) Vol 1.( 1); 118-127.*

Umoh,C.G.(2003). A theoretical analysis of the effects of gender and family education on human resource development. Journal of Curriculum Organization of Nigeria, 10 (1),1-4.

USA(2004, September) Department of Education. No child left behind. Retrieved February 28, 2015, from http://www.ed.gov/nclb/accountability/ayp/testingforresults.html

Usiskin, Z. (2003). Current trends in school Mathematics, and the challenges they create. Paper presented at the International Conference on Science and Mathematics Education: Which Way Now? University Malaya, Kuala Lumpur.

Usiskin, Z. (2012). What does it mean to understand some mathematics? In Proceedings of the 12th International Congress on Mathematical Education. Seoul, Korea: ICME

Usman, K.O., Harbor, P. VFA (1998). Process Errors Committed by Senior Secondary Students in Mathematics. *Journal of Science, Technology and Mathematics Education,* 1(1): 34-39.

Usun, S. (2004).Undergraduate student's attitudes on the use of computers in education. Turkish Online Journal of Educational Technology.3 (2).Retrieved July 22, 2004, Fromhttp://www.tojet.sakarya.edu.tr.

Vale, C. (2009). Trends and Factors Concerning Gender and Mathematics in Australasia.Fromhttp://www.tsg.icmell.org/document/get/169.Retrieved on 15, November 2013

Van der Sandt, S. (2007). Pre-service geometry education in South Africa: A topical case? IUMPST: *The Journal, 1 (Content Knowledge), 1–9.*

Van der Walt, M. (2009). Study orientation and basic vocabulary in mathematics in primary school. *South African Journal of Science and Technology, 28, 378–392.*

Van Dijk, J. A. G. M. (2005). *The deepening divide: Inequality in the information society. (1st Ed.).*Thousand Oaks, CA: Sage Publications.

Vashist, R.P. (2007). *Secondary School Curriculum*, New Delhi: Ajay Verma Publisher.

Vicki, A. J. & Back, A. L. (2011). Teaching Communication Skills Using Role-Play: An Experience-Based Guide for Educators. *Journal of Palliative Medicine. 14( 6), 775 – 781*

Vicki, S. (2017) Mathematics Delivering the Advantage: The Role of Mathematicians in Manufacturing and Beyond. *Journal Proc Math Phys Eng Sci. 2017 May; 473(2201): 20170094 Published online 2017 May 31. doi: 10.1098/rspa.2017.0094*

Victoria State Government.(2009). *Mental computation and estimation*. Department of Education and Early Childhood Development. Retrieved from https://www.Eduweb .vic.gov.au/edulibrary/public/teachlearn/student/mathscontinuum/readmentalcompest. pdf

Vundla, B. (2012) *School curriculum*. Pretoria: North Publishers.

Vygotsky, L. (1978). *Mind in the society*. Cambridge Massachusetts Harvard University press.

Wageman, R. (1995). Interdependence and group effectiveness. *Administrative science quarterly, 40 (1), 145-180.*

Wageman, R., & Baker, G. P. (1997). Incentive and cooperation: the joint effects of task and reward interdependence on group performance. *Journal of organizational behavior, 18 (2), 139-158.*

Walklin, (1982).*Instructional Teaching Practices.* England: Stanely Thornes Publishers LTD,

Wambua.R. (2007). The Making of an Engineer: Background Characteristics of Female Engineering Students in Kenyan National Polytechnics. *Int. J. Learn. 14(2):31-39.*

Wang, P, Vaughn, B.K. & Liu, M. (2011).The impact of animation interactivity on novices' learning of introductory statistics. *Computer & Education, 56(1), 300 – 311.*

Watson, A., Jones, K. &Pratt, D. (2013) *Key Ideas in Teaching Mathematics.* Oxford: Oxford University Press.

West African Examination Council (WAEC) (2011).West African senior secondary school certificate examination May/June Chief examiner's report. WAEC: Lagos.

Wedege, T. (2011).*What does "technology" mean in educational research on workplace mathematics?* Paper submitted to TSG 5, ICME 12.

Wertsch, J. V. (1991). *Voices of mind. A sociocultural approach to mediated action*. Hemel Hempstead: Havester Wheatsheaf.

Westhoff, B. W., Bergman, D. & Carroll, J. (2010).*The effects of computer animations on high school student's performance and engagement in biology.* Proceedings of the 6th Annual GRASP Symposium, Wichita State University, 2010.

Wilcox, R. R. (2012). *Introduction to robust estimation and hypothesis testing (3rd ed.)*. San Diego, CA: Academic Press.

Wilcox,R. R. (2015). *ANCOVA: A Global Test Based on a Robust Measure of Location or Quantiles When There is Curvature*: Dept of Psychology University of Southern California

Wilen,W.W. (1992). *Questions, Questioning Techniques and Effective Teaching (3rd Ed.).* Washington, D.C.: NEA Professional Library, National Education Association.

Wilkins, J. L., & Ma, X. (2002).Predicting student growth in mathematical content knowledge. The Journal of Educational Research, 95, 288-298.

Winn, W., &D. Snyder. 1996. Cognitive perspectives in psychology. In Handbook for research for educational communications technology, ed. D. H. Jonassen, 112–42. New York: Simon and Schuster Macmillan.

Wiśniowski, W. (2009).The importance of mathematical education in today's complex society.http://www.ydp.eu/resources/the-importance-of-mathematical-education visited on 15/5/2014

Wolfe, P. (2001). *Brain Matters: Translating Research into Classroom Practice.* Virginia: Association for Supervision and Curriculum Development.

Wolfinger, D. M. & Stockard, J., W. (1997).*Elementary Methods,* New York: Longman Publishers.

World Bank.(2007). *Secondary Education in Africa, Developing Science Mathematics and ITC Education* in Sub-Saharan Africa.

Wong, K.Y (2005). Add cultural values to mathematics instruction: A Singapore initiative. In: ASIAN MATHEMATICAL CONFERENCE. Singapore. Proceedings... Singapore: National University of Singapore. Electronic publication, 2005.p.1-11. Available at: http://ww1.math.nus.edu.sg/AMC/papers-invited/Wong-KY.pdf Accessed at: 10 Aug. 2017

Worthen, B. R., & Sanders, J. R. (1989). *Educational evaluation.* New York: Longman.

Wright, B. D., & Stone, M. H. (1999).*Measurement Essentials (2nd ed.)*. Wilmington, DE: Wide Range, Inc.

Wright, K., 2008. Drug calculations part 1: a critique of the formula used by nurses. *Nursing Standard 22 (36), 40–42.*

Wurdinger, S. D., & Carlson, J. A. (2010).*Teaching for experiential learning: Five approaches that work.* Lanham, MD: Rowman & Littlefield Education.

Wyndhamn, J. R. (1997). Word Problems and Mathematical Reasoning- A study of children's Mastery of Reference and Meaning in Textual Realities. *Learning and Instruction, 7(4), pp.361-382.*

Yair, Y., Mintz, R., & Litvak, S. (2001). 3-D virtual reality in science education: An implication for astronomy teaching. *Journal of Computers in Mathematics and Science Education 20, (3), 293-301.*

Yang, D. C., Reys, R. E., & Wu, L. L. (2010). Comparing how fractions were developed in textbooks used by the 5th- and 6th-graders in Singapore, Taiwan, and the USA *School Science and Mathematics, 110(3), 118–127.*

Yisa (2014).*Effectiveness of computer animation on a progressive learning achievement of secondary school biology students in Niger State, Nigeria.* Unpublished PhD Thesis. Department of Education, FUT Minna.

Yisa, N. C., & Ojiaku, F. C. (2016).Effectiveness of computer animation on a progressive learning achievement of secondary school biology students in Niger state, Nigeria. *International journal of education and evaluation*. Vol. 2 No.4, ISSN 2489-0073.

Young, R. & Collin, A. (2003).Constructivism and social constructivism in career field, *J. Vocal Behavior, 64: 373-388*

Yount, R. (2006). *Populations and Sampling.* The Rationale of Sampling Steps in Sampling Types of Sampling Inferential Statistics: A Look Ahead the Case Study Approach

Yusha'u. M. A. (2013). Investigating and Remediating Gender Difference in Mathematics Performance among Dyslexic and Dyscalculic Learners in Sokoto State, Nigeria.*Journal of Education and Practice Vol.4, No.8,15 – 22*

Yusuf, M. O. & Afolabi. A. O. (2010). Effects of Computer Assisted Instruction (CAI) on Secondary School Students' Performance in Biology. *Turkish Online Journal of Educational Technology 9(1).*Available online at www.tojet.com

Zadshir,M., Reza, A.K, and Abolmaali, A. (2013). Investigating barriers to math performance as viewed by teachers: Emphasis on textbook content and students' performance in junior high school. *European Journal of Experimental Biology, 3(2):332-341*

Zaslavsky, C. (1994). *Africa Counts and Ethno mathematics. For the learning of the curriculum.* Chicago: Lawrence Hill Books.

Zietsman, A.I., & Hewson, P.W. (1986).Effect of instruction using microcomputer simulations and conceptual change strategies on science learning. *Journal of Research in Science Teaching, 23, 27-39.*

# APPENDICES

## APPENDIX A: MATHEMATICS ACHIEVEMENT TEST (MAT)

Gender: [Male] [Female]

**Instructions**

**Class: Form 4**

**Time: 2 Hours**

**Put a tick on your gender**

**Don't write your school, name or admission number on the question paper.**

**Answer all the questions in the spaces provided below each question.**

1. Define locus (3 marks)
2. Name and describe **three** common types of loci (3 marks)
3. Draw a line AB 4.3 cm and construct a perpendicular bisector to it. (2 marks)
4. Using a protractor construct angle ABC= $30^0$, bisect angle ABC (2 marks)
5. Describe and sketch the locus traced by the following
   a) Describe and Sketch the Loci traced by axle of a bicycle wheel as it move forward on a level ground (4 marks).
   b) The locus of points traced by a point on the rim of a bicycle wheel as it moves forward on a level road. (4 marks)
   c) The tip of the minute hand of a clock during a 45 minutes interval. (3 marks)
   d) The bob tip of a swinging pendulum as it swings. (3 marks)
   e) A ball that moves such that it is always 4 Metres from fixed straight wall. (3 marks)
6. Using a ruler and a pair of compasses construct the following angles.

   (a) $45^0$ (1marks) (c) $30^0$ (1marks)

   (b) $75^0$ (1marks) (d) $112.5^0$ (1marks)
7. A goat is tethered at the corner of a fenced squared field of length 50 metres. If the length of the rope used is 40 metres draw the locus of the goat's grazing field.

   (5 marks)

8. (a) A solid 30 cm ruler which lies on a flat surface is rotated about one of its shorter edge until it is flat on the surface again. State the loci traced by the ruler.

   (4 marks)

   (b) After defining loci and giving the common types of Loci, the mathematics teacher came to school driving and parked the car near the assembly ground. He told the student to observe the wheel tyre print. Does the print represent loci? Discuss.

(2 marks)

9. Use ruler and pair of compasses only for all constructions in this question.

(a) Construct triangle ABC such that BAC = $30^0$, AC = 8.6 cm and line AB = 12 cm. Measure BC. (3 marks)

(b) Construct a perpendicular line from A to meet BC produced at D. Measure CD.

(2 marks)

(c) Construct triangle $A^1BC$ such that the area of the triangle is two third of the area of triangle ABC and on the same side of BC as triangle ABC and (5 marks)

10. In this question use a ruler and a pair of compasses.

(a) Line PQ= 8.6cm is part of a triangle PQR. Construct the triangle PQR in which QPR = $30^o$ and line PR = 8cm. (3 marks)

(b) On the same diagram construct triangle PRS such that points S and Q are on opposite sides of PR, PS = SR and QS = 8cm. (4 marks)

(c) A point T is on a line passing through R and parallel to QS. If QTS = $90^o$, locate two possible positions of T and label them T1 and T2. Measure the length of T1 T2.

(3 marks)

11. (a) Using a ruler and a pair of compasses only, construct triangle PQR such that QR = 6cm, angle PQR = $90^0$ and angle PRQ = $60^0$. (4 marks)

(b) Measure PR (2 marks)

(c) Draw a circle using a pair of compasses only so that it passes through points P, Q and R of triangle PQR. (2 marks)

12. (a) Construct triangle ABC in which BC = 7.6 cm, ABC = $105^o$ and BAC = $45^0$ Using a ruler and a pair of compasses only. Measure AC and AB. (4 marks)

(b) Drop a perpendicular line from A to meet CB produced at P. Hence, find the area of triangle ABC. (4 marks)

13. Using ruler and compasses only, construct a parallelogram ABCD such that AB = 10cm, BC = 7cm and < ABC = $105^0$. Also construct the loci of P and Q within the parallel such that AP $\leq$ 4 cm, and BC $\leq$ 6 cm. Calculate the area within the parallelogram and outside the regions bounded by the loci. (8marks)

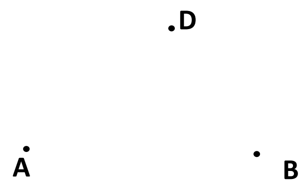
14. Use ruler and compasses only in this question. Use ruler and compasses only in this question the diagram below shows three points A, B and D

(a) Construct the angle bisector of acute angle BAD (1 mark)

(b) A point P, on the same side of AB and D, moves in such a way that < APB = 22½$^0$ construct the locus of P (6 marks)

(c) The locus of P meets the angle bisector of < BAD at C measure < ABC

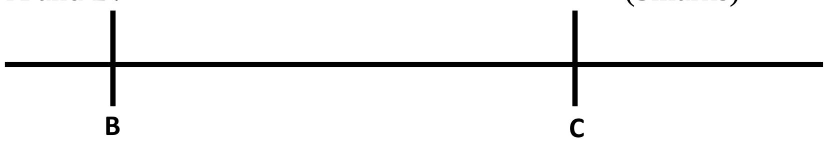
Hence find area of the image $A^1 B^1 C^1$ (3 marks)




15. The line segment BC given is one side of triangle ABC

(a) Use a ruler and compasses to complete the construction of a triangle ABC in Which angle ABC = 45$^0$, AC = 5.6 cm and angle BAC is obtuse measure angle BAC and AB (2 marks)

(b) Draw the locus of point P such that P is 3.1 cm from a point C and equidistant from A and B. (3marks)



**APPENDIX B: MARKING SCHEME OF MATHEMATICS ACHIEVEMENT TEST (MAT)**

**Answer all the questions in the spaces provided below each question.**

1. Define locus (3 marks)
   - As a line traced by a point $B_1$
   - As an area or a region traced by a line $B_1$
   - As volume traced by an area or region $B_1$

2. Name and describe **three** common types of loci (6 marks)

(i) Perpendicular bisector loci $B_1$

– Bisects a line perpendicularly $B_1$

(ii) Locus of points equidistant from a fix straight line $B_1$

– Parallel lines $B_1$

(iii) Locus of points equidistant from a fixed point – $B_1$

– Circle $B_1$

Or *accept any other common type of Loci*

(i) Locus of points equidistant from two intersecting line

– Angle bisector locus

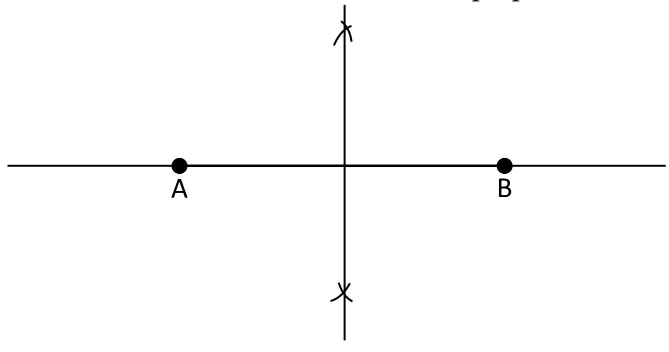
(ii) Constant angle loci

(iii) Locus involving inequalities

(iv) Intersecting loci

(v) Locus involving chords

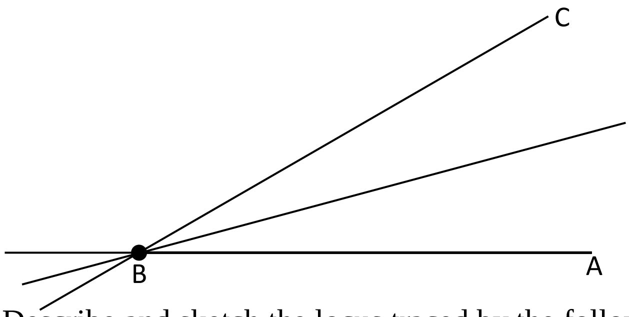
3. Draw a line AB 4.3 cm and construct a perpendicular bisector to it. (2 marks)




$B_1$ – 2 arcs drawn correctly

$B_1$ – perpendicular bisector

4. Using a protractor construct angle ABC= $30^0$, bisect angle ABC (2 marks)




$B_1$ – Angle $30^0$ constructed

$B_1$ – angle $15^0$ correctly done

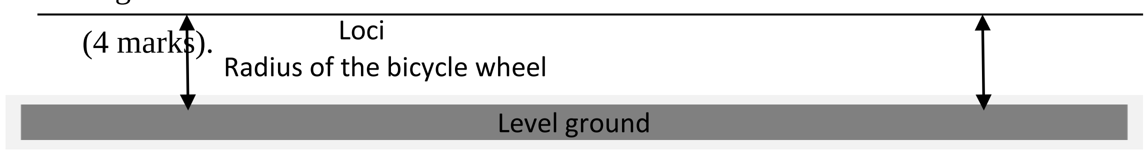
<u>Note</u>

Use a tracing paper for accuracy

5. Describe and sketch the locus traced by the following

a. Describe and Sketch the Loci traced by axle of a bicycle wheel as it move forward on a level ground

(4 marks).



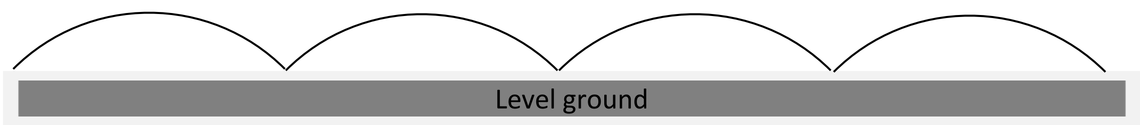

$B_1$ – loci represent a line

$B_1$ – description loci represent a line parallel to the level ground.

$B_1$ – if the radius of the bicycle wheel is given as the distance between the loci and the level ground

$B_1$ – if the diagram is completely labeled.

b. The locus of points traced by a point on the rim of a bicycle wheel as it moves forward on a level road. (3 marks)



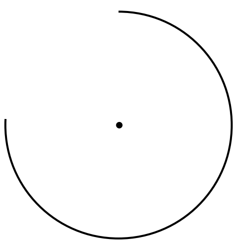

$B_1$– loci represent

$B_1$ - if the description as arcs is given.

$B_2$ – at least one more arc- using a pair of compass

$B_1$ – if one arc drawn and or at least one arc draw but using a free hand

b. The tip of the minute hand of a clock during a 45 minutes interval. (3 marks)

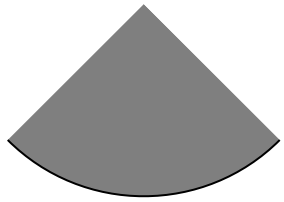


$B_1$ – an arc

$B_1$ – three quarter arc

$B_1$ – sketch correctly drawn

c. The bob arm of a swinging pendulum as it swings. (3 marks)

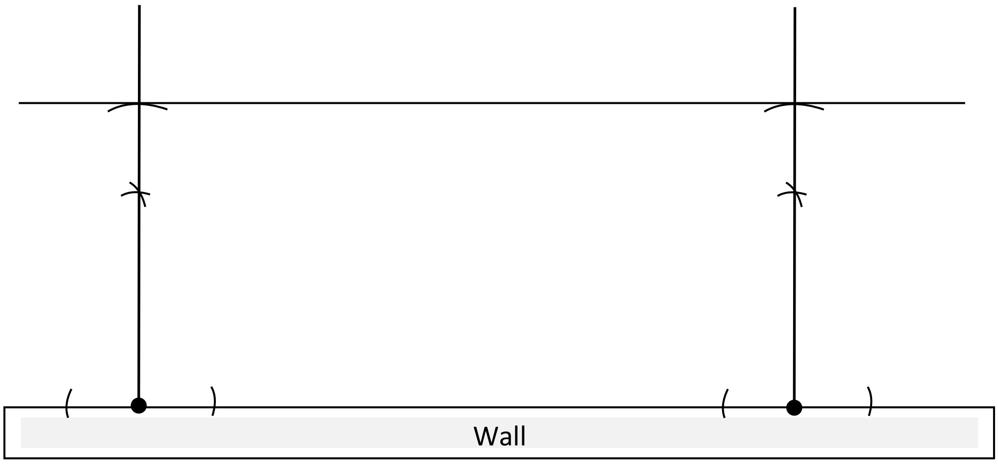


$B_1$ – a sector

$B_2$ – sketch correctly drawn – using a pair of compass

*Give $B_1$ – if sketched using free hand.*

d. A ball that moves such that it is always 4 Metres from fixed straight wall. (3 marks)




1cm to represent 1m

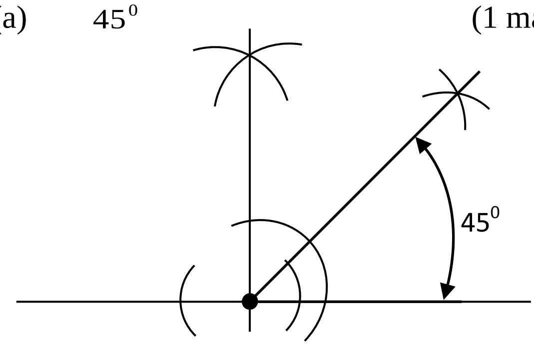
$B_1$ – ball move parallel to the wall and always 4m from the wall

$B_1$ – wall shown

$B_1$ – 2 perpendiculars to the wall drawn or any valid method of drawing parallel lines

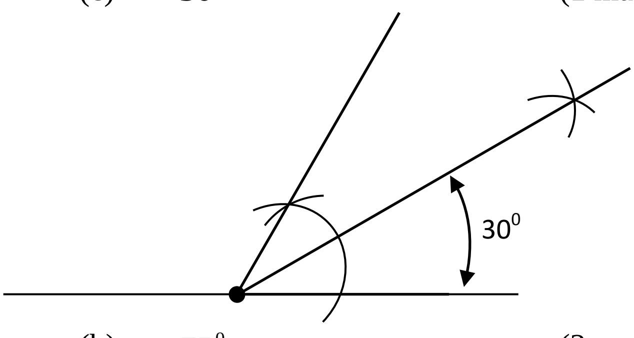
6. Using a ruler and a pair of compasses construct the following angles.

(a) $45^0$ (1 marks)



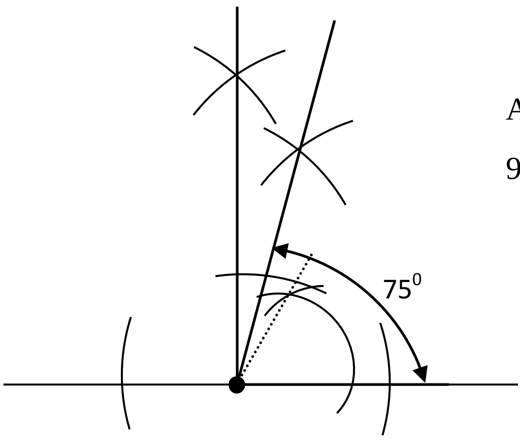

$B_1$ - $45^0$

(c) $30^0$ (1 marks)




$B_1$ - $30^0$

(b) $75^0$ (2 marks)



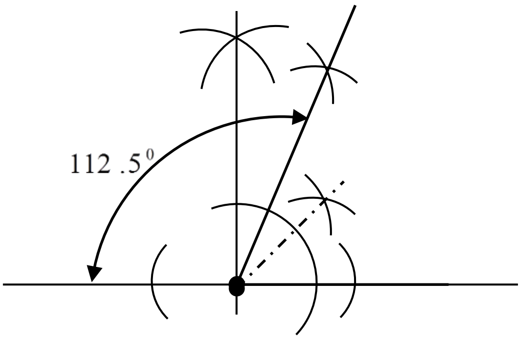

$B_1$ - $90^0$& $60^0$

$B_1$ – $15^0$& $75^0$

Accept other equivalent

90, 45 60, 30, 75

(d) $112.5^0$ (2 marks)



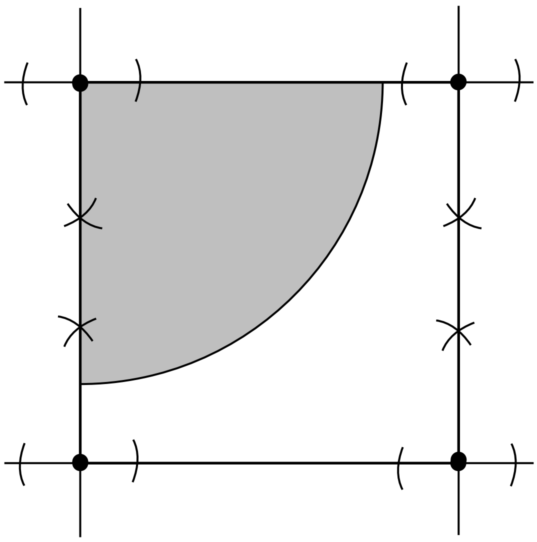

$B_1$ - $90^0$& $45^0$

$B_1$ – $22.5^0$& $112.5^0$

Accept other equivalent

$90^0$, $60^0$, $30^0$, $15^0$, $7.5^0$

7. A goat is tethered at the corner of a fenced squared field of length 50 metres. If the length of the rope used is 40 metres draw the locus of the goat's grazing field. (5 marks)



$B_1$ –Scale 1 cm rep 10 m

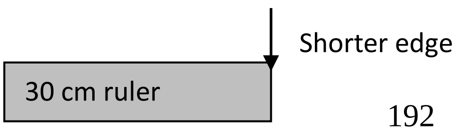
$B_1$ – perpendicular lines

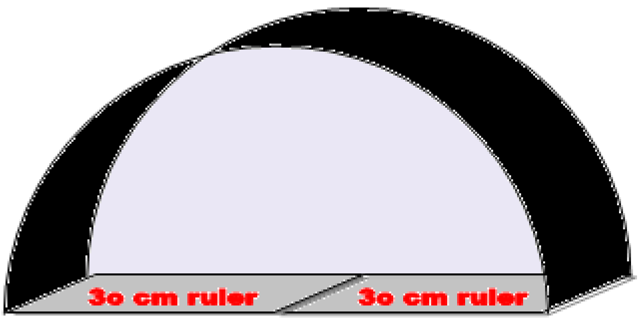
$B_1$ – square correctly drawn

$B_1$ – sector

$B_1$ – correct grazing field

8. (a) A solid 30 cm ruler which lies on a flat surface is rotated about one of its shorter edge until it is flat on the surface again. State the loci traced by the ruler. (4 marks)






$B_1$ – correctly identifying shorter edge

$B_1$ – semi cylinder

$B_2$ –diagram correctly drawn showing diameter as 60 cm

(b) The print is not Loci, note the tyre is not tracing but printing $B_1B_1$

9. Use ruler and pair of compasses only for all constructions in this question.

(a) Construct triangle ABC such that BAC = $30^o$, AC = 8.6 cm and line AB = 12 cm. Measure BC. (3 marks)

(b) Construct a perpendicular line from A to meet BC produced at D. Measure CD.

(2 marks)

(c) Construct triangle such that the area of triangle is two third of the area of triangle ABC and on the same side of BC as triangle ABC and find its area (5 marks)

(a) $B_1$ – construction of $30^0$

$B_1$ – construction of triangle

$B_1$ – BC = 6.2±0.1 cm

(b) $B_1$– Construction of a perpendicular

$B_1$ CD =2.4±0.1 cm

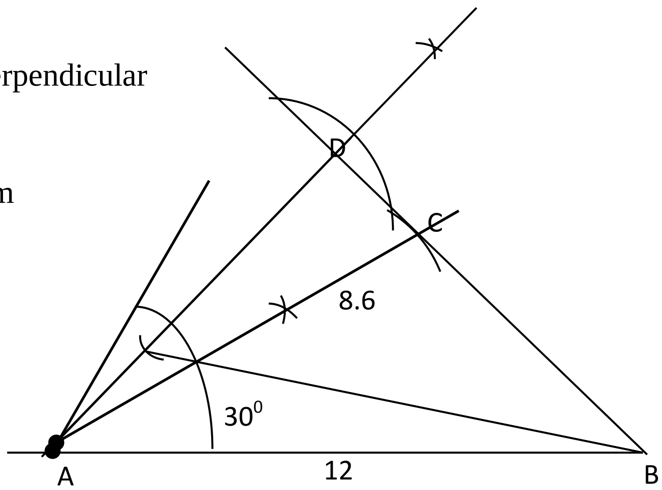
(c) $B_1$ AD = 8.4 ±0.1 cm

$B_1$= $\frac{2}{3} \times 8.4 = 5.6\ cm$

$B_1$ – the triangle

A = $\frac{1}{2} \times 8.6 \times 5.6$ $M_1$

= 24.08 $cm^2$ $A_1$



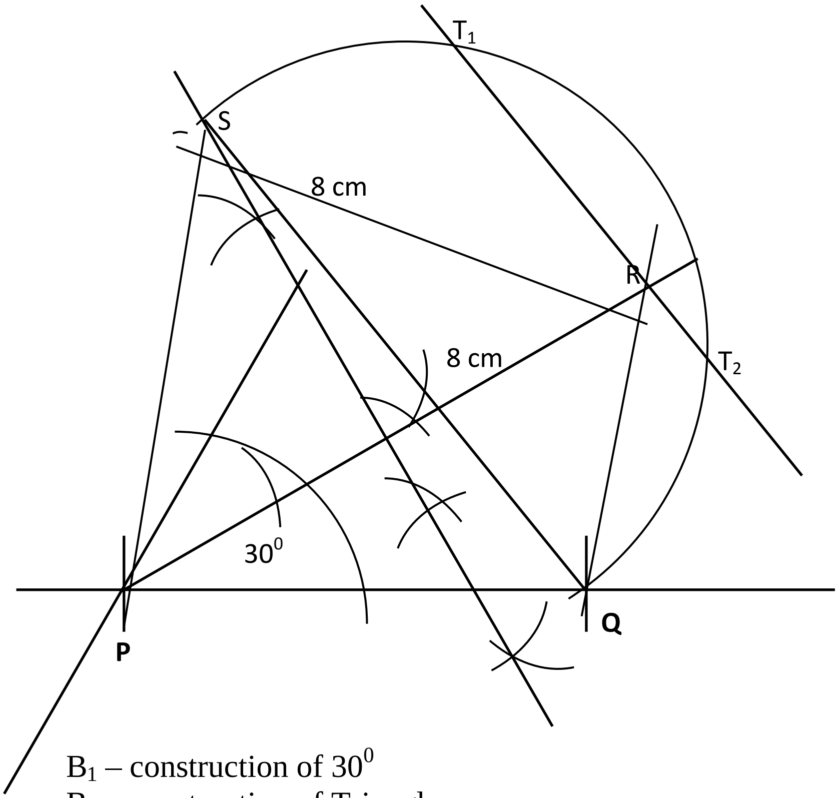

*Accept equivalent answers from other accepted measurements*

10. In this question use a ruler and a pair of compasses.

(a) Line PQ drawn below is part of a triangle PQR. Construct the triangle PQR in which QPR = $30^o$ and line PR = 8cm. Measure RQ (3 marks)

(b) On the same diagram construct triangle PRS such that points S and Q are on opposite sides of PR, PS = SR and QS = 8cm. (4 marks)

(c) A point T is on a line passing through R and parallel to QS. If QTS = $90^o$, locate two possible positions of T and label them T1 and T2. Measure the length of T1 T2. (3 marks)

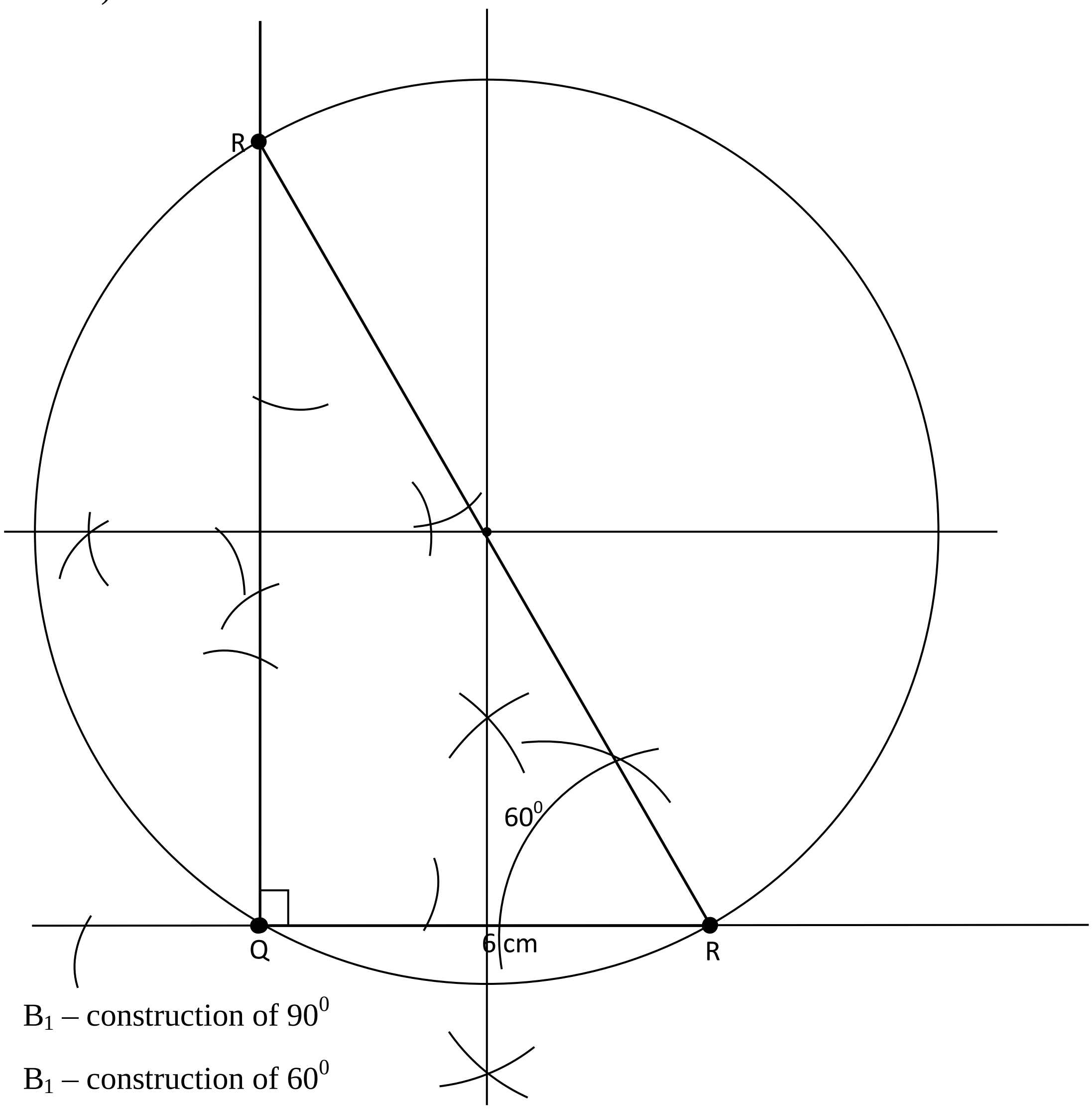



$B_1$ – construction of $30^0$
$B_1$ – construction of Triangle
$B_1$ – RQ = 4.1 ±0.1 cm
$B_1$– perpendicular bisector of PR
$B_1$ – locating point S
$B_1$ – line QS
$B_1$ – triangle PRS
$B_1$ – parallel line through R
$B_1$ – semi circle
$B_1$ – $T_1T_2$ = 4.1 ±0.1 cm

11. (a) Using a ruler and a pair of compasses only, construct triangle PQR such that QR = 6cm, angle PQR = $90^0$ and angle PRQ = $60^0$. (3 marks)

(b) Measure PR (1 marks)

(c) Draw a circle using a pair of compasses only so that it passes through points P, Q and R of triangle PQR. Measure the radii of the circle (4 marks)




$B_1$ – construction of $90^0$

$B_1$ – construction of $60^0$

$B_1$ – triangle PQR

$B_1$ – PR = 12±0.1 cm

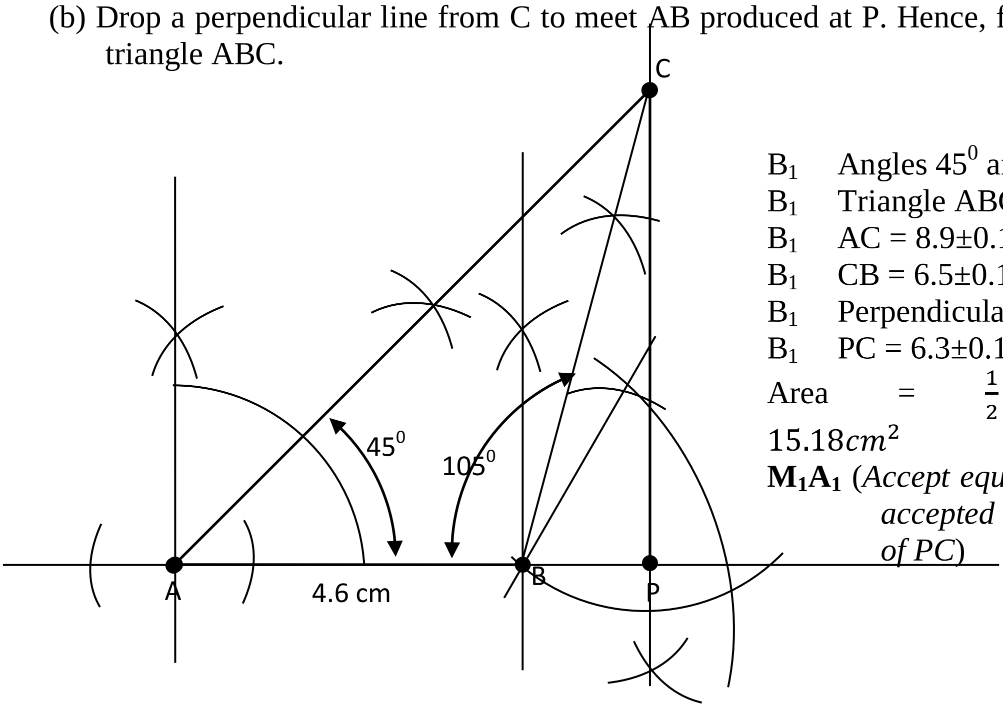
$B_2$ – At least 2 perpendicular bisectors.Give $B_1$ if perpendicular bisector is one

$B_1$ – circle

$B_1$ – radius = 6 ±0.1 cm

12. (a) Construct triangle ABC in which BA = 4.6 cm, ABC = 105$^o$ and BAC = 45$^o$ Using a ruler and a pair of compasses only. Measure AC and CB. (4 marks)

(b) Drop a perpendicular line from C to meet AB produced at P. Hence, find the area of triangle ABC. (4 marks)




B$_1$ Angles 45$^0$ and 105$^0$

B$_1$ Triangle ABC

B$_1$ AC = 8.9±0.1 cm

B$_1$ CB = 6.5±0.1 cm

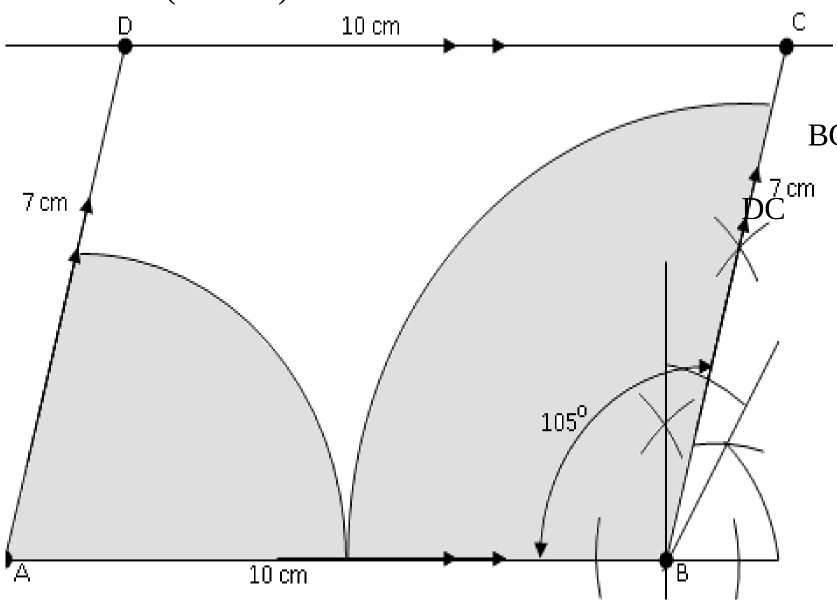
B$_1$ Perpendicular

B$_1$ PC = 6.3±0.1 cm

Area = $\frac{1}{2} \times 4.6 \times 6.3 = 15.18cm^2$

**M$_1$A$_1$** (*Accept equivalent answer accepted measurement of PC*)

13. Using ruler and compasses only, construct a parallelogram ABCD such that AB = 10cm, BC = 7cm and < ABC = 105$^0$. Also construct the loci of P and Q within the parallel such that AP ≤ 4 cm, and BQ ≤ 6 cm. Calculate the area within the parallelogram and outside the regions bounded by the loci.
(8 marks)




B$_1$ 105$^0$-construction

B$_1$ Parallel line AD & BC

B$_1$ Parallel line AB & DC

B$_1$ both locus P and Q

Area of parallelogram

$=10 \times 7\sin(105)$ M$_1$

$= 67.6148\ cm2$ A$_1$

Area of sectors $\frac{75}{360} \times 3.142 \times 4^2 + \frac{105}{360} \times 3.142 \times 6^2$ = 10.4733 + 32.991 = 43.4643 M$_1$

Area = 67.6148 – 43.4643 = 24.1505 $cm^2$ $A_1$

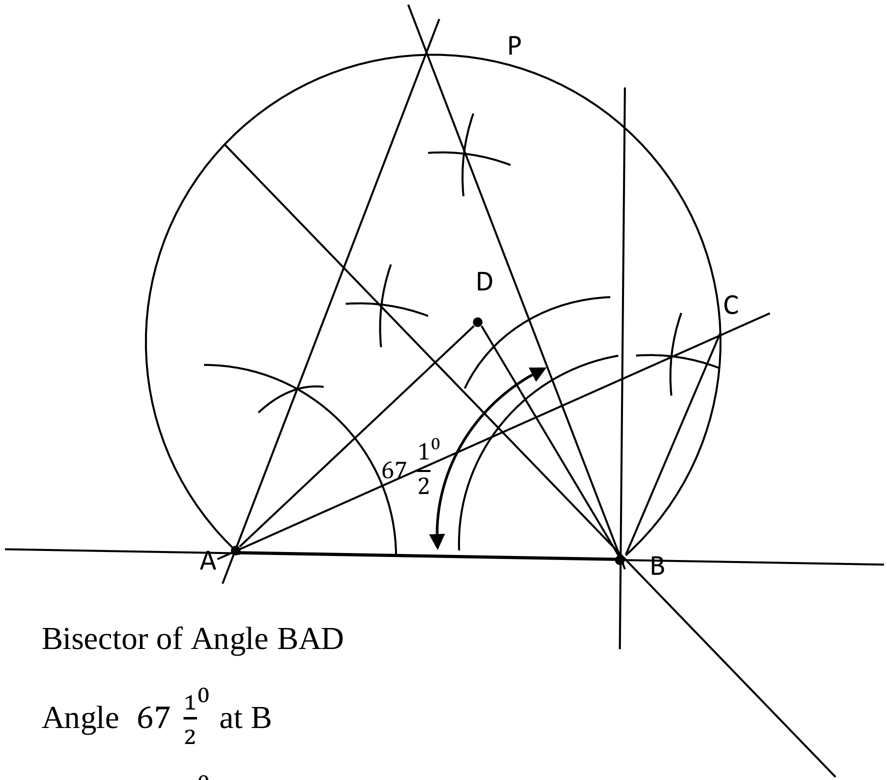
14. Use ruler and compasses only in this question the diagram below shows three points A, B and D

(a) Construct the angle bisector of acute angle BAD (1 mark)

(b) A point P, on the same side of AB and D, moves in such a way that < APB = 22½$^0$ construct the locus of P (5 marks)

(c) The locus of P meets the angle bisector of < BAD at C measure < ABC

Hence find area of ABC to (2sf) (4 marks)




$B_1$ Bisector of Angle BAD

$B_1$ Angle $67\ \frac{1}{2}^0$ at B

$B_1$ Angle $67\ \frac{1}{2}^0$ at A

$B_1$ locating the centre of the loci

$B_1$ correct arc

$B_1$ Loci

$B_1$ Angle ABC =112±1$^0$

Area = $\frac{1}{2} \times 3.3\ \times 5\ \times \sin(112)$ $M_1$

= 7.6493 $M_1$ (accept other area with accepted angles and measurements)

=7.6 $A_1$

15. The line segment BC given below is one side of triangle ABC

(a) Use a ruler and compasses to complete the construction of a triangle ABC in Which angle ACB = $45^0$, AC = 5.6 cm and angle BAC is obtuse. Measure angle BAC and AB
(2 marks)

(b) Draw the locus of point P such that P is 3.1 cm from a point C and equidistant from A and B. (3marks)

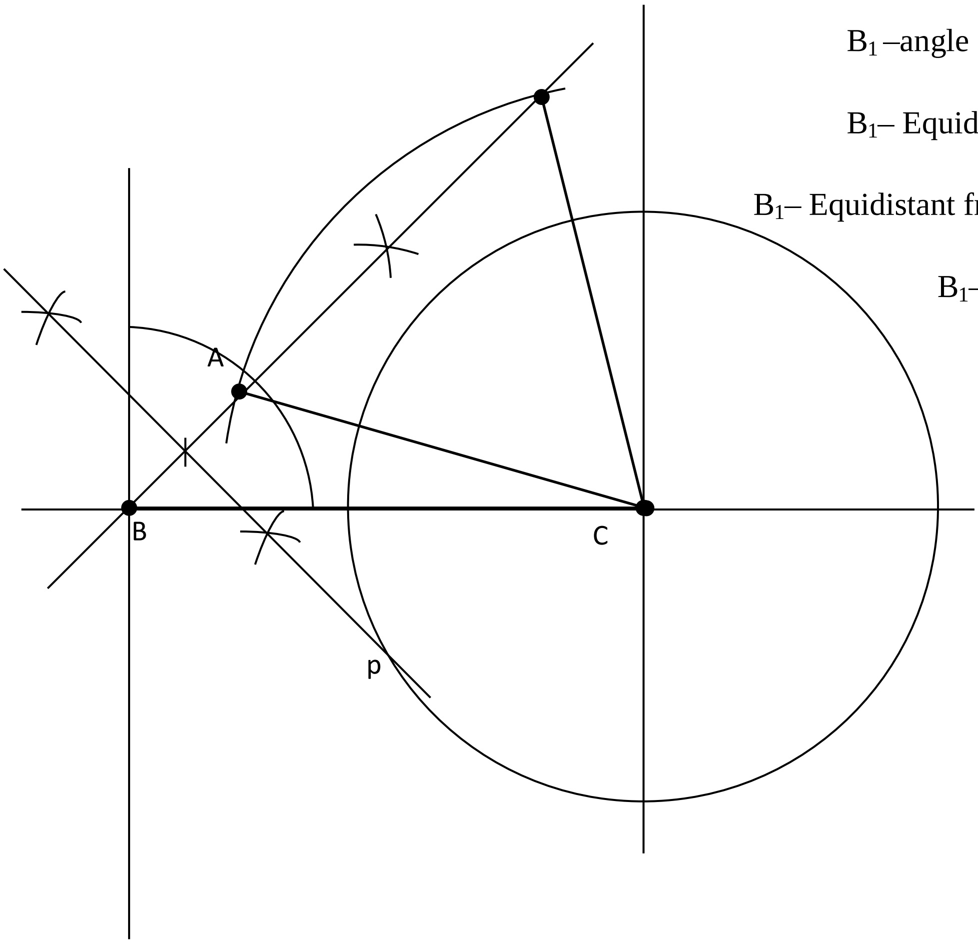
$B_1$– AB = 5.5±0.1 cm

$B_1$ –angle BAC = $120 \pm 1^0$

$B_1$– Equidistant from C

$B_1$– Equidistant from A & B

$B_1$– locating P



**APPENDIX C: TEACHING MODULE FOR LOCI- TOPIC IN FORM 4 CLASS**

The module helped the mathematics teachers to understand and adopt Computer Animated Loci Teaching Technique in teaching and learning of loci. It provided sequential order in which the lessons was presented, the specific objectives achieved in each lesson, the teaching and learning activities and the instructional approach used in each lesson. The following Specific objectives of teaching Loci were to be achieved by the Form Fourstudents at end of the topic: define loci.(in two and three dimensions ), give some of the examples of common types of loci, construct various common types of loci, apply loci to solve real-life problems (KIE, 2002; Kibui & Macrae, 2005; Kinyua *et al*, 2005; MOE, 2006 ; KNEC, 2010)

**References**


Kibui, P. and Macrae, M.F. (2005). *Explore Mathematics*, Nairobi: Longman Kenya,.

KIE, (2005).*Secondary Mathematics Students Book Four*, Nairobi: KLB.

Patel, N.M. & Patel, G.A. (2005).*Mathematics for Kenya School, Nairobi:* Malimupublication.


| LESSON Number & Time | TOPICS | SUBTOPICS | SPECIFIC OBJECTIVES | METHODOLOGY TEACHING / LEARNING ACTIVITIES | LEARNING / TEACHING RESOURCES & REFERENCE FOR TEACHING LOCI |
|---|---|---|---|---|---|
| 1-2<br><br>80 Min. | | Review of form one constructions. | The students should be able to:<br>i) Construct angles using:<br>• A protractor<br>• A ruler and a pair of compasses only | A work sheet is provided with teacher made examples for students to do the constructions.<br>The teacher supervises the practice and demonstrates the concepts on the chalk board after students have attempted. | ➢ Chalk board geometrical set,<br>➢ Each student should have a full geometrical set.<br>➢ one work sheet of |

| | | | | | |
|---|---|---|---|---|---|
| | | | ii) bisect angles using<br>• A protractor<br>• A ruler and a pair of compasses only<br>iii)construct parallel and perpendicular lines using:<br>• A set square and a ruler<br>• Angle transfer.<br>v). Construction of polygons | | problems on basic construction<br>Kibui and Macrae (2005) pg 38-40<br>Patel and Patel (2005) pg 71-72 |
| 3<br><br>80 Min. | LOCI | Introduction<br>Loci definition | The students should be able to:<br>(1) Define Loci in<br>➢ Two dimension.<br>➢ Three dimension. | • The students are asked to define loci.<br>• The teacher gives the three demonstration of the definition of loci.<br>• The students are asked to construct the three definitions of loci.<br>• The students to present their definitions to class for discussion. | i) Point<br>ii) Line<br>iii) Area<br>iv) Classroom door<br>KIE (2005), pg 66-67 |
| 4-5<br><br>80min | | Demonstrating loci in the real-life situation. | The students should be able to:<br>i) Give past experirences on the knowledge of object modelled from day to day life.<br><br>ii) State and sketch the Locus of given cases. | i) The student are asked to draw a sketch of the following objects<br>• Wall clock • Sea-saw<br>• Bicycle<br>➢ Axle and Nozzle<br>• Solid set square<br>• Solid protractor<br>ii) The students are asked first state and sketch the loci.<br>iii) Six students are choosen to present their findings to others for discussion before the teacher demonstrate the loci. | ➢wall clock with its minute hand and tip<br>➢ Model wheel Bicycle<br>➢ A Sea saw with both the tip and arm of sea-saw<br><br>KIE (2005), pg 67-68<br>Patel and Patel (2005) pg 73-74. |

| | | | | | |
|---|---|---|---|---|---|
| | | | | iv) The teacher demonstrates some of the concept by use of computer graphics.<br>v) Some students chosen at random are asked to demonstrate other concepts not demonstrated by the teacher.<br>Home work Kibui and Macrae (2005) Ex 3c No. 6, 8 & 11 | |
| 6<br><br>40 Min | | Common types of Loci.<br>(a) Perpendicular bisector locus.<br>(b) Locus of points at a given distance from a given straight line. | The students should be able to:<br>i) Describe the type of locus.<br>ii) Construct the locus. | The student are asked to draw a sketch of the common types of loci<br>The teacher demonstrate the loci using Loci simulations and animations,<br>The student to draw the loci after the demonstration. | Use of computer simulations and animations to demonstrate the loci<br>Kibui and Macrae(2005) pg 41-42<br>Patel and Patel (2005) pg 71-72<br>KIE (2005), pg 68-70 |
| 7<br><br>40 Min | | (c) Locus of point at a given distance from a fixed point<br>(d) Angle bisector locus<br>(e) Constant angle loci | The students should be able to:<br>i) Describe the type of locus.<br>ii) Construct the locus. | The student are asked to draw a sketch of the two common types of loci<br>The teacher demonstrate the loci using Loci simulations and animations,<br>The student to draw the loci after the demonstration. | Use of Computer Simulations And Animations demonstrate the loci<br>Kibui and Macrae (2005) pg 41-42<br>Patel and Patel (2005) pg 74-76<br>KIE (2005), pg 70-72 |
| 1& 2<br><br>80 Min | | (f) Loci of inequalities representing region | The students should be able to:<br>(i) Describe the type of locus. | The student are asked to draw a sketch of the two common types of loci<br>The teacher demonstrate the loci using Loci simulations and animations,, | Use of computer simulations and animations to demonstrate the loci |

| | | | | | |
|---|---|---|---|---|---|
| | | (g)Locus involving chord. | (ii) Construct the locus. | The student to draw the loci after the demonstration. | Kibui and Macrae (2005) pg 43-44<br>Patel and Patel (2005) pg 82-87<br>KIE (2005), pg 72-84 |
| 3<br><br>40 Min | | Intersecting loci<br>i) Circumscribed circle | The students should be able to:<br>i) Construct circumscribed circle | ➢ Use of 4 teacher made examples<br>➢ Supervised practice KIE (2005) EX.3.3 No. 3.<br>KIE (2005) Homework EX. 3.5 No 4, 5, and 8. | Chalkboard geometrical set.<br>Patel and Patel (2005) pg 80 Kibui and Macrae (2005) pg 50 |
| 4 & 5<br><br>40 Min | | ii) Inscribed circle<br>iii) Escribed circle | The students should be able to:<br>i) Construct Inscribed<br>i) circle Construct escribed | ➢ Use of 4 teacher made examples<br>➢ Supervised practice KIE (2005) EX.3.5 No. 3 and 7.<br>Kibui and Macrae (2005) Homework EX. 3e, No. 18 | Chalkboard geometrical set.<br>Patel and Patel (2005) pg 81 Kibui and Macrae (2005) pg 51 |
| 6 & 7<br><br>40 Min | | Application of loci to real-life situations | The students should be able to:<br>i) Apply loci to real-life situation. | The students a given 3 teacher made examples on application of real-life situations to loci. | Chalkboard geometrical set.<br>Patel and Patel (2005) pg 81 Kibui and Macrae (2005) pg 51 |
| 1 & 2<br>40 Min | | Application of loci to real-life situations | The students should be able to:<br>i) Apply loci to real-life situation. | The students a given 3 teacher made examples on application of real-life situations to loci | Chalkboard geometrical set.<br>Patel and Patel (2005) pg 81 Kibui and Macrae (2005) pg 51 |
| 3 & 4<br>40 Min | | KCSE sampled questions | The students should be able to:<br>Solve KCSE sampled questions | students attempt sampled KCSE questions as the teacher marks | Past KCSE questions 1989 to 2009 |
| 5 - 7<br>120 min | | MAT | The students should be able to Solve problems from loci. | A twenty two question MATL is administered | K.I.E (2005) pages 94 to117. |

## APPENDIX D: TEACHERS' TRAINING MANUAL FOR LOCI TOPIC

### Aim of the manual.

The purpose of the teachers' guide was to help the teacher to plan and organize the implementation of teaching and learning programme based on the use of Computer Animated Loci Teaching Technique to teach the topic loci in Form Four. The training manual reduced variability among teachers when teaching the topic loci. Loci is a topic that is sometimes labeled as difficult by many pupils (Kinyua *et al*. 2005). Computer Animated Loci Teaching Technique are loci concepts designs constructed by the researcher, for teaching and demonstrating the concepts of Loci. (See appendix E). The designs are supposed to provide concrete link to abstract concepts in loci. Each design was made such that it can be used to explain at least a concept in the entire loci topic. According to Walklin (1982), before using any teaching aid, the teacher must be fully conversant with its operation and application. Mathematics teachers in the experimental schools were trained on the use of Computer Animated Loci Teaching Technique for five days before teaching the topic for three weeks (21 lessons).

### Instructional objectives

Instructional objectives specify exactly what is supposed to be learned. They are helpful to the teachers as well as the learner throughout the learning process and are invaluable in the evaluation process (Gronlund, 2004). Instructional objectives are often classified according to the kind of learning that is required in order to reach the students. The taxonomy of educational objectives divides objectives into three categories cognitive, affective, and psychomotor.

### Cognitive domain

Bloom categorises cognitive objectives into various levels from the simplest cognitive tasks to the most complex cognitive task. The following are the levels in order of hierarchy of learning demands:

i). Knowledge involves recall data or information.

ii). Comprehension test ones understanding of meaning, translation, interpolation, and interpretation of instructions and problems. State a problem in one's own words.

iii). Application is using a concept in a new situation or unprompted use of an abstraction; applies what was learned in the classroom into novel situations in the work place.

iv). Analysis is to separates material or concepts into component parts so that its organisational structure may be understood. Distinguishes between facts and inferences.

v). Synthesis involves building of a structure or pattern from diverse elements. Put parts together to form a whole, with emphasis on creating a new meaning or structure.

vi). Evaluation is making judgments about the value of ideas or materials (Anderson, and Krathwohl, 2001)

**Affective domain**

Affective objectives focus on emotions. Whenever a person seeks to learn to react in an appropriate way emotionally, there is some thinking going on. The affective objectives are subdivided into the following levels:

(i) Receiving – the objectives uses the words such as choose, listen.

(ii) Responding - the objectives uses the words such as Discuss, Report.

(iii) Valuing - the objectives uses the words such as Accept, Argue about it, Complete.

(iv) Organization - the objectives uses the words such as Organize, Relate, and Modify.

(v) Characterization by value - the objectives uses the words such as Propose, Oppose, and Verify (Maag, 2004).

**Psychomotor domain**

Psychomotor objectives focus on the body and the goal of these objectives is the control or manipulation. Computer Designs Animated Loci has several activities that need to be manipulation. All skills requiring fine or gross motor coordination fall into the psychomotor category. Objectives in this domain are grouped into 6 classes;

(i) Reflex Action.

(ii) Perception abilities-interprets various stimulus.

(iii) Physical abilities- physical strength and stamina required for sustained effort.

(iv) Skilled movements- refer to efficiency and skills in performing complex tasks e.g. swimming, driving.

(v) Non- discursive communication- communication without producing sound (gesture, facial expression).

(vi) Basic fundamental movement- these are walking, gripping, finger manipulation (Maag, 2004).

The purpose of a learning objective is to communicate the desired learning outcome. Therefore, a well-constructed learning objective should leave little room for doubt about what is intended. The learning objective describes an intended learning outcome and contains three parts, each of which alone means nothing, but when combined into a sentence or two, communicates the conditions under which the behaviour is performed, a verb that defines the behaviour itself, and the degree (criteria) to which a student must perform the behaviour. If any one of these three components is missing, the objective cannot communicate accurately. Thus an instructional objective is specific, measureable, achievable, and realistic and time bound (SMART). By the end of the topic the learner should be able to: define loci, describe common types of loci, and construct loci involving points under given conditions, inequalities, chords and intersecting loci. They should also solve real-life situation questions involving loci under given conditions.

**APPENDIX E: SCRIPT ON COMPUTER ANIMATED LOCI TEACHING TECHNIQUE**

1. **Prerequisite Knowledge:**

    a) Perpendicular line: -animations of lines that are intersecting:

    At a glance the students to identify lines that are perpendicular and give reasons for their solutions.

    b) Perpendicular bisector of lines: students to differentiate between Perpendicular line and Perpendicular bisector

    From the Pairs of lines provided in PowerPoint students to differentiate the between Perpendicular line and Perpendicular bisector

    c) Parallel line: -animations of lines that are in pairs :

    At a glance the students to identify lines that are parallel and give reasons for their solutions.

    d) Angle Bisectors: - student to define angle bisector from previous experiences.

    e) Construction of angles using a ruler and a pair of compasses

    - A video demonstration of angle bisector of:

    ► $60^0$ ► $30^0$ ► $45^0$ ► $37.5^0$

    Is provided to provoke students thinking and give directions on key concept that are required.

    f) Students are then required to do the following constructions using a ruler and a pair of compasses only.

    ► $15^0$ ► $75^0$ ► $52.5^0$ ► $112.5^0$

    g) Draw a sketch of the following plane figures and give their geometrical properties.

    ► Triangle ► Square ► Rectangle

    ► Circle ► Trapezium ► Rhombus

**Definition of Loci: Loci as a Path**

a) Students are provided with animated paths/road from real-life situations in PowerPoint.

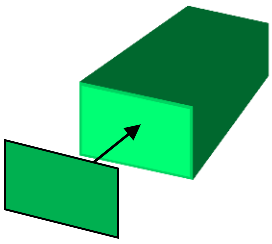


b) After completion of a) above: Geogebra integrated

The students are presented through PowerPoint Geogebra animations of various paths that are traced by:

- Line
- Lines.

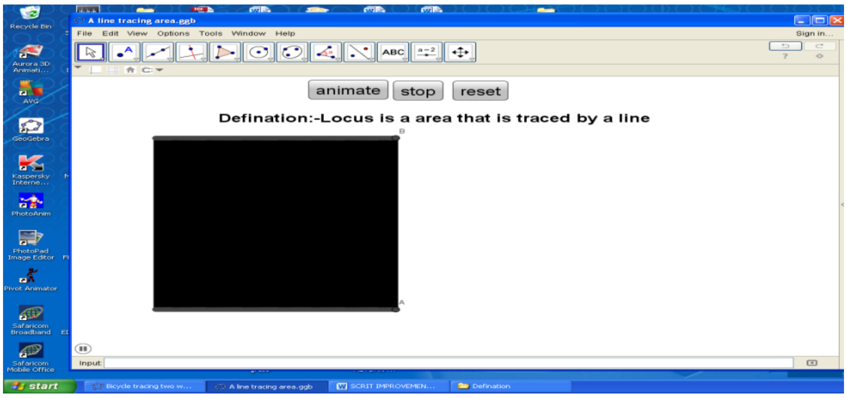

- Area.



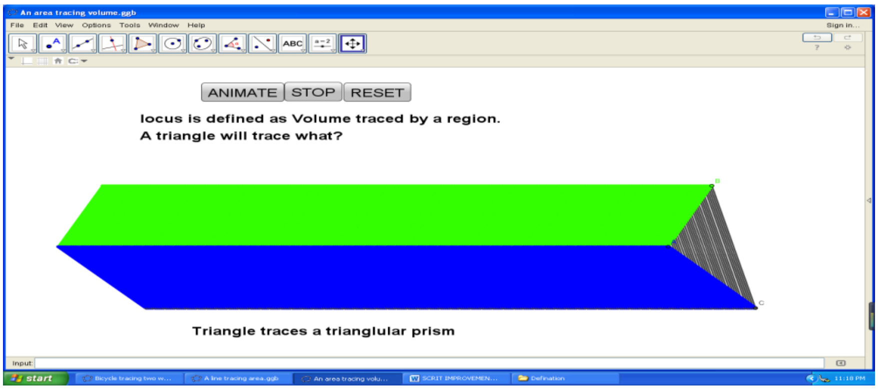
c) Construction of the definition of Loci:

- Is a line traced by a point
- An area traced by a line
- Volume traced by an area or a region

**Expected outcome**




**A line tracing region**




**A region tracing volume.**

## 2. Demonstration Activities Involving Loci From Day to Day Experiences

A. Wall clock

❖ Identify the following parts of a wall clock,

- Hour hand
- Minute hand
- Second hand
- Tips of the minute hand
- Arm of a minute hand

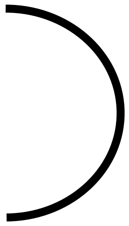
a) Describe and Sketch the Loci traced by the tip of the minute hand of a wall clock in 30minutes intervals.

❖ The students are given some times to think and put their solutions in writing after being shown a wall clock and the tip correctly identified.

(i). The students are presented with Geogebra animated minute hand as its tip traces locus in 30 minutes interval.

- ❖ The students are given some times to think and put their solutions in writing after the animations of a minute hand tip.

(ii). The expected results



The locus traced is a semi-circle

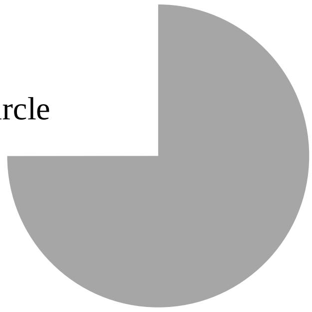
b) Describe and Sketch the Loci traced by the arm of the minute hand in $45^0$ intervals.

- ❖ The students are given some times to think and put their solutions in writing after being shown a wall clock and the minute hand arm correctly identified.

i. The students are presented with Geogebra animated minute hand as its arm traces locus in 45 minutes interval.

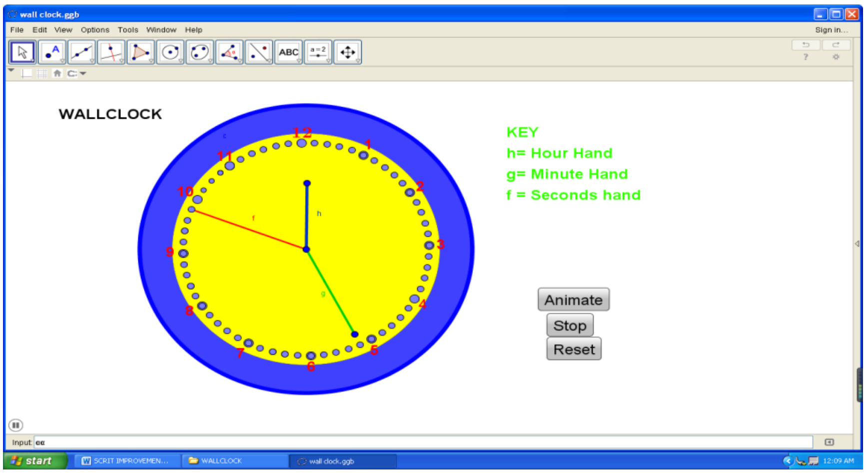
- ❖ The students are given some times to think and put their solutions in writing after the animations of a minute hand tip.

ii. The expected results

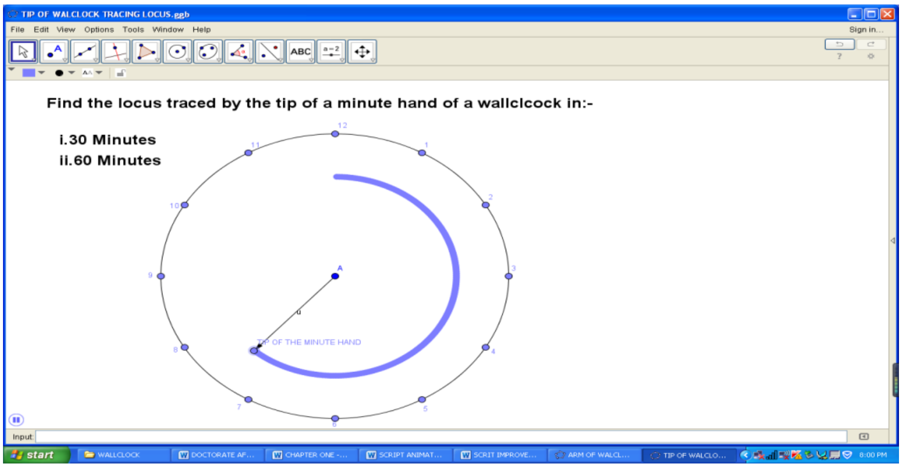


The locus traced is a three quarter sector of a circle

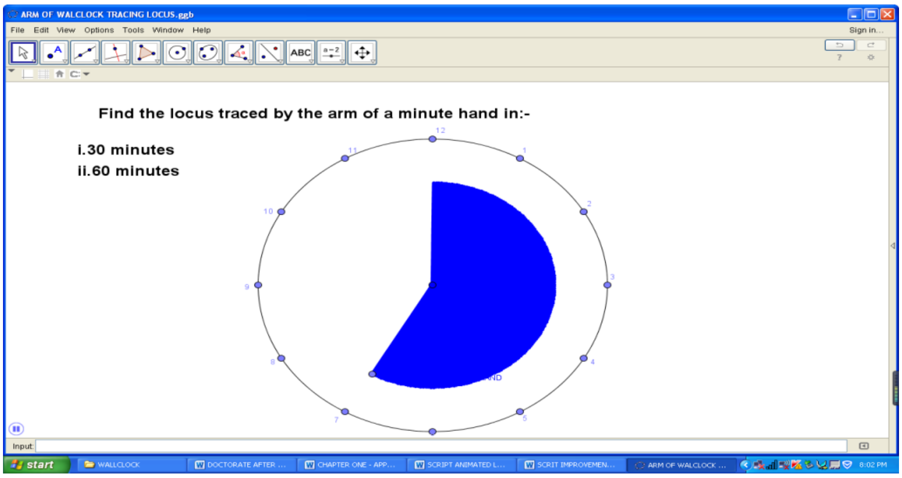
## Expected results




## Geogebra Animated wallclock

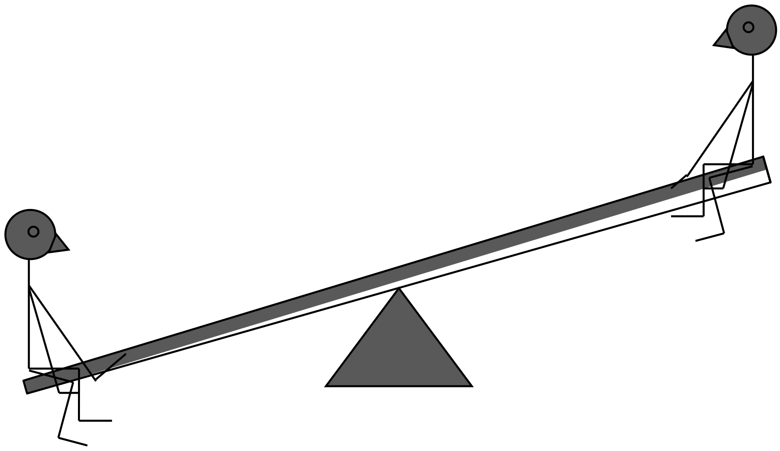



## Tip of a Wallclock Tracing loci in Geogebra animations




## The arm of a wallclock tracing loci in geogebra animations

B. See saw



- ❖ Identify the following parts of a see saw,
  - Tips of a see saw
  - Arm of a see saw

**c) Describe and Sketch the Loci traced by the tip of a See saw.**

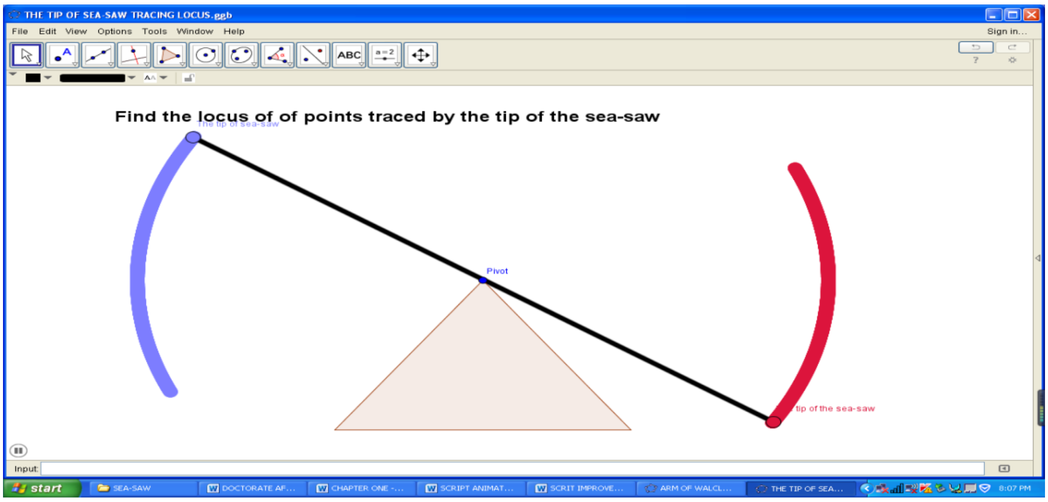
❖ The students are given some times to think and put their solutions in writing after being shown a see saw and its tip correctly identified.

i. The students are presented with animated and simulated see saw as tip traces locus.

❖ The students are given some times to think and put their solutions in writing after the animations and simulations of a tip of see saw.

ii. The expected results

The locus traced is an arc of a circle




**The tip of a see-saw tracing loci in GeoGebra animations**

d) Describe and Sketch the Loci traced by the arms a See saw.

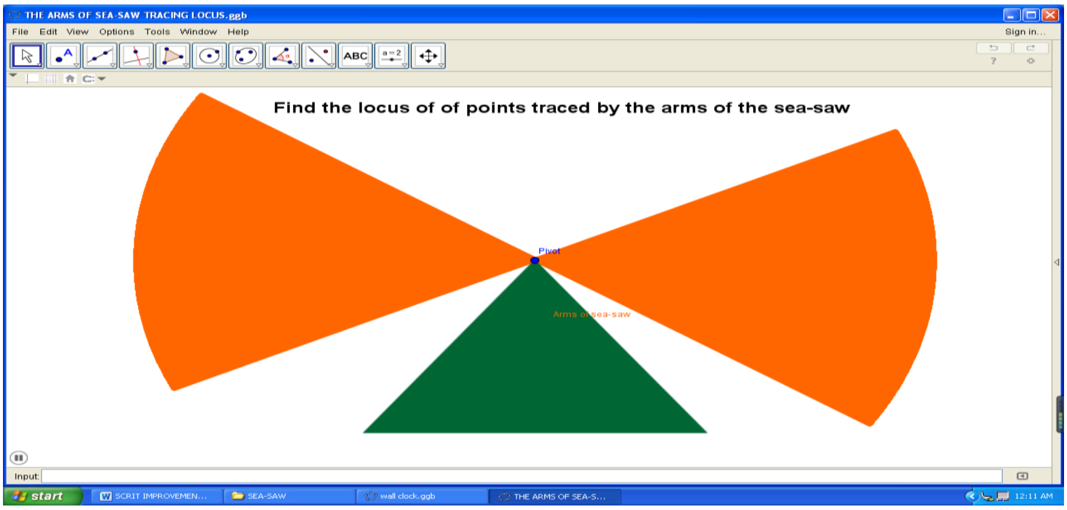
❖ The students are given some times to think and put their solutions in writing after being shown a see saw and its arms correctly identified.

i. The students are presented with animated and simulated see saw as arms traces locus.

❖ The students are given some times to think and put their solutions in writing after the animations and simulations of the arms of see saw.

ii. The expected results

The loci traced are two sectors of a circle




**The arms of a see-saw tracing loci in Geogebra animations**

**e) Bicycle**

i) Name the parts of a Bicycle

❖ Axles

❖ Rims

ii) The students are presented with a moving bicycle

iii) Describe and Sketch the Loci traced by the axle of a bicycle wheel as it move on a level ground.

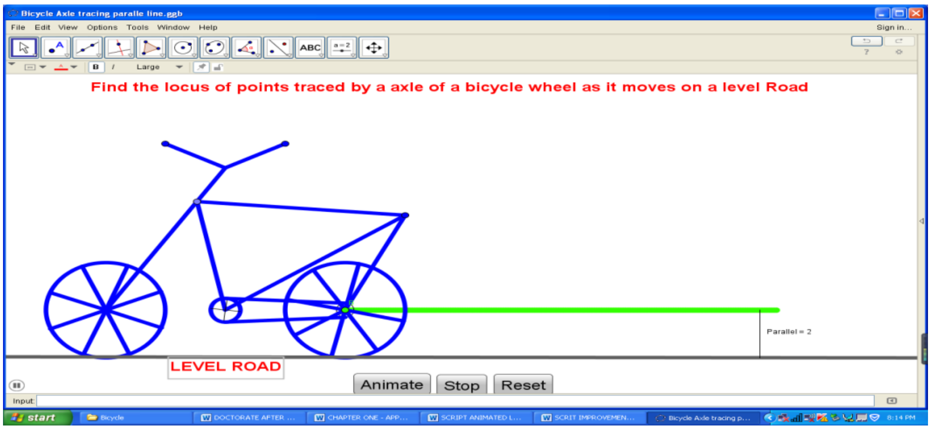
❖ The students are given some times to think and put their solutions in writing.

iv) The students are presented with a Geogebra animated moving bicycle as the axle traces locus

**f) Describe and Sketch the Loci traced by axle of a bicycle wheel as it move forward on a level ground.**

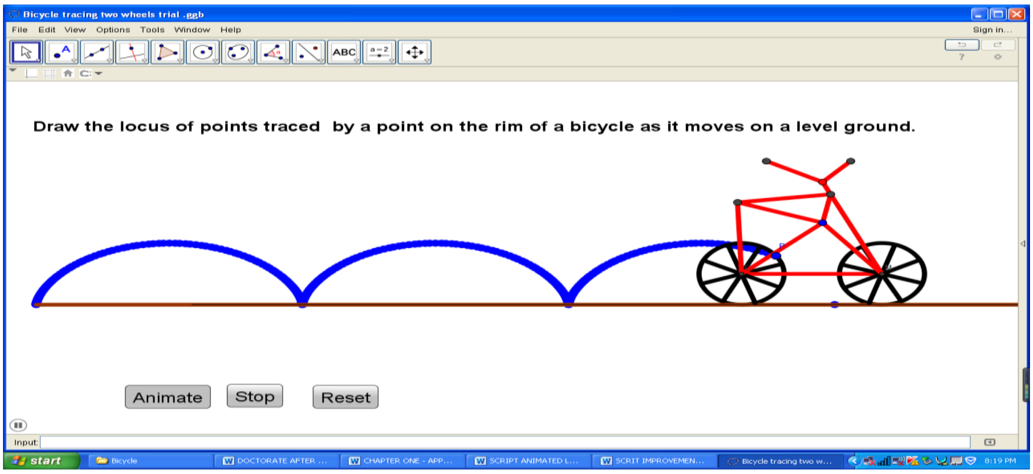
- ❖ The students are given some times to think and put their solutions in writing.

i) The students are presented with a Geogebra animated moving bicycle as a point on the rim of the bicycle traces locus



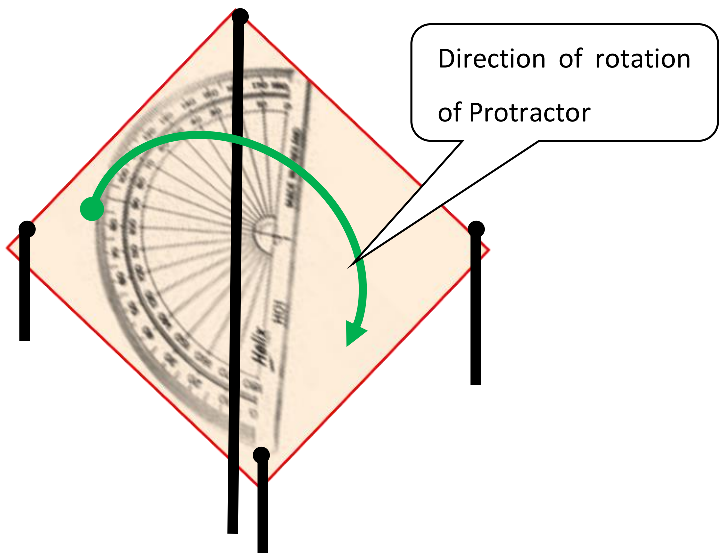

**The expected locus traced by the axle of a bicycle as it moves on a level ground.**

ii) The expected locus of points traced by the nozzle of the bicycle as the bicycle moves forward on a level ground is demonstrated in the Figures 21




**The expected locus traced by a point on the rim of a bicycle as it moves on a level ground.**

g) Protractor :Describe and Sketch the Loci traced by a solid Protractor that is flat on a table and flipped on its straight edge until it is flat again




The students are given some times to think and put their solutions in writing after being shown a table and a protractor flat on it.

h) The students are presented with an animated and simulated protractor flat on a table and it's rotated until its flat again on the table.

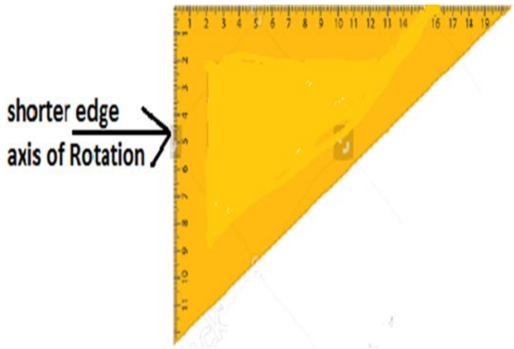
i) The students are given some times to think and put their solutions in writing after the animations and simulations of the protractor.

j) Expected Results

The protractor traces a hemispherical bowl.

k) set square

l) Describe and Sketch the Loci Traced by a solid set square that is rotated on one of its short edges through an angle of $360^0$



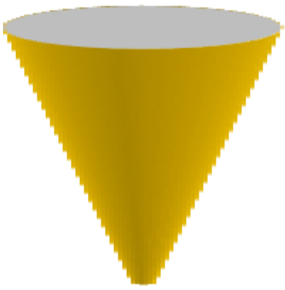

❖ The students are given some times to think and put their solutions in writing.

i. The students are presented with an animated and simulated set square it's rotated about the axis for $360^0$.

m) The students are given some times to think and put their solutions in writing after the animations and simulations of the set square.

n) Expected Results

The set square traces a right cone.

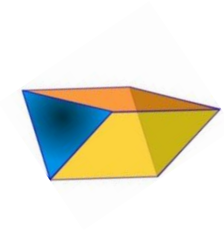


o) Describe and Sketch the Loci traced by the following areas in groups:

► Square ► Circle ► Triangle ► Rectangle ► Pentagon

Expected results

| Surface | Volume traced description | Sketches – diagrammatic representation of loci |
|---|---|---|
| Square | Cube |  |
| Circle | Cylinder |  |

| | | |
|---|---|---|
| Triangle | Triangular prism |  |
| Rectangle | Cuboid |  |

**3. Common Types of Loci in Two and Three Dimensions.**

a) Perpendicular bisector loci

(i). In two dimension students are asked:

- To draw a line AB that is 10 cm.
- To draw a perpendicular bisector line PQ of the line AB.
- PQ is referred to as perpendicular bisector locus of the line AB

(ii). In three dimension

- Students are asked:
  - To define a plane.
  - To draw a plane ABCD
  - To draw plane PQRS that perpendicularly bisect plane ABCD.
- Students are presented with animated and simulated planes ABCD that is then perpendicularly bisected by another plane PQRS

b) Angle bisector loci

(i). In two dimension the students are asked to:

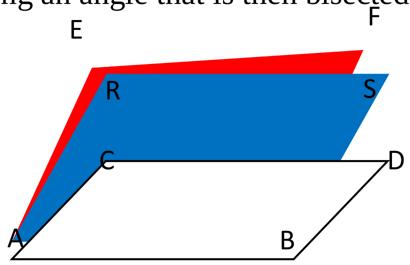
- Draw angles of their choice.
- Measure the angle.
  - Bisect it using a protractor.
  - Bisect it using a ruler and a pair compass.
  - The line bisecting the angle is referred to as angle sector locus

(ii). In three dimension

- Students are asked:
  - To draw two planes ABCD and ABEF that intersects on the line AB.

- To draw plane ABRS that perpendicularly bisect the angle formed by the planes ABCD and ABEF.

- Students are presented with animated and simulated planes ABCD and ABEF forming an angle that is then bisected by another plane ABRS



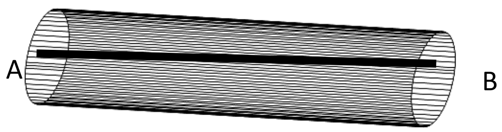

c) Loci of points equal distance from a given straight line.

(iii). In two dimension students are asked:

- To draw a line AB that is 9.4 cm.
- To draw straight lines equal distant from the line AB.
- Students are likely to come up with two lines PQ and RS which are parallel to AB. Locus of point's equal distance from a given straight line is line parallel to it.

(iv). In three dimension

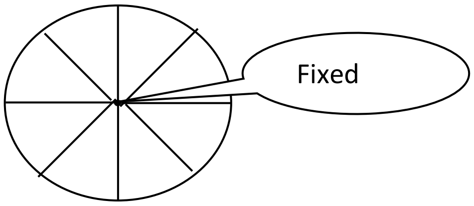
- Students are presented with animated and simulated lines equal distant from a fixed line.
- When the lines are infinite they form a cylinder.




d) Loci of points equal distance from a fixed point.

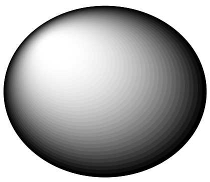
(v). In two dimension students are asked:

- To draw a set of points that are 4.2 cm from fixed point O
- Students likely to come up with diagrams like



(vi). In three dimension

- Students are asked:
    - Sketch the locus and identify it
- Students are presented with animated and simulated locus of points equal distant from a fixed point O

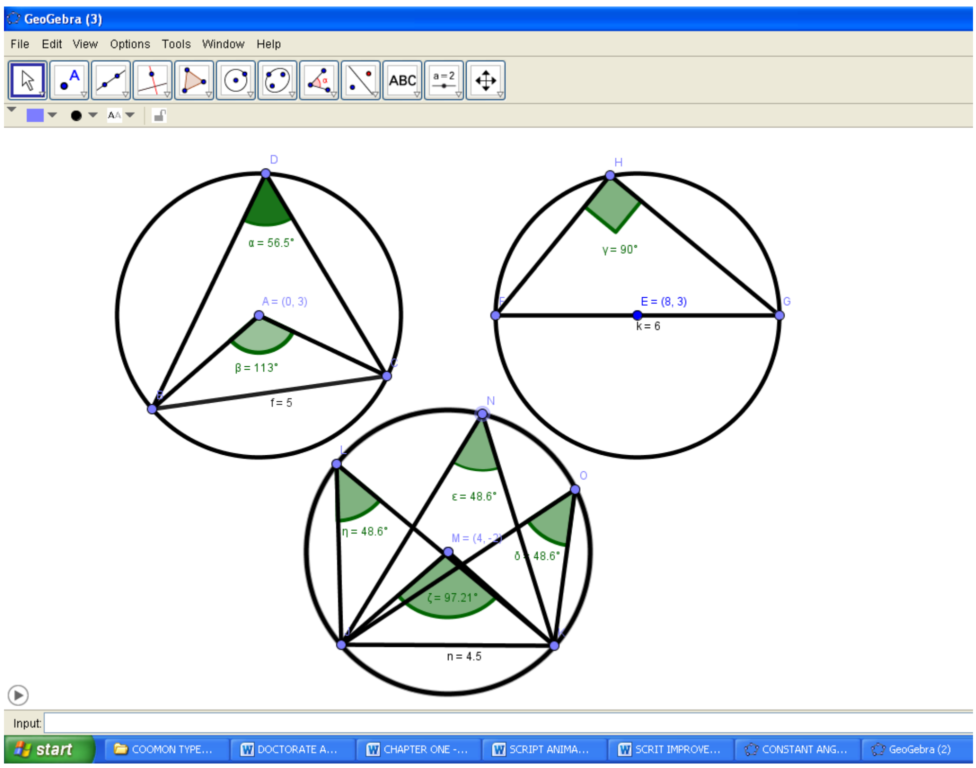


e) Constant angle loci

(i). The teacher reviews the angle properties of circle.

- Angles subtended by the same chords are equal.
- The diameter subtends an angle of $90^0$ at the circumference of a circle.
- A chord subtends an angle at the circumference of a circle that is halving the one it subtends at the centre of the circle.

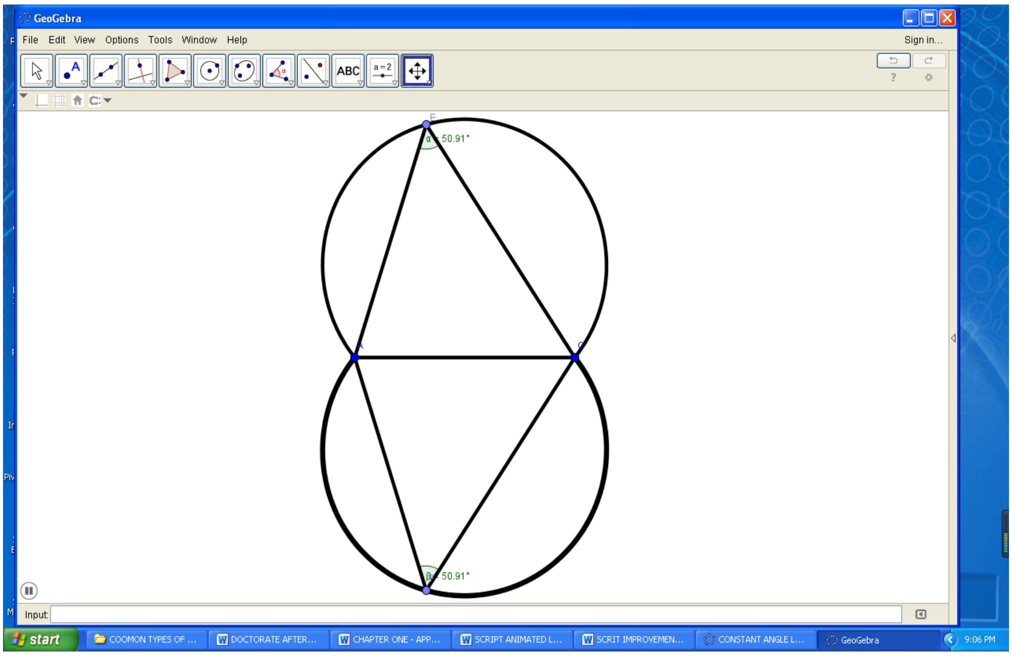
- The students are presented with Geogebra animations of the angle properties of circle.



(ii). Student show which parts of the circle the angles subtended by the chord are constant or equal.

(iii). The students are presented with Geogebra animations loci of constant angles.

- ❖ Expected results




f) Intersecting loci.

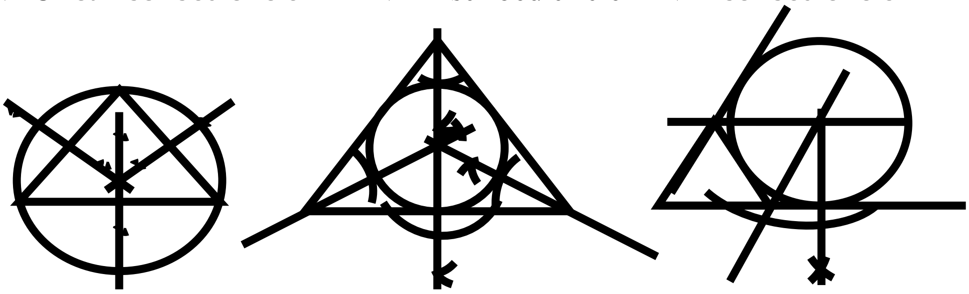
(i). Students are asked to draw the following:

- ❖ Circumscribed circle
- ❖ Inscribed circle
- ❖ Escribed circles
  - ➢ To locate, circum-centre, in-centre and ex-centre.
  - ➢ Explain the common types of loci involved in construction of the circles

(ii). The students are presented with Geogebra animated intersecting loci.

- Expected results

►Circumscribed circle ► Inscribed circle ►Escribed circle



g) Loci involving inequalities.

(i). Students are asked to draw the graph of the following inequalities and show the region satisfying the inequalities:

Y$> 2x + 5$, y $\leq -$ x + 6 and y $\geq$x -2

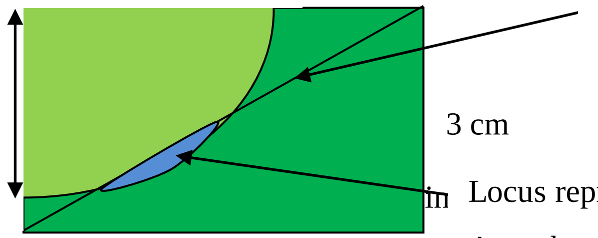
**4. Application of Loci to Real-life Problems**

Tethering goats.

❖ A Goat is tethered with a rope of 17.5 m at a corner of a rectangular piece of land measuring approximately 21 m by 28 m. A river runs across it diagonal show the

The expected results from the scaledrawing Scale drawing 1cm rep 7m

**Solutions**




types of loci is applied

(iii). Architecture

- The students are presented with building structures to discuss which common types of loci is applied

(iv). Astronomy

- The students are presented with solar system features to discuss which common types of loci is applied

(v). Survey

- The students are presented with survey techniques used to discuss which common types of loci is applied

## APPENDIX F: RESEARCH AUTHORIZATION LETTER FROM NACOSTI

NACOSTI

**NATIONAL COMMISSION FORSCIENCE, TECHNOLOGY ANDINNOVATION**

Telephone:+254-20-2213471, 2241349,3310571,2219420
Fax: +254-20-318245,318249
Email: dg@nacosti.go.ke
Website: www.nacosti.go.ke
When replying please quote

9th Floor, Utalii House
Uhuru Highway
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No **NACOSTI/P/17/45810/19078**

Date: **12th September, 2017**

Mwangi Simon Warui
Egerton University
P.O. Box 536-20115
**EGERTON.**

**RE: RESEARCH AUTHORIZATION**

Following your application for authority to carry out research on ***"Effects of the use of computer animated technique on loci during instruction on secondary school students' mathematics achievement and misconceptions in Kitui County, Kenya,"*** I am pleased to inform you that you have been authorized to undertake research in **Kitui County** for the period ending **12th September, 2018.**

You are advised to report to **the County Commissioner and the County Director of Education, Kitui County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

**GODFREY P. KALERWA MSc., MBA, MKIM**
**FOR: DIRECTOR-GENERAL/CEO**

Copy to:

The County Commissioner
Kitui County.

The County Director of Education
Kitui County.

**APPENDIX G: RESEARCH PERMIT**

**THIS IS TO CERTIFY THAT:**
***MR. MWANGI SIMON WARUI***
**of EGERTON UNIVERSITY-MAIN CAMPUS**
**NJORO, 0-90137 KIBWEZI,has been permitted to conduct research in *Kitui County***

**on the topic: *EFFECTS OF THE USE OF COMPUTER ANIMATED TECHNIQUE ON LOCI DURING INSTRUCTION ON SECONDARY SCHOOL STUDENTS' MATHEMATICS ACHIEVEMENT AND MISCONCEPTIONS IN KITUI COUNTY, KENYA***

**for the period ending:**
***12th September,2018***

............................
***Applicant's Signature***

**Permit No : NACOSTI/P/17/45810/19078**
**Date Of Issue : 12th September,2017**
**Fee Recieved :Ksh 2000**

..........................................
***Director General***
***National Commission for Science, Technology & Innovation***

**CONDITIONS**

1. **The License is valid for the proposed research, research site specified period.**
2. **Both the Licence and any rights thereunder are non-transferable.**
3. **Upon request of the Commission, the Licensee shall submit a progress report.**
4. **The Licensee shall report to the County Director of Education and County Governor in the area of research before commencement of the research.**
5. **Excavation, filming and collection of specimens are subject to further permissions from relevant Government agencies.**
6. **This Licence does not give authority to transfer research materials.**
7. **The Licensee shall submit two (2) hard copies and upload a soft copy of their final report.**
8. **The Commission reserves the right to modify the conditions of this Licence including its cancellation without prior notice.**

**REPUBLIC OF KENYA**

NACOSTI

**National Commission for Science, Technology and Innovation**

**RESEARCH CLEARANCE PERMIT**

**Serial No.A 15717**

**CONDITIONS: see back page**

## APPENDIX H: RESEARCH AUTHORIZATION LETTER FROM KITUI COUNTY COMMISSIONER

THE PRESIDENCY

MINISTRY OF INTERIOR AND COORDINATION OF NATIONAL GOVERNMENT

E-mail;cckitui@gmail.com
Telephone:

........................................................

When replying please quote

OFFICE OF THE
COUNTY COMMISSIONER
KITUI COUNTY
P.O. BOX 1 - 90200
**KITUI**

**Ref: K.C.603/1/205**

**27th September 2017**

Mwangi Simon Warui
Egerton University
P.O. Box 536-20115
**EGERTON**

**RE: RESEARCH AUTHORIZATION**

Reference is made to a letter Ref. NACOSTI/P/17/45810/19078 dated 12th September 2017 from the National Commission for Science, Technology and Innovation on the above subject matter.

You are hereby authorised to carry out research on ***"Effects of the use of computer animated technique on loci during instruction on secondary school students' mathematics achievement and misconception"*** in Kitui County for a ending 12th September, 2018.

**M.G. MAUKI**
FOR: COUNTY COMMISSIONER
**KITUI COUNTY**

## APPENDIX I: RESEARCH AUTHORIZATION LETTER FROM KITUI COUNTY DIRECTOR EDUCATION

**MINISTRY OF EDUCATION, SCIENCE & TECHNOLOGY**
**State Department for Basic Education**


Telegrams "EDUCATION"
Kitui
Telephone: Kitui 22759
Fax :04444-22103
E-Mail :
cde.kitui@gmai.com


REPUBLIC OF KENYA


COUNTY EDUCATION OFFICE
KITUI COUNTY
P.O BOX 1557-90200
KITUI


*When replying please quote;*

**Ref. No: KTIC/ED/RES/22/241** **Date.27th Sept, 2017**

Mwangi Simon Warui
Egerton University
P.O.BOX 536-20115
EGERTON

**RE: RESEARCH AUTHORIZATION**

Following your application for authority to conduct a research on "**Effects of the use of computer animated technique on loci during instruction on secondary school students' mathematics achievement and misconceptions** in Kitui County, Kenya I am pleased to inform you that your request is hereby granted for the period ending 12th September, 2018.

You are advised to liase with the respective Sub County Directors of Education before embarking on the exercise. In addition, on completion of the research, you are expected to give this office a copy of the research findings/feedback.

COUNTY DIRECTOR OF EDUCATION
KITUI
P. O. Box 1557, KITUI.

**Samuel Maghanga**
**For: County Director of Education**
**KITUI**