# EFFECTS OF USING LOCI-KIT MODELS ON SECONDARY SCHOOLS STUDENTS' ACHIEVEMENT IN THE MATHEMATICS TOPIC "LOCI" IN KIBWEZI DISTRICT, KENYA

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## ABSTRACT

*Students have continued to perform poorly in mathematics at the Kenya Certificate of Secondary Education (KCSE) examinations in Kenya secondary schools. Their performance in certain mathematics topics has consistently been poor. One such topic is Loci that is taught to 18 year old form four students in secondary schools ,Kenya. The poor performance in mathematics has been attributed to several factors, which include: poor teaching methods, lack of teaching and learning resources, and the abstract nature of mathematics. This study sought to investigate effects of using Loci-Kit Models in the mathematics topic loci, during instruction, on students' achievement in mixed-sex secondary schools of Kibwezi District, Kenya. There is however inadequate research conducted in Kenya on the effects of using models in mathematics classrooms on students' achievement in mathematics. The researchers constructed Loci Kit Models to augment the teaching of loci in form four mixed-sex secondary schools in Kenya. A simple random sample of four schools was obtained from 44 mixed-sex district secondary schools in the district. The study was carried out in a mathematics classroom setting. Solomon Four, Non-Equivalent Control Group Design was used. The two experimental groups were exposed to the use of Loci Kit Models as the treatment while the two control groups were taught using the conventional teaching methods. The sample size was 195 students, 82 girls and 113 boys. .A Mathematics Achievement Test (MAT), constructed by the researcher was used. The instrument was pilot tested and its reliability estimated at 0.77. The instrument was validated by five experts from the Department of Curriculum, Instruction and Educational Management of Egerton University and three secondary school mathematics teachers. The MAT was administered to the two groups, one experimental and one control before intervention and then to all the four groups after intervention. Inferential statistics (t-test, ANOVA and ANCOVA) were used to analyze the data. The level of significance for acceptance or rejection of the hypotheses was set at 0.05 α level. The findings of this study are likely to benefit secondary school students and mathematics teachers for they will understand the effects of using models in mathematics in general and device ways of intervention in order to improve mathematics performance.*

**Keywords:** Loci-Kit Models, mathematics achievement, Kenya

## INTRODUCTION

Mathematics takes a significant position in human civilization. It is a medium of social functions in our everyday life (Mondoh, 2005). The social functions include buying, selling, and banking, among others. Mathematics helps to develop powers of logical thinking, accuracy and spatial awareness (KIE, 2002). If Kenya is to achieve the Vision 2030, whose aim is making Kenya a newly industrialized middle income country (GOK, 2007), then student population must excel in sciences, and the vehicle for this is mathematics.


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Learners' mathematics performance has continued to be poor over the years internationally. The results of the 'Trends in International Mathematics and Science Study' (TIMSS) of 2004 indicate that the United States students' achievements in mathematics are far below world class standards, (Gonzales, Guzman, and Jocelyn, 2004; Martin, Mullis, and Chrostowski, 2004). Other studies conducted in Nigerian secondary schools Aburime, (2009; and Amoo 2001), have expressed concerns about learners' low achievement in mathematics. The consistent poor performance in mathematics has also been a source of concern, worry and anxiety to all stakeholders in the education sector in Ghana (Adetunde and Asare, 2009). According to Legotlo, Maaga and Sebego (2002) and Mashile, (2001), the South African recurring poor learners' performance in mathematics similarly calls for a concerted effort on measures that will help in its improvement.

In Kenya mathematics has consistently been ranked last in performance in comparison with the other subjects offered at the KCSE (KNEC, 2008). A critical look at the students' overall performance in mathematics at the KCSE from the year 2002 to 2008 national examinations reveal that the students' performance persistently remained low, as shown in the Table 1.

**Table 1. KCSE Mathematics Examination Mean Scores for Years 2002 to 2008**

| *Year* | *2002* | *2003* | *2004* | *2005* | *2006* | *2007* | *2008* |
|---|---|---|---|---|---|---|---|
| Paper 1: mean score (Percentage) | 19.95 | 17.17 | 14.57 | 14.87 | 22.71 | 19.55 | 22.76 |
| Paper 2: Mean score (Percentage) | 19.51 | 21.45 | 22.63 | 17.04 | 15.36 | 19.91 | 19.82 |

*Source: KNEC report 2004 – 2009*

In particular learners' mathematics performance in Kibwezi District of Kenya has been poor for the years between 2002 and 2009.

According to a report by Makueni District Strengthening of Mathematics and Science in Secondary Education (SMASSE) project of Kenya, Learners mathematics performance index was persistently below 3 out of 12 points for the years 2002 to 2008.

A Baseline survey research carried out by Makueni District SMASSE trainers on 10$^{th}$ May 2007 in Makueni District revealed that the mathematics topic loci was rated as the most challenging topic in form four after the topic of linear inequalities (MDSBS,2007).

## THE CONCEPT OF LOCI IN MATHEMATICS

Locus is a latin word which means "place" (Robert and Glenn, 1992). A locus of points is a set of points, and only those points that satisfy given conditions. A locus can be a straight line, curved line, area or region in two dimensions or a volume in three dimensions (Kibui and Macrae, 2005)

Locus is a path, an area or volume traced by point, line or an area that satisfy given conditions (KIE, 2005). Examples of loci include the following:

i. The locus of points a given distance from a fixed line traces, two parallel lines in two dimensions and a cylinder in three dimensions.
ii. The locus of points a given distance from a fixed point traces a set of points describing a circle in two dimensions and a sphere in three dimensions.

In Kenya the topic loci in mathematics is taught to form four 18 year old students in secondary schools and covers the following subtopics in Geometry: constructing angles; bisecting angles; constructing parallel lines; constructing perpendicular lines to given straight lines; locus of points at a given distance from a fixed point; angle bisector locus; constant angle locus; Loci of chord, inequalities; circumscribed, inscribed and escribed circles; and application of loci to solution of problems (K.I.E, 2002; KIE, 2005; Kinyua, Maina and Odera, 2005a).

Research studies conducted in Kenya (Kinyua, Maina and Odera, 2005b) indicated that learners find the topic of Loci difficult to learn and to understand. Salmon (2005) confirmed that learners find it difficult to grasp concepts in loci while a majority of teachers dislike teaching the topic (KNEC, 2007).

Salmon (2009) proposed the use of relevant concrete materials in the teaching of mathematics in which students participate and interact with models and manipulates in order to promote meaningful understanding of mathematics concepts among learners. Other Studies indicate the importance of using concrete models in both primary and junior high schools (Sowell, 1989; Thomson and Lambdin, 1994; Elswick, 1995) to teach mathematics. The studies indicate that the use of concrete models instills in learners the confidence to think and communicate mathematically and also develop essential learning skills.

According to Chandran (2004), "visual communication is the most effective way of communication". It is important when a concrete model or real object is used for demonstration during mathematics instruction as the teacher works through an example, verbalizes the procedure and then leaves the model for the class to refer to it.

In this study the researchers constructed Loci – Kit models to augment the teaching of the topic loci to secondary school form four 18 year old learners in Kibwezi district of Kenya. A kit is a set of tools or equipment that one uses for a particular purpose (Oxford, 2006). In this study a set of different models were used to teach different mathematical concepts in the topic loci. Some models in the kit were joined while others were used singly. The experimental schools were exposed to the loci-kit models while the control schools were taught using the conventional teaching methods.

## PROBLEM OF THE STUDY

Despite learners' poor performance in mathematics at national examinations worldwide and particularly in Kenya, the subject is perceived by society as being very useful to an individual and society globally. Among reasons given for the dismal mathematics achievement is ineffective teaching methods and lack of appropriate use of teaching resources effectively in mathematics classrooms. In an attempt to seek a teaching strategy that can improve learners' achievement, this study investigated the effects of the use of Loci-kit models on learners' achievement on the mathematics topic Loci which is taught in Kenya's secondary schools.

## PURPOSE OF THE STUDY

The purpose of this study was to investigate the effects of using Loci-Kit Models on secondary schools students' achievement in the mathematics topic loci in Kibwezi District, Kenya.

## OBJECTIVE OF THE STUDY

Keeping in view the purpose of study the objective of stuy was to establish the effect of Loci Kit Models on students' achievements in mathematics topic l.

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## HYPOTHESIS OF THE STUDY

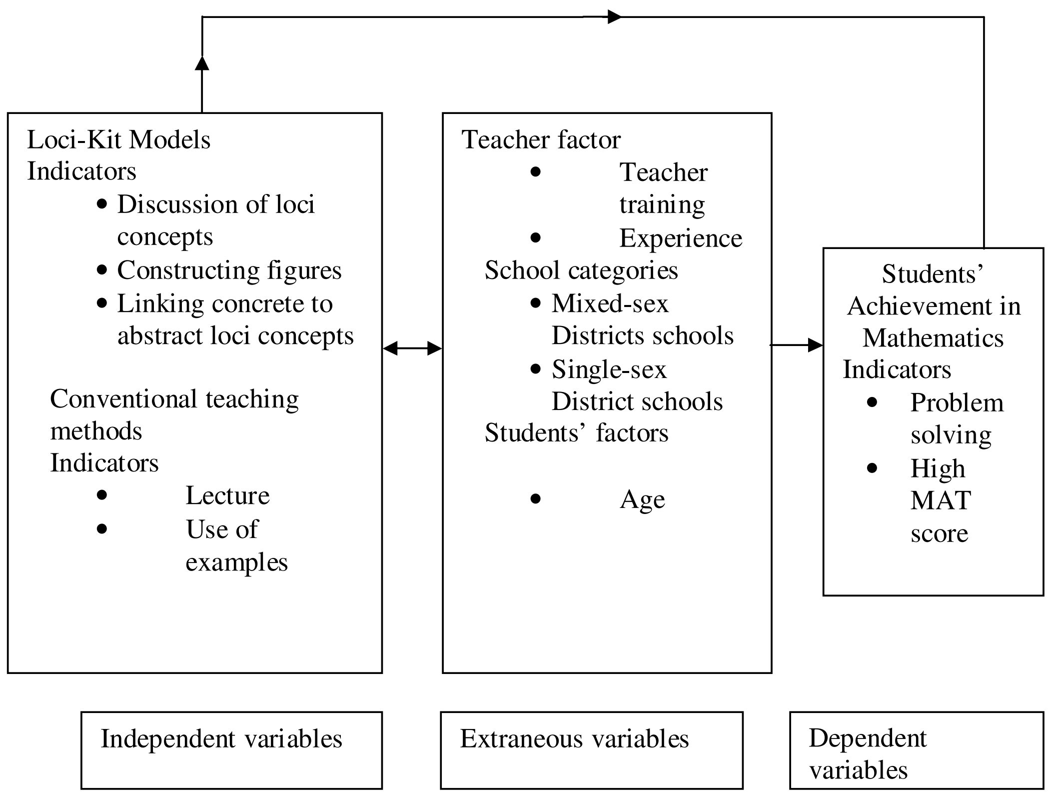
**$H_{O1}$:** There is no statistically significant difference between the mathematics achievement scores of students exposed to Loci- Kit Models and those not exposed to it during mathematics instruction.

## CONCEPTUAL FRAMEWORK

The conceptual framework of this study was based on the Piaget's theory of cognitive development (Piaget, 1983) and constructivist's theory Glasserfield (1989). The Piaget's theory holds that mathematical understanding in young children is closely associated with sensory perception and concrete experience while constructivist's theory hold that humans construct their own knowledge from daily life experiences.

The framework in figure 1 shows the Independent variables being teacher's use of Loci Kit models and the conventional teaching methods. Conventional teaching methods in this study refer to all the regular methods of teaching mathematics as opposed to the use of Loci-Kit Models .The extraneous variables in the research were teacher factors, school factors and student's factor. The teacher factors were categorized into teacher training and experience. To account for these variables, the researchers worked with teachers of minimum qualification of a diploma in education and had taught form four class for a minimum of 2 years. Mathematics achievement was the dependent variable.

**Table 1. Conceptual Framework Showing the Relationship Among Independent, Extraneous and Dependent Variables of the Study**



## RESEARCH METHODOLOGY

This study used Solomon Four, Non-Equivalent Control Group Design (Figure 2) which is appropriate for experimental and quasi-experimental studies (Ogunniyi, 1992) as cited by Githua and Nyabwa (2008). The design is preferred because secondary schools' classes once constituted exist as an intact groups and the schools' authorities do not allow such classes to be broken and re-constituted for research purposes (Borg and Gall, 1989). The design helped to: assess the effect of the experimental treatment relative to the control group; assess the interaction and treatment conditions; assess the effect of pre-test relative to post-test; assess the homogeneity of the groups before administration of the treatment(Borg and Gall, 1989). The non- equivalent groups, Pre-test and Post-test approaches were used to partially eliminate the initial differences between the experimental groups and control groups.

**Table 2. Solomon Four, Non-Equivalent Control Group Design**

| | *Pretest* | *Intervention* | *Post-test* |
|---|---|---|---|
| $E_1$ | $O_1$ | X | $O_2$ |
| $C_2$ | $O_3$ | - | $O_4$ |
| $E_2$ | - | X | $O_5$ |
| $C_2$ | - | - | $O_6$ |

In Figure 2, Groups C1 and C2 represented sampled schools that used Conventional teaching methods. Groups E1 and E2 represented the sampled schools that received the treatment. The variables are defined such that: O1 and O3 are Pre-test O2, O4. and O6 are Post – test; and X is Experimental treatment using Loci Kit Models. Dotted line (---------) indicates the use of non-equivalent groups while continuous line ( — ) means no treatment (Mugenda & Mugenda, 1999).

### Population of the Study

The target population was secondary school students in Kibwezi District. The accessible population was 2580 Form four 18 year old students (Kibwezi District, 2010) because the study topic is taught to form four classes in Kenya (KIE, 2002). Kibwezi District has 49 secondary schools: 2 Single-Sex Provincial Secondary schools, 44 Mixed-sex District secondary Schools, 2 Single– Sex District secondary Schools and 1 Private secondary school. The study concentrated on Mixed-Sex District secondary schools which are the majority in the district.

### Sampling Procedure and Sample Size

Simple random sampling was employed to select four schools out of the possible 44. This sampling procedure was appropriate because it ensured that all the schools had equal chances of being included in the study. Four schools were chosen because the Solomon 4-Group Design requires four groups. Each school formed a group in the Solomon 4-Group Design so that the interaction between students was minimized during the exercise. The four schools were again randomized to end up with two experimental groups and two control groups using simple random sampling. According to Mugenda and Mugenda (1999), the required sample size is at least 30 cases per group. Each class had more than 30 students. The sample size was 195 students, 82 girls and 113 boys.

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## Instrumentation

The mathematics achievement test (MAT) was used to collect the required data. It was a twenty five item instrument that tested students' knowledge, comprehension, application and mathematics skills on working out short answer questions that were set on definition, construction of common types of loci and application of loci to real life. The maximum score for the test was 80.Its reliability was 0.7725 from K-R-20 formula. The pilot testing was conducted in Makindu district that is next to Kibwezi district.

## How Loci-Kit Models Were Made and Used For Teaching

The mathematics topic loci was taught to form four students in the experimental schools by use of Loci-Kit models .The following Specific objectives of teaching Loci were to be achieved by learners at the 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, Maina and Ondera, 2005b; MOE, 2006a ; KNEC, 2010). The researchers made the Loci- Kit Models which represented the real life situations, items, and objects that students meet in their day-to-day life. The models were used to demonstrate the concepts in loci. Oxford (2006) defines a kit as a set of tools or equipment that one uses for a particular purpose, hence Loci Kit Models is a collection of models, and some joined together for teaching and demonstrating the concepts of Loci. The Loci models that were joined together in the Loci Kit are: a model of wall clock; model of a see-saw; model of paint brush representing a line; a model of tracing tray where volumes were traced; model of a goat tethered in a grazing field; model wheel of bicycle. The Loci -Kit Models also constituted the following models which were not joined together: Loci demonstration box, where various loci are drawn; models of surfaces that traces volume; model of intersecting chords; model of a tip of a minute hand; model of an arm of a minute hand; model of a tip of a see-saw; model of an arm of a see-saw; model of a solid set square; model of a solid protractor; models of biscuit shape tracer; model of a farm; mark pens; clay; mark pen ink; protective gloves to avoid ink contact; and chalk board geometrical set. All the models were discussed by mathematics teachers and researchers in experimental schools only. Teachers in control groups were expected to use conventional teaching methods to teach the topic.

## RESULTS

### Results of the Pre-Test

Table 3 shows the number of students who participated in the study by school.

**Table 3. Students who participated in the research study by experimental and control schools**

| | *C1* | *E1* | *C2* | *E2* | *Total* |
|---|---|---|---|---|---|
| Total | 38 | 55 | 56 | 46 | 195 |

The groups C1 and E1 sat for pre-test MAT, which made it possible for the researchers to assess the homogeneity of the groups before treatment application as recommended by Gall, Borg and Gall (1996); Wiersma and Jurs (2005) as cited in Shihusa. and Keraro (2009). Table 4 shows the t-test of pre-test scores in MAT

**Table 4. 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 | 38 | 20.79 | 8.08 | 91 | 0.3454 | 1.9864 | 0.7306 |
| | E1 | 55 | 20.13 | 9.72 | | | | |

The independent sample t- test for MAT pre-test mean score for groups E1 and C1 were not significantly different, $t(91)= 0.3454$ and $p > 0.05$ as shown in Table 4, implying that the groups had similar characteristics and were suitable for the study.

### Effects of Loci-Kit Models on Students' Achievement in Mathematics

To establish the effects of Loci Kit Models on students' performance in Loci, the Post-test scores of the MAT were analyzed. Hypothesis $HO_1$ sought to establish whether there was a significant difference in performance between students taught using Loci Kit Models and those taught using the conventional teaching methods. Table 6 shows the MAT mean scores obtained by the four groups.

**Table 5. Post –test MAT mean scores obtained by the students in the study groups**

| Groups | C1 | C2 | E1 | E2 | Total |
|---|---|---|---|---|---|
| N | 38 | 56 | 55 | 46 | 195 |
| Mean Scores | 28.55 | 25.02 | 38.35 | 40.13 | 33.03 |
| Standard deviation | 11.17 | 11.45 | 16.25 | 8.790 | |

C1 = Control group 1, E1 = Experimental group 1
C2 = Control group 2 E2 = Experimental group 2

Table 5 shows a higher mean score for experimental groups that used Loci Kit Models compared to control groups that did not. 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 6

**Table 6. 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 | 8229.785 | 3 | 2743.262 | | | |
| Within groups | 29566.031 | 191 | 154.796 | 17.7218 | 2.6519 | 0.0000 |
| Total | 37795.815 | 194 | | | | |

Table 6 indicates that differences in mean scores among the four groups were statistically significant $F(3,191) = 17.7218$ and $p < 0.05$. To show which groups had significant mean differences in MAT achievement, a post hoc test of multiple comparisons using Scheffe's method was used. Table 7 shows the results of Scheffe's post hoc comparisons.

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**Table 8. Scheffe's post hoc comparison of the post-test MAT means for the study groups**

| *Dependent Variable* | *(I) Group* | *(J) Group* | *Mean Difference (I-J)* | *Significance* |
|---|---|---|---|---|
| Sum of post –test achievement | C1 | C2 | 3.5348 | .610 |
| | | E1 | -9.7928(*) | .004 |
| | | E2 | -11.5778(*) | .001 |
| | C2 | C1 | -3.5348 | .610 |
| | | E1 | -13.3276(*) | .000 |
| | | E2 | -15.1126(*) | .000 |
| | E1 | C1 | 9.7928(*) | .004 |
| | | C2 | 13.3276(*) | .000 |
| | | E2 | -1.7850 | .915 |
| | E2 | C1 | 11.5778(*) | .001 |
| | | C2 | 15.1126(*) | .000 |
| | | E1 | 1.7850 | .915 |

* The mean difference is significant at the .05 level

The results in Table 7 indicated that the differences of pairs of MAT scores of groups E1 and C1, E2 and C1, E1 and C2 and E2 and C2 were significant at $\alpha = 0.05$ significance level. However, the mean scores of groups E1 and E2, and C1and C2 were not significantly different at $\alpha = 0.05$ 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 .therefore Analysis of Covariance (ANCOVA) using pre-test scores as the covariate was used as a confirmatory test. ANCOCA reduces the effects of initial group differences statistically by making compensating adjustment to post-test means of the group involved (Gall *et al.,* 1996;Borg and Gall, 1989). With nonrandomized designs, the main purpose of ANCOVA is to adjust the posttest means for differences among groups on the pre-test, because such differences are likely to occur with intact groups. It is important to note that when pre-test scores are not reliable, the treatment effects can be seriously biased in nonrandomized designs (Dimitrov, & Rumrill, 2003).

**Table 8. 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* | *Standard error* |
|---|---|---|---|---|
| E1 | 55 | 38.55 | 37.83 | 2.3261 |
| C1 | 38 | 28.55 | 27.74 | 1.9872 |

The results from Table 8 and Table 9 confirmed that the differences in mean scores in the experimental group E1 and control group C1 are statistically significant.

**Table 9. ANCOVA of the Post –test MAT scores with pre-test as covariate**

| | *Sum of squares* | *Df* | *Mean square* | *F* | *P* |
|---|---|---|---|---|---|
| Pre-test for MAT | 2420.21 | 1 | 2420.21 | 1 6.92 | 0.000086 |
| Use Loci Kit Model | 723.26 | 1 | 723.26 | 5.3 | 0.023659 |
| Error | 12876.61 | 90 | 143.07 | | |
| Total | 15296.82 | 91 | | | |

A further comparison was made 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 10

**Table 10. Comparison of mean scores and mean gain obtained by students in the MAT**

| | | *Experimental group E1* | *Control group C1* |
|---|---|---|---|
| Pre –test mean | | 20.13 | 20.79 |
| Post –test mean | *Overall (N= 93)* | 38.35 | 28.55 |
| Mean gain | | 18.22 | 7.76 |

Table 10 shows that the experimental group E1 had a higher mean score gain as compared to control group C1.

The group that was taught using Loci Kit Models 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 Loci Kit models and those taught through the conventional teaching methods was rejected at the 0.05α level. Therefore, using Loci Kit Models 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.

## DISCUSSION

### Effect of the Use of Loci- Kit Models on Students' Achievement in Loci Topic of Mathematics.

The researchers found that students who were taught by use of Loci-Kit models achieved significantly higher scores in MAT than those who were taught through the conventional teaching methods. This is an indication that the Loci-Kit models were more effective in improving students' achievement as compared to the conventional teaching methods. This finding agrees with research works of Raphael & Wahlstrom, (1989); Sowell, (1989); Suydam, (1986), that students who use manipulative in their mathematics classes usually outperform those who do not. In addition Kurumeh and Achor (2008 found that there was a significant difference between the mean achievement score of the pupils taught decimal fractions using concrete materials (Cuisenaire rods) as compared to the use of the conventional teaching methods. Rule and Hllagan (2006), found that use of manipulative that involve hands-on and minds-on activities have positive effects on improving pupils' academic achievement especially in mathematics. Chester, Davis and Reglin (1991), found that third grade students who were presented geometry concepts with manipulative scored significantly higher on the posttest than the group that was presented concepts using only drawings and diagrams. Munger (2007) found that the experimental group using mathematical manipulative scored significantly higher in mathematical achievement on the post-test scores than the control group. The findings in this study on students' achievement were therefore in support of earlier findings. The results indicated that the use of concrete materials, manipulative and in particular Loci – Kit models, resulted in better students' achievement than when students learn through the conventional teaching methods.

A study by Hougas (2003) however, found out that there was no significant difference in achievement between the experimental and the control groups after using manipulative while teaching addition and subtraction of fractions. Outhred and Mitchelmore (2000), whose study focused on "Rectangular Area Measurement" and pictorial representations of area, found that that the uses of manipulative when finding the area of a rectangle were not effective.

Several studies suggest that concrete materials are likely to be misused when a teacher has in mind that students will learn to perform some prescribed activity with them ( Boyd, 1992; Thompson and Thompson, 1994). It is important to ensure that the Loci-Kit models are used well and for sufficient time for effective and meaningful learning to take place.

If secondary schools in Kenya use the Loci-Kit models in teaching of loci, the students' achievement at KCSE national examinations is likely to improve significantly.

## IMPLICATIONS OF THE STUDY

Loci- Kit models resulted in higher mathematics achievements in mixed-sex district secondary schools. Since majority of students in Kenya are in mixed-sex secondary schools, Loci-Kit models should be used in teaching mathematics to improve the current trend of learners' dismal performance in mathematics.

## RECOMMENDATION

It is recommended that the use of Loci-kit models be encouraged in Teacher Education programs and at In-service programs for mathematics teachers. Further research should be carried out in the following areas that were out of scope of the current study.

1. A study to determine the mathematics teachers' and students' perceptions of the classrooms environment while teaching and learning using Loci-Kit models.
2. A study of the effect of computer simulation of the Loci-Kit models with respect to mathematics achievement.
3. A study to determine the effects of using models in other mathematics topics with respect to mathematics achievement at the end of secondary school education.

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