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Effects of Concretised Geometrical Models during Instructions on Secondary School Students' Mathematics Achievement by Gender in Kibwezi Sub-county, Kenya

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Abstract:
Secondary school students in Kenya have continued to perform poorly in mathematics in the Kenya Certificate of Secondary Education (K.C.S.E) national examinations. This raises a lot of concern for all stakeholders in education due to the importance they attach to mathematics. Some of the factors that are attributed to the students' dismal performance in the subject include: inadequate teaching and learning resources, poor teaching methods, the abstract nature of mathematics, and gender stereotypes. This study sought to investigate effects of using Geometrical Models in the mathematics topic Loci a subset of Geometry, during instruction, on students' achievement in Mixed-Sex Secondary Schools of Kibwezi Sub-County, Kenya. There is inadequate research conducted in Kenya on the effects of using models in mathematics classrooms on students' achievement in mathematics. The researchers made Geometrical Models to find out their effects on the teaching of and learning of Loci in form four mixed-sex secondary schools in Kenya. Purposive random sample of four schools was obtained from 51Mixed-Sex Sub-County Secondary Schools in the Sub-County. Solomon Four, Non-Equivalent Control Group Design was used. Two experimental groups were exposed to the use of Geometrical Models as the treatment while the two control groups were taught using the conventional teaching methods. The sample size was 178 students, 75 girls and 103 boys. A Mathematics Achievement Test (MAT), constructed by the researcher was used. The instrument was pilot tested and its reliability estimated at 0.73. The instrument was validated by experts Egerton University and 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, tutors in teacher training colleges and mathematics educators at universities 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: *Geometrical Models, mathematics achievement, Loci Topic, Kenya*

1. Introduction

Mathematics is a language without which science, commerce, industry, the internet, and the entire global economic infrastructure is struck dumb (Vorderman, 2011). It is the only truly universal language, and it is an essential part of our personal and working life. Mathematics is not only a language and a subject in itself, but also critical in fostering logical and rigorous thinking. According Odili (2006) mathematics is a subject that helps students to form the habit of clarity, brevity, accuracy, precision and certainty in expression. Mathematical literacy is a must element in providing the child with the basic skills to live their life. Thus, everybody requires a certain amount of competence in basic topics in mathematics for the purposes of handling money, prosecuting daily businesses, interpreting mathematical graphs and charts, as well as thinking logically (Bandura, 1997). If Kenya is to achieve the Vision 2030, whose aim is making Kenya a newly industrialised middle-income country (GOK, 2007), then students must excel in mathematics.

Learners' mathematics performance has continued to be poor over the years globally. Colwell (2000) studied the performance of American students in the international mathematics tests and noted that they were performing poorly. The reports on PISA assessment, ascertains that in U.S. students are performing slightly lower in mathematics than other OECD countries (Kloosterman, and Ruddy 2011). According to Kaur (2005), since 1995, Singapore students have consistently ranked among the top nations on the Trends in International Mathematics and Science Study (TIMSS), while the United States has ranked lower than many industrialised countries. The poor performance in mathematics year-in-year-out has similarly been a constant source of concern, worry and anxiety to all stakeholders in the education sector in Ghana (Adetunde and Asare, 2009).

Gender differences in mathematics performance and ability remain a concern in U.S.A. at all level of Education but more referent at the highest levels of mathematics, (Hyde, Lindberg, Linn, Ellis, & Williams, 2008), in Denmark the gender differences in mathematics exist at all levels (Joensen and Nielsen,2013). Örs, Palomino & Peyrache (2013) and Jurajda and Münich (2011), found that not only does gender difference exist but males dominate at the top of the mathematics test score distribution. Females underperform in high-stake tests relative to males with similar abilities, (Niederle and Vesterlund, 2010). According to Pourmoslemi, Erfani, & Firoozfar (2013), gender differences in mathematics exists among students at higher levels of learning in Hamedan Iran. According to Kiptum, Rono, Too, Bii & Too (2013) Mathematics is viewed as a subject favouring male students' due to factors like attitude, methods used for teaching among others. This has resulted to gender differences between male and female students in Mathematics performance

In Kenya mathematics performance has consistently been poor in comparison with the other subjects offered at the KCSE (KNEC, 2013).Table 1 shows KCSE mathematics performance by gender. The results reveal that boys' performance is slightly better than girls.

Year	2011	2012	2013	2014
Female Mean Score %	21.00	25.30	24.51	21.26
Male Mean Score %	27.80	31.38	30.13	26.40
Overall Grade Total %	24.79	28.66	27.56	24.02

Table 1: KCSE Mathematics Examination Mean Scores for Years 2008 to 2012 By Gender.
Source: KNEC reports 2011 pp (vi); 2015 pp (xii)

KNEC (2013), reported that there were gender disparities in mathematics performance with boys doing better in overall performance at the KCSE national mathematics examinations. In particular learners' mathematics performance in Kibwezi Sub-County of Kenya has been poorfor the years as cited in Kibwezi (2013). The same trend at the national level is revealed at Kibwezi Sub-County where, comparatively the girls perform slightly poorer than boys. The KNEC give annual reports analysing the topics that were found challenging. One such topic is Loci which is subset of Geometry. The students are tested annually but keep on failing.The same topic was found to be the second most challenging topic in form four syllabus in a Makueni Sub-County Baseline survey (MDSBS, 2007). The topic Loci is quite challenging to students as evident from the Table2.

Marks	0	1	2	3	4
% of candidates scoring the marks	80	1	15	0	2

Table 2: Percentage of Candidates' Scoring the Indicated Marks at the 1993 KCSE Mathematics Paper One Question Number 11
Source: KNEC, 1995 KCSE Mathematics report pp 12-13

The question tested candidates' understanding of loci. It was a compulsory question and 80% of students scored zero mark out of a maximum 4. Only 2% of candidates were able to score 4 marks, which was the maximum a candidate would have scored in the question. The other candidates faced challenges in answering the question.

1.1. The Concept of Loci in Mathematics

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. "Loci" is a subset of A locus is the set of all points satisfying some condition (Casey, 2001). A locus of points is a set of points, and only those points that satisfy given conditions. It can also be defined as a path, an area or volume traced by point, line or an area that satisfy given conditions (KIE, 2005). Some of the conditions or common types of Loci include the following: The locus of points equidistant from two fixed points, which represents perpendicular bisector in two dimensions and perpendicular plane in three dimensions; locus of points a given distance from a fixed line traces, which represents two parallel lines in two dimensions and a cylinder in three dimensions; 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 (Kibui, & Macrae, 2005).In Kenya, the topic loci in mathematics is taught to form four students in secondary schools. They are tested application common types of loci to solve real life problems (MOE, 2006)

According Kinyua, Maina and Odera(2005) learners find the topic of Loci difficult to learn and to understand. The same is emphasized by KNEC (2007) who see learners finding it difficult to grasp concepts in loci while a majority of teachers' dislike teaching the topic.Salman (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. 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/ learning methods. Rule and Hllagan (2006), found that use of manipulatives that involve hands-on and minds-on activities have positive effects on improving pupils' academic achievement especially in mathematics. Kinyua *et al.* (2005) in support of using concrete objects quotes a Chinese saying that states:

> I hear and I forget,
> I see and I remember,
> I do and I understand. (p,17)

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(Walklin, 1982). In this study, the researchers constructed Geometrical models to augment the teaching of the topic loci to secondary school form four learners in

Kibwezi Sub-County of Kenya. In this study, a set of different models were used to teach different mathematical concepts in the topic loci. Some the models were joined while others were used singly. The experimental schools were exposed to the Geometrical models while the control schools were taught using the conventional teaching methods.

1.2. Problem of the Study

Mathematics is an important subject that enhances a person's logical reasoning, problem-solving skills, and in general, the ability to think critically. It is important for understanding other academic disciplines such as science and technology, medicine, economics, and engineering among others. Mathematics is generally performed poorly globally; regionally; nationally and locally. Specifically, in Kibwezi Sub-County in Kenya the performance is poor with boys performing slightly better than girls. In an attempt to seek a teaching strategy that can improve learners' achievement and reduce gender difference in mathematics, this study investigated the effects of the use of Geometrical models on learners' achievement on the mathematics topic Loci which is taught in Kenya's secondary schools by gender.

1.3. Purpose of the Study

The purpose of this study was to investigate effects of using Geometrical Models during instructions on secondary school students' achievement in the mathematics topic "loci" by gender in Kibwezi Sub-County, Kenya

1.4. Objective of the Study

The objective of study was to establish the effect of Geometrical Models on students' achievements by gender in mathematics topic Loci.

1.5. Hypothesis of the Study

- H_O: There is no statistically significant difference in mathematics achievement scores by gender among secondary school students when exposed to Geometrical Models.

1.6. Conceptual Framework

The conceptual framework to guide 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. The framework in figure 1 shows the Independent variables being teacher's use of Geometrical 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 Geometrical Models. The intervening 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 degree in education and had taught form four class for a minimum of 2 years. Mathematics achievement was the dependent variable.

- Figure 1: shows the representation of the relationships among variables within the conceptual framework.

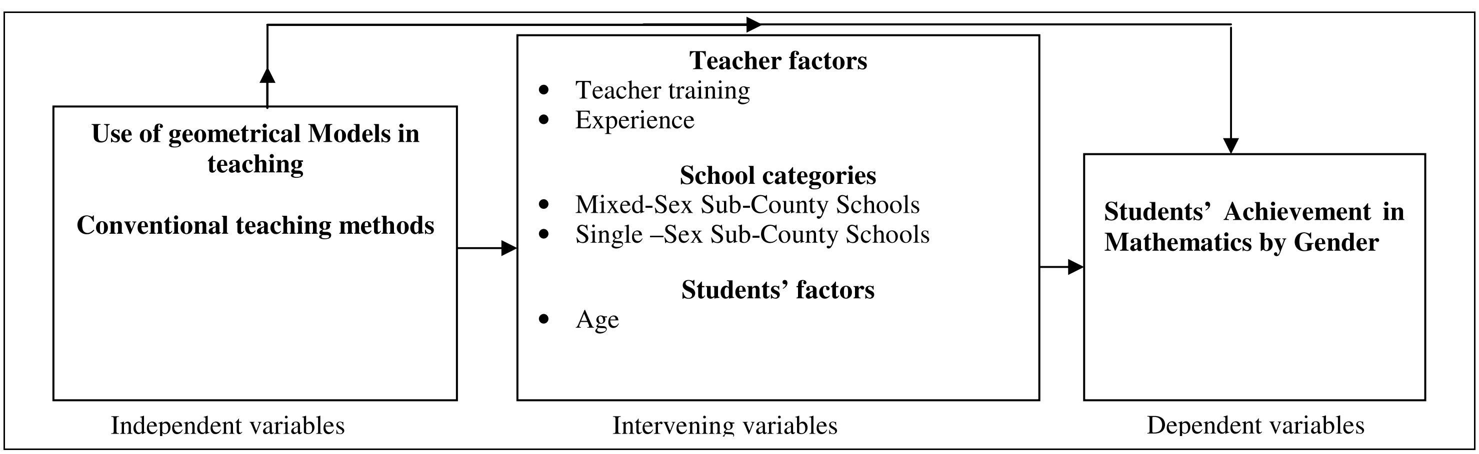

Figure 1: Conceptual Framework Showing the Relationship among Independent, intervening and Dependent Variables of the Study

2. Research Methodology

The study used a quasi-experimental method to explore the relationship between variables, as the subjects are already constituted and school authorities don't allow reconstitution for research process (Borg & Gall, 1989). This study used the Solomon 4-group; nonequivalent control group design which is appropriate for experimental and quasi-experimental studies (Ogunniyi, 1992). The design overcomes external validity weaknesses found in other designs and also provides more vigorous control by having two control groups as compared to other experimental designs. This design involves a random assignment of intact classes to four groups. 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.

Group	Pre-test	Intervention	Post-test
$T_1(45)$	A_1	X	B_1
$C_1(37)$	A_2		B_2
T_2 (44)		X	B_3
C_2 (52)			B_4

Figure 2: Solomon Four, Non-Equivalent Control Group Design

In Figure 2, Group C_1 and C_2 represent sampled control schools that will be using Conventional teaching methods. Groups T_1 and T_2 represent the sampled treatment schools that will receive the treatment. The variables are defined such that: $A_1$and A_2 are Pre-test;B_1,B_2, B_3 *and* B_4 are Post – test; and X is Experimental treatment using Geometrical Models. (---------) dash line indicates the use of non-equivalent groups while (—) means no treatment (Mugenda & Mugenda, 1999)

2.1. 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 Kibwezi sub county Education office there are 62 secondary schools that are categorised as follows: 2 Single-Sex Extra County Secondary Schools, 5 Mixed –sex County Secondary schools, 2 Single-Sex County Secondary Schools, 51 Mixed –Sex Sub-County Secondary Schools, and 2 Private Secondary School. The target population in this study will be 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 will be form four students in Mixed-Sex Sub-County schools which have enough schools for the chosen research design. There are 3,440 forms four students in Kibwezi Sub-County out of which 2,472 are in Mixed Sex Sub-County schools (Kibwezi Sub-County Education Office, 2014).

2.2. Sampling Procedure and Sample Size

Four schools were chosen because the Solomon 4-Group Design requires four groups where each school will form a group. To ensure that there are minimal interactions between the experimental and control groups, a simple random sampling was used to assign each group to a Division. Kibwezi sub-county has four Administrative Divisions namely: Machinery, Mtito, Kibwezi, and Kambu with mixed sub-county schools' distribution being 12, 14, 15 and 10 respectively in the four Divisions. A purposive random sampling was used to select schools in each Division that have even distribution of gender and have graduate teachers teaching form four. The purposively selected schools were again simply random sampled to select schools that participated in the research in each Division. The sampling was appropriate because it ensured that all schools had equal chances of being included in the study sample. According to Mugenda and Mugenda (1999), the required samplesize is at least 30 cases per group. Each class had more than 30 students. The sample size was178 students, 75 girls and 103 boys.

2.3. Instrumentation

The mathematics achievement test (MAT) was used to collect the required data. It was a thirty-one items 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 minimum and maximum score for the test were 0 and100 respectively. Its reliability was 0.73 from K-R-20 formula. The pilot testing was conducted in Makindu Sub-County that is next to Kibwezi Sub-County.

2.4. How Geometrical Models Were Made and Used for Teaching

The mathematics topic loci were taught to form four students in the experimental schools by use of Geometrical models. The following Specific objectives of teaching Loci were to be achieved by learners at the end of the topic: Define loci in two, 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, 2006; KNEC, 2010). The researchers made the Geometrical Models which represented the real-life situations, items, and objects that students meet in their day-today life. The models were used to demonstrate the concepts in loci. Some of the Geometrical models that were joined together while others worked singly. Some models represented the following: 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 other model'sdemonstration box, where various loci are drawn; 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 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.

3. Results

3.1. Results of the pre-test

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

	C1	E1	C2	E2	Total
Female	18	19	24	20	75
Male	19	26	28	24	103
Total	37	45	52	44	178

Table 3: Students who participated in the research study by experimental and control schools and by gender

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 treatment application as recommended by Gall, Borg and Gall (1996). Table 4 shows the t-test of pre-test scores in MAT

Variable	Group	N	Mean	SD	df	t-computed	t-critical	p-value
MAT	Female	37	19.38	9.22	80	0.9172	1.9864	0.3615
	Male	45	21.13	8.93				

Table 4: Independent sample t-test of pre-test scores on MAT based on group's gender
Not significant at p>0.05 level

Table 4 shows the results of pre-test with reference to gender. 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 (91) = 0.9172 and p>0.05 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 Geometrical Models, 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; Wachanga, 2002) as cited in Njoroge (2005).

3.2. Effect of Geometrical Models on students' Achievements by Gender in Loci Topic of Mathematics

Further analysis was performed with Hypothesis HO_1 that sought to establish whether there was a statistically significant gender difference in mathematics achievement scores among secondary school students when exposed to Geometrical Models. Table 5 shows the t-test results of post-test MAT score based on gender.

Variable	Group	N	Mean	SD	df	t-computed	t-critical	p-value
MAT	Female	39	36.44	13.89	87	1.7088	1.9842	0.0906
	Male	50	41.02	13.77				

Table 5: Independent sample t-test of post-test scores on MAT based on gender

The t-test revealed no significant gender difference in mathematics achievement score between the female and male students, t (99) = 1.7088, p > 0.05. Both male and female students performed relatively the same. There was no significant difference between the 39 girls and 50 boys exposed to the Geometrical models though the boys had a slightly higher MAT mean gain score as shown in Table 6.

Test	Male	Female
Pre-test	21.13	19.38
Post-test	41.02	36.44
Mean gain	19.89	17.06

Table 6: Comparison of mean gain of students' pre-test and post-test scores in MAT

The Hypothesis HO_1 that stated that there are no statistically significant differences in mathematics achievement scores gender among secondary school students when exposed to Geometrical Models was therefore accepted at 0.05 α – level.

3.3. Discussion

3.3.1. Effect of Geometrical Models on Students' Achievements by Gender in Loci Topic of Mathematics

The findings of this study have shown that there was no statistically significant difference in mathematics achievement scores between male and female students taught through Geometrical Models. The result also indicated that both male and female student taught using Geometrical Models performed significantly better than their counterparts who were taught using conventional teaching /learning methods. Therefore, Geometrical models proved to be more effective in enhancing mathematics achievement for both male and female students than the conventional methods.

KNEC results, shows that female students continue to underachieve in mathematics at national examinations despite various interventional measures (KNEC, 2007, 2005, 2003, 2002). Gender differences in mathematics achievement begin to appear at upper primary school level and increase in secondary schools (Mondoh, 2001) as cited in Njoroge (2005). Most girls underestimate their own academic ability and believe boys to be relatively more superior and intelligent in handling difficulty 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). This view supports an earlier finding by Makau and Coombe (1995) that attributes gender difference, in mathematics achievement to interaction of factors within and outside the school as well as students' background.
The finding of this research agrees with other findings (Vale, 2009), who found no significant gender difference in mathematics achievement. In Nigeria, gender-achievement studies by Abiam and Odok (2006), found no significant relationship between gender and achievement in number and numeration, algebraic processes and statistics. They however found the existence of a weak significant relationship in Geometry and Trigonometry. On the contrary other 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). According to Agwagah (1993), the female students perform significantly better than their male counterparts in Nigeria. Loci- Kit models assisted the mathematics teachers in balancing interaction patterns in class for both male and female students. Teachers were therefore able to give both male and female students similar attention and reward. This resulted in higher achievement by both. The gender differences in achievement at KCSE mathematics can therefore be addressed by using Geometrical Models.

4. Implications of the Study

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

5. Recommendation

It is recommended that the use of Geometrical 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.

(i). A study to determine the mathematics teachers' and students' perceptions of the classrooms environment while teaching and learning using Geometrical models.
(ii). A study of the effect of computer simulation of the Geometrical models with respect to mathematics achievement.
(iii). 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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