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Effects of Mathematical Vocabulary Instruction on Students' Achievement in Mathematics in Secondary Schools of Murang'a County, Kenya

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Abstract
This article is based on a study whose main objective was to determine the effects of mathematical vocabulary instruction on students' achievement in Mathematics in Secondary schools in Murang'a County, Kenya. The study was a non-equivalent control group pretest-posttest quasi-experimental design and was conducted in the two purposively selected secondary schools in Kahuro District in Murang'a County, Kenya. Both the experimental and the control groups consisted of fifty four (54) students from each school. The experimental groups were exposed to mathematical vocabulary instruction using the Graphical Organizer based on the Frayer Model with ICT integration instructional approach for ten (10) weeks. The control group was taught mathematical vocabulary by the definition-only method for the same period. Data were analysed using one-way ANOVA, independent t-test and paired t-test. The findings indicated that there is a statistically significant mean difference in the students' performance in Mathematics between those taught Mathematics vocabulary using the Frayer Model with Technology and those taught Mathematics using the definition-only method.
Keywords: Mathematics vocabulary instruction, Frayer Model, Mathematics Vocabulary

1. Introduction

Mathematics is one of the key subjects offered in the Kenyan secondary school curriculum. Due to value afforded to mathematics by the society, the subject has been made compulsory for all learners until the end of the secondary school course. Despite the importance to which the society values mathematics, the performance of the students in the annual National secondary school examination (KCSE) has been dismal. In this paper we show posit that a key component in understanding mathematics is learning mathematics vocabulary. Mathematical vocabulary refers to words that label mathematical concepts for example quotient, volume, vertex, dividend, and hexagon (Sanders, 2007). According to Miller (1993: 12) students are likely to be handicapped in their effort to learn mathematics if they do not understand the vocabulary that is used in mathematics classrooms, textbooks and assessment tests. One of the obstacles that make mathematical vocabulary difficult to learn is lack of opportunity (Paul and Sinha, 2010). This is because much of the vocabulary used in mathematics classroom is rarely encountered in everyday life. In addition, mathematics teachers often neglect meaningful vocabulary instruction. Also, many terms have meanings in the realm of mathematics that differ from their meanings in everyday usage (Njoroge, 2003).

Without appropriate vocabulary instruction, students are likely to experience difficulties and interference in the learning of concepts for which they have background knowledge that appears unrelated to mathematics. Students need to know the meaning of mathematics vocabulary words-whether written or spoken-in order to understand and communicate mathematics ideas. According to Sanders (2007), terms, phrases, and symbols are essential in communicating mathematical ideas; and becoming fluent with them is vital for children's mathematical learning. Research reveals that the knowledge of mathematics vocabulary directly affects achievement in arithmetic, particularly problem-solving (Staley, 2005). Riordain and O'Donoghue (2009) indicated that vocabulary knowledge is strongly related to overall academic achievement in school. Although students may excel in computation, their ability to apply their mathematics skills will be hindered if they do not understand the vocabulary required to master content and able to apply in future situations. Thus teaching vocabulary in the mathematics content area is a critical element of effective instruction.

Although Mathematics is a visual language of symbols and numbers, it is expressed and explained through written and spoken words. Thus, for students to excel in Mathematics, they must recognize, comprehend and apply the requisite mathematical vocabulary. Teaching mathematical vocabulary words solely as definitions as is the practice in most Kenyan schools does not assist students in comprehending the word when found in Mathematics textbooks and examination items. Students must be actively engaged in building background knowledge using key content-specific vocabulary. This paper is based on findings from a study that was carried out in Murang'a County, Kenya to determine the effects of Mathematical vocabulary instruction on students' achievement in Mathematics.
The study**; "***effects of mathematical vocabulary instruction on students' achievement in mathematics in secondary school" was carried out in Murang'a County, Kenya by the first author.*

The objective of the study was to determine the extent to which mathematical vocabulary instruction influence students' performance in Mathematics and the following null hypothesis was used to answer the research question:

$H_0 1$: There is no significant difference in students' performance in Mathematics between those taught Mathematics vocabulary using the Frayer Model with ICT integration and those taught mathematical vocabulary using the definition-only method.

2.0. Literature Review

According to Chall (1987), there are two general methods for teaching vocabulary: Direct teaching and Meaningful Context. Direct teaching of vocabulary guides students to assign deeper meaning to words. The method commonly used by teachers who teach vocabulary directly is the definition-only method (Naggy, 1988). In this instruction, students typically look up the word in the dictionary or are told its definition, write meaning of the word, and memorize it. According to Irvin (1990), this method is ineffective because it leads to minimal understanding. In contrast to the definition-only method, which leads to surface understanding only, some direct methods can be effective in helping students assign deeper meaning to words. According to Moore & Readance (1984) and Dunston (1992), the graphic organizer may be one of the more promising approaches. A graphic organizer represents concepts and their relationships visually.

Monroe & Pendergrass (1997) carried a study on the combined approach. In a learning context emphasized student construction of meaning, the teacher provided opportunities for learners to learn to represent, discuss, read, write and listen to Mathematics. Once students had some experiences with a concept, the teacher taught vocabulary directly using graphic organizer to help access and organize newly acquired knowledge. The graphic organizer also provided a structure for guiding students to extend relationships among concepts. In conclusion, approaches that combine meaningful context and direct teaching through the use of graphic organizer were used in the current study in teaching mathematical vocabulary. The method employed was the Frayer Model with ICT integration.

The Frayer Model was designed by Dorothy Frayer (1969) and her colleagues at the University of Wisconsin USA. The Frayer model provides a graphic organizer that asks students to organize their thinking about a term in four ways; definition, characteristics, examples and non-examples. The definition goes in the top left square, characteristics in the top right square, examples in the bottom left square and non-examples in the bottom right square. The definition should be one the student develops rather than something copied from a dictionary or glossary. The characteristics of the term should be things that are essential. The examples and non-examples help push students' thinking about the term. The structure and thinking processes incorporated in this strategy provides an opportunity for students to build a deep understanding of the term (Roe & Smith, 2012).A template of the Frayer model is displayed in Figure 1.

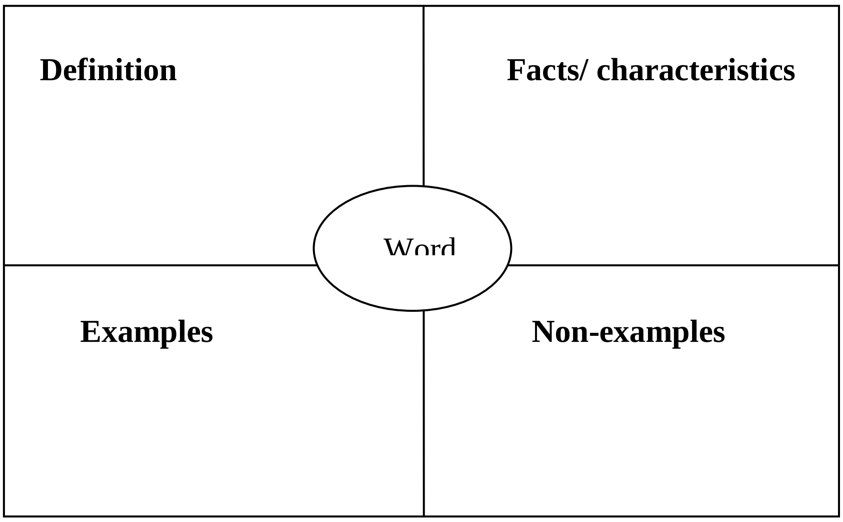

Figure 1.0 A Template of The Frayer Model
Source: Frayer, D., Frederick, W. C., and Klausmeier, H. J. (1969). *A Schema for Testing the Level of Cognitive Mastery*. Madison, WI: Wisconsin Center for Education Research.

One advantage of this strategy is that, students are active learners and are noticeably highly motivated. Students learn best through active involvement in learning new words (Roe & Smith, 2012). Consequently, students exposed to the Frayer model tend to go far beyond learning mere definitions of words; instead, they develop a far deeper understanding of concepts. As a result the use of the Frayer model increases the students' understanding of new vocabulary, and they show a deeper and more complex understanding of concepts (Cohen & Cowen, 2008). The process of stating a definition, describing characteristics and articulating examples and non-examples helps students develop a deeper understanding of a word than they might achieve from only a definition (Greenwood, 2010).

3.0 Methodology

The study employed a non-equivalent control group pretest-posttest quasi-experimental design. According to Wiersma & Jurs (2005), a nonequivalent control group pretest-posttest quasi-experimental design is suitable when intact groups of participants are used in an experiment rather than assigning participants at random to experiments treatments. The design was found to be suitable because as Mugenda (2008) notes the administrators in educational institutions do not allow dismantling of the intact classes so as to allow for random assignment.

The notational paradigm of the design can be summarized as shown below:

Experimental Group	O_1	X	O_3
....			
Control group	O_2	●	O_4

Key: O_1 and O_2 represent the pre-test observations, X-Mathematics Vocabulary Frayer Model with ICT integration, ● -Mathematics Vocabulary Instruction using the definition-only method, O_3 and O_4 represent post-test observations for the experimental and control groups respectively. The dashed line separating the parallel rows in the diagram indicates that the experimental and control groups have not been equated by randomization (Cohen, Manion and Morrison 2011, p. 323)**.**

The independent variables were the mathematical vocabulary teaching strategies while Students' performance in Mathematics formed the dependent variables. The teaching strategies for this study were the Frayer Model with ICT integration for the experimental group and the definition-only for the control group.

The study sample consisted of two Secondary Schools in Kahuro District, Kiharu Constituency of Murang'a County, Kenya. The schools were purposively chosen. The choice of the two schools was informed by the fact that they are in the same administrative Location, get students from the same catchment area, score almost equal Mean Standard Scores in KCSE, have similar facilities and are accessible in terms of communication.. Moreover, the schools were equipped with ultra-modern computer laboratories where students' of the experimental group could access the maths dictionary by Jenny Eather at www.amathsdictionaryforkids.com.

Simple random sampling technique was used to select two out of the four (4) Form Two (II) classes in the boys' school. Similarly, two out of the five (5) Form Two (II) classes in the girls' school were randomly selected.. Census strategy was used in the selection of the participating students. A sample of 108 Form Two (II) students from each school was selected for the study giving a total study sample of Two Hundred and Sixteen (216).

The 216 study participants responded to a Pre-test Mathematics test. The study involved teaching the control and experimental groups mathematical vocabulary using different strategies. Participating teachers were trained on how to use the Frayer model The presentation rate was one word per lesson to a total of ten items for the study similar to the one employed by other research implementation studies (Mastropieri, Sweda and Scruggs, 2000; Sander, 2007). The two control groups were taught the 10 Mathematics vocabulary words for a period of ten weeks between May and July 2013 using the definition-only strategy The other two experimental groups were taught 10 Mathematics vocabulary words for the same period but using the Frayer Model with ICT integration strategy. The students from all the groups were given The Mathematics Vocabulary Dictionary (SMVD) during the lesson and collected after. Guiding notes for the lesson planning for teaching Mathematical vocabulary were developed by the researcher with collaboration of experts in Mathematics Education from Kenyatta University and CEMASTEA. The lessons for the experimental group were taught in the Computer Laboratory and students were allowed to access the site:
http:// www.amathsdictionaryforkids.com in the course of the lesson. The control group was also taught one lesson per week in the computer laboratory but did not access the site. One vocabulary was taught by the trained teachers per lesson per week. The ten (10) vocabularies were taught for 10 weeks. After the 10 weeks, the study participants responded to the Post-Test Mathematics Achievement Test, POSMAT.

In order to achieve the objective and increase reliability of findings,, the study employed five (5) instruments namely: Pre-test Students' Mathematics Vocabulary Test (PRESMVT), Posttest Students' Mathematics Vocabulary Test (POSMVT), Students' Mathematical Vocabulary Dictionary (SMVD), Pretest Students Mathematics Achievement Test (PRESMAT) and Posttest Students Mathematics Achievement Test (POSMAT). The Pre-test Students' Mathematics Vocabulary Test (PRESMVT) constituted five (5) Mathematical words drawn from Form One Mathematics syllabus. To determine the target vocabulary for this study, the following rigorous procedure was used to select the five words for the PRESMVT. First, the Mathematics teachers in the study location were requested through an email to identify from their experience, problematic words from the 8.4.4curriculum, Form One syllabus. The initial suggestions were combined and mailed out again, this time with a rating scale. Teachers rated the difficulty level of each word on a scale of 1-5.

1. Not a problem
2. A small problem
3. Sometimes a problem when used in certain contexts
4. Always a problem

5. and a major difficulty to most of the learners

The teachers also rated the words according to their impact on test success. (1) No impact on test scores (2) small impact on test success (3) some impact on test success (4) big impact on test success (5) a major impact on test success. The rating depended on their perception of how the word would influence success rate of a student to get a question right if the word appeared in a question. The scores from each of these categories were averaged and then both averages were added together to form a composite score. The total score for each word was calculated and the words rank ordered. The teachers then received another email asking for their final input. The most top-scoring words on the final list were removed and others were also removed due to the difficulty in representing in a picture or diagram. The final selection lists of 15 vocabulary terms were emailed to the teachers. They included (1) Product (2) Factors (3) chord (4) polygon (5) degree (6) scale (7) power (8) area (9) integer (10) multiple (11) perimeter (12) capacity (13) ratio (14) angle (15) percentage.

Five vocabulary words were used for the pre-test survey while ten (10) were used for the post-test survey. This included perimeter, percentage, capacity, ration and angle. Students were required to define the word, use the word in a sentence and draw a picture or diagram that visually represents the meaning of the word. Each attracted one mark totaling to fifteen (15) marks.

The Pre-test Students' Mathematics Achievement Test (PRESMAT) aimed at determining students' application of Mathematical vocabulary in answering Mathematical questions. It was constructed with some items adapted from KNEC (2008, 2009 & 2010). It consisted of five (5) Mathematical problems applying the five (5) Mathematical Vocabularies of the PRESMVT. A table of specification was drawn and the items written following Bloom's levels of cognitive taxonomy. The five questions were from each of the five levels. Each question was scored a maximum of three (3) marks totalling to 15 marks. The Post-test Students' Mathematics Achievement Test (POSMAT) also aimed at determining students' application of Mathematical vocabulary in answering Mathematical questions. It was constructed with some items adapted from KNEC (2008, 2009 & 2010). It consisted of ten (10) Mathematical problems applying the ten (10) Mathematical Vocabularies of the POSMVT. A table specification was drawn and the item written following Bloom's levels of cognitive taxonomy. There were two questions from each of the first five levels. Each question scored maximum of three (3) marks totalling to 30 marks. It was administered to the students in a staggered manner, each at the end of the day after the lesson for the ten (10) weeks. Scores of the ten (10) tests were compiled for each student at the end of the 10 (ten) weeks.

Data germane to the study was both quantitative and qualitative. Quantitative data were analysed using Statistical Package for Social Sciences (SPSS) Version 21.0. Quantitative analysis involved presentation of statistical data in form of frequency distribution tables whose explanation was mainly descriptive and inferential statistics. The analysis focused on comparing the mean scores of students' performance in the POSMAT for those exposed to the Frayer Model and those exposed to the conventional method. The statistical significance of the results was then examined at $\alpha = 0.05$ statistical confidence level. Quantitative data was further analyzed using independent t-test, paired-t-test and 2-way ANOVA. Student's t-test was used to compare the means in student's performance in the Mathematics Achievement Test between the experimental and control groups. Qualitative data was analysed thematically whose main focus was to determine the strategies for mathematics vocabulary instruction.

4.0 Findings

The study performed a paired samples t-test for the four groups between pre-test and post-test.

Table 1. Paired samples t-test for the four groups between pre-test and post-test

Group	**n**	**PRE-TEST**		**POST-TEST**		**PAIRED MEAN DIFFERENCE**		**t-test**		
		MEAN	SD	MEAN	SD	MEAN	SD	t	df	Sig. (2-tailed)
Boys Exp	54	5.28	3.212	9.57	5.812	4.296	6.512	4.848	53	.000
Boys Control	54	6.02	2.798	6.78	2.912	0.759	2.480	2.250	53	.029
Girls Exp	54	5.80	2.131	8.70	3.298	2.907	3.997	5.356	53	.000
Girls Control	54	5.78	2.508	6.65	2.283	0.870	3.172	2.015	53	.049

The results (Table 1) shows that there was a significant mean gain in all groups between pre-test and post-test; Boys experimental (mean gain= 4.296, $t(53) = +4.848$, $\rho > .0001$), Boys Control (mean gain = +0.0759, $t(53) = +4.848$, $\rho = .029$), Girls experimental (mean gain = + 2.907, $t(53) = 4.848$, $\rho > .0001$) and Girls control (Mean gain = + 0.870, t (53) = 4.848, ρ =.049).this can be explained by the fact that mathematics vocabulary instruction whether by definition only or by the Frayer model contributes significantly to students performance in Mathematics.

In order to test if there is any significant difference between students' performance in Mathematics for students taught Mathematics vocabulary using the Frayer model with ICT integration and those taught using definition-only method, an independent t-test was performed.

Table 2. Independent t-test for students performance in Post-test Mathematics test

Group	*n*	*Mean*	*SD*	T	df	Sig. (2-tailed)
Boys Experiment	54	9.57	5.826	-3.155	106	.002
Boys Control	54	6.78	2.912			
Girls Experiment	54	8.70	3.289	-3.773	106	.000
Girls Control	54	6.65	2.283			

The results (Table2) indicated that that boys experimental group (M = 9.57, SD = 5.826) performed better than the boys control group (M = 6.78, SD = 2.912) in the post-test Mathematics achievement test (POSMAT). On the other hand, the girls experimental group (M = 8.70, SD = 3.298) performed better than the girls control group (M = 6.76, SD = 2.283) in the post-test Mathematics achievement test. The study shows that there is a statistically significant mean difference between boys experimental and the boys control group, absolute t (106) = 3.155, ρ = .002. Also, it shows that there is a statistically significant mean difference between the girls experimental and girls control groups, absolute t (106) = 3.773, ρ > .0001. A Tukey's H*SD* post hoc test revealed that there was a statistically significant mean difference between the mean scores of the POSMAT between the boys control and the boys experimental groups (ρ = .001) and the girls control and the experimental groups (ρ =.001). The study hypothesis, $H_0 1$, *there is no statistically significant difference in students' performance in Mathematics between those taught Mathematics vocabulary using the Frayer model with ICT integration and those taught using definition-only method* was rejected. The alternative hypothesis, H_3 was accepted. Thus, the study concluded *that there is a statistically significant mean difference in students' performance in Mathematics between those taught Mathematics vocabulary using the Frayer Model with ICT integration and those taught mathematical vocabulary using the definition only method.* The effect size, r = 0.1875 obtained indicated a small effect size.

5. Conclusions

The study found that the Frayer Model when integrated with Technology provided better opportunities for learners to understand the interaction with mathematics content. The study concluded that a well-developed and executed mathematics vocabulary instruction can effectively improve students' achievement in Mathematics. It also concluded that the use of graphical organizers based on the Frayer model with ICT integration is an effective method for Mathematics vocabulary instruction. The method is a cognitively guided instructional strategy. It involves three broad steps. The first step is the *Introduction stage*. Here, the teacher presents the mathematical vocabulary that might be confusing because of its relational qualities or one to be encountered in a topic. The teacher then divides the class into groups, provides materials and worksheets. The teacher then explains the Frayer model diagram to the learners. The second step is the *Development stage*. The learners find the examples, non-examples, facts and characteristics of the vocabulary to complete the diagram. They also use textbooks, login in the internet and other supplementary materials to aid in the exercise. They then makes foldable of the word. Once their diagrams are complete, the various groups make their presentations. The teacher harmonizes the results from the groups. The last stage is the *Conclusion stage*. It is the closure stage. In this step, the review of the lesson is done. Exercises for further activities are also given.

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