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EFFECTS OF PRACTICING MATHEMATICAL CREATIVITY ENHANCING LEARNING/TEACHING STRATEGY DURING INSTRUCTION ON SECONDARY SCHOOL STUDENTS' MATHEMATICS ACHIEVEMENT BY GENDER IN KENYA'S NAKURU MUNICIPALITY

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ABSTRACT

Learners' mathematics achievement worldwide and Kenya in particular has been unsatisfactory. Mathematics examination results at the Kenya Certificate of Secondary Education (KCSE) for instance have been consistently dismal over the last decade. Findings of most studies globally and in Kenya attribute this unfavorable state of affairs to ineffective teaching methods employed by mathematics teachers among other factors. The purpose of this study was therefore to determine the effects of using mathematical creativity enhancing learning/teaching strategy on learners' mathematics achievement by gender. The study used the Solomon Four non-Equivalent Group Research Design. The target population comprised of form 2 students aged 16 years in sampled secondary schools of Nakuru Municipality. The students were randomly assigned in their intact classes to the four groups, namely experimental group one (E_1), experimental group two (E_2), control group one (C1) and control group two (C2). All the four groups were taught the topic: 'Quadratic Expressions and Equations' in Kenya's form 2 secondary school mathematics syllabus. Teaching was conducted with an emphasis on enhancement of the four dimensions of mathematical creativity namely; fluency, flexibility, elaboration and originality in the experimental groups while the control groups were taught using conventional teaching methods. A mathematics achievement test (MAT) validated by experts had reliability coefficient of 0.84. Data was analyzed using the statistical package for social sciences (SPSS) by use of both descriptive and inferential (t-test and ANOVA) statistics to assist in the interpretation. A significance level of $\alpha=0.05$ was used to test the null hypotheses. The results indicated that students taught using mathematical creativity enhancing teaching strategy had significantly higher scores in MAT than students taught in the conventional teaching strategy. The results were inconclusive on whether there is or no statistically significant gender difference in the learning of mathematics among secondary school students who were exposed to mathematical creativity enhancing teaching strategy (MCETS). The researchers concluded that MCETS is an effective teaching/learning strategy which mathematics teachers need to incorporate in their teaching.

Keywords: Practicing mathematical creativity enhancing learning/teaching strategy, mathematics achievement, Kenya

INTRODUCTION

There is a general agreement in society that every child should study mathematics at school in order to acquire skills for adult life (Orton & Wain, 1996). Mathematics is regarded by most people as being essential because of the type of skills and knowledge that learners acquire for use in everyday life, and also for its application to modern science and

technology, industry, commerce and related professions (Baxton, 1984; Cockcroft, 1982). Knowledge of mathematics is a filter of students into science related courses at Universities and careers (Eshiwani, 1984).

Science and mathematics are closely intertwined with the development of modern technology. Mathematics to a greater extent is the language of science (Johnson & Rising 1972). The development of skills in logical reasoning and problem solving is a goal of both science and mathematics instruction (National Council for Teachers of Mathematics, (NCTM), 1980; National Science Teachers Association, (NSTA), 1983). Consequently, science and mathematics reinforce each other in facilitating better learners' cognitive development (Almy, 1996).

Despite its importance to individuals and society globally, mathematics is a subject that is poorly performed at national examinations by many secondary school students worldwide and in Kenya (Miheso, 2012; Mji and Makgato, 2006). There are various factors that affect the learners' performance in mathematics. Some of these are: use of difficult specialized mathematical language (Nor et al, 2011); students' negative attitudes (Onyango, 2012) poor teaching methods and shortage of textbooks (Eshiwani, 2001); ineffective teachers-centered teaching methods (Miheso, 2012) and lack of motivation by teachers and learners' in the mathematics classrooms (Tswani, 2009).

Students' mathematics performance has persistently been dismal at the Kenya Certificate of Secondary Education (KCSE) national examinations in Kenya (KNEC, 2010) and in Nakuru municipality of Kenya in particular.

Table 1 show that the mean mathematics achievement scores at KCSE in Nakuru municipality for the years 2007 to 2010 was below 40% for all the four years.

Table 1. Students Mathematics performance in Nakuru Municipality, Kenya between the years 2007 and 2010

Year	*Mean score %*
2010	33.22
2009	37.43
2008	39.39
2007	38.62

Source: Nakuru Municipality, Kenya Educational Statistics 2007 to 2010

The dismal students' performance in mathematics at KCSE closes many candidates from the university entry into prestigious science-based courses at the Universities in Kenya. At the international scene learners' performance in mathematics in both primary and secondary schools is not any better as indicated by TIMMS of 2004. The findings showed that there were large differences across countries in the world as indicated by percentages of students' mathematics scores compared to international benchmarks at the fourth grade. Singapore had 38% of its students reaching the advanced international benchmark, followed by just over 20% of the students in Hong Kong and those from Japan. The highest performing countries at the eighth grade had about one third or more of their students reaching the advanced international benchmark. In contrast, 19 of the lowest-performing countries had 1% or less of their students reaching this benchmark.

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In an attempt to seek more effective teaching/learning strategies in mathematics classrooms in order to improve learners' mathematics achievement at the end of secondary schools, this study investigated whether the use of mathematical creativity enhancing teaching strategy during mathematics instruction has any improvement on learners' achievement in the subject in secondary schools of Nakuru Municipality, Kenya.

MATHEMATICAL CREATIVITY

In the current study a teaching/learning strategy was employed in a mathematics classroom in an attempt to enhance learners' mathematical creativity. According to Haylock (1987) there is no one accepted definition of mathematical creativity. It is a multifaceted construct describing learners' ability to be involved in convergent or divergent thinking, mathematical problem finding and problem solving, clear, precise expression of mathematical facts and a possession of intrinsic motivation to learn mathematics. There are four dimensions of mathematical creativity (Kim, et al, 2003: Imai, 2000; Haylock, 1997). These include (i) fluency which is the number of responses a learner can give to a mathematical question (ii) flexibility, the shift in categories or methods in the responses to a given mathematics task (iii) originality, when responses are novel compared to others to the same mathematical task and (iv) elaboration, the ability of a learner to extend, improve or give constructive criticism to standard known methods of solving a mathematical problem (Imai, 2000).

Criteria to measure creative mathematical potential had been developed in earlier studies to include: ability to formulate hypothesis; identify patterns in mathematics situations; breaking mindsets when solving problems; evaluate unusual mathematical ideas; sense what is missing and fill missing information in a mathematical situation; and ability to split a mathematical problem into specific sub problems (Balka, 1974a). These characteristics were encouraged in mathematics classrooms in secondary schools of Nakuru Municipality, Kenya. In this study the mathematics topic "Quadratic Expressions and Equations" was taught to Form two secondary school 16 year old learners in Kenya's Nakuru Municipality with a conscious effort to enhance their mathematical creativity in the four dimensions.

Previous studies show that there is significant relationship between mathematical creativity and achievement (Kadir & Maker, 2011; Ganihar and Wajiha, 2009; Brunkalla, 2009). Others however Erdogan, Aydin and Kabaca (2008) found no significant relationship between students' mathematical creativity and achievements. Gender differences on mathematical creativity has been found to exist in flexibility dimension favoring girls (Bare, 2008; Sak & Maker, 2006; Ai, 1999) while the boys surpass the girls on the other three dimensions of mathematical creativity. Pooja (2012) concurs that girls surpass boys on flexibility while solving problems but do not differ with boys on; fluency, originality and elaboration.

STATEMENT OF THE PROBLEM

Mathematics is important to an individual and for national and international development. However learners perform dismally worldwide and at KCSE examinations in Kenya. The same poor learners' performance is witnessed at KCSE in Nakuru Municipality of Kenya. In an attempt to seek better teaching strategies in order to improve learners' achievement in the subject, the current study investigated the effect of mathematical creativity enhancing teaching strategy on learners' mathematics achievement by gender.

PURPOSE OF THE STUDY

The purpose of this study was to develop and use the mathematical creativity enhancing teaching strategy on students' achievement in mathematics by gender.

RESEARCH OBJECTIVES

1. To compare the students' achievement in mathematics between learners taught through mathematical creativity enhancing teaching strategy and those taught using conventional teaching methods.
2. To compare students' mathematics achievement by gender between those exposed to mathematical creativity enhancing teaching strategy and those taught through conventional teaching methods.

RESEARCH HYPOTHESES

The following null hypotheses were tested at 0.05α level:

HO_1 There is no statistically significant difference in mathematics achievement between students' exposed to mathematical creativity enhancing teaching strategy and those taught through conventional teaching methods.

HO_2 There is no statistically significant gender difference in students' mathematics achievement between those exposed to mathematical creativity enhancing teaching strategy and those taught through conventional methods.

CONCEPTUAL FRAMEWORK

The conceptual framework for this study was guided by the system theory as postulated by Joyce and Weil (1980). The framework shown in Figure 1 was based on the assumption that a teaching approach that involves the use of mathematical creativity enhancing teaching strategy leads to worthwhile learning than a purely transmission teaching strategy would do. The dependent variable in this study was the students' achievement in quadratic expressions and equations. The researcher investigated whether the use of mathematical creativity enhancing teaching strategy would influence the students' achievement in mathematics as compared to the use of "conventional" or traditional teaching methods which are teacher-centered. The independent variables in this study were the mathematical creativity enhancing strategy and the regular or conventional teaching methods.

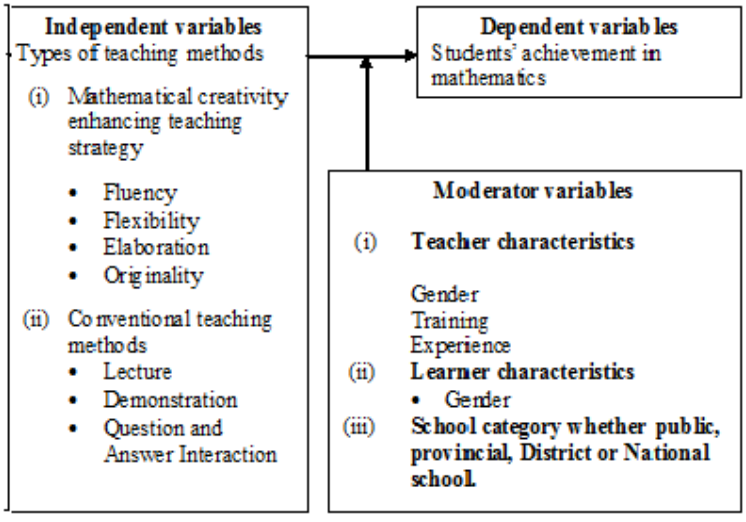

Figure 1. The representation of the relationship among variables within the conceptual framework

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In addition to these variables and noting that the outcome of the study was likely to be influenced by the gender of students, teacher's characteristics and school category, the researcher introduced three moderator variables in the study.

Women and men mathematics teachers were also involved. To account for the teachers' experience and qualification, the study included teachers who have minimum qualification of a diploma in education and had taught form two class for a minimum of two years. Four public, provincial, co-educational secondary schools were used from Nakuru municipality.

METHODOLOGY

Solomon Four-quasi-experimental research design was used in the study. It had four non-equivalent groups (Gall et al., 1996). This design was considered appropriate because the subjects were already constituted and it was not possible to randomly select them individually. The design involved a random assignment of intact classes to four groups with two groups being experimental and other two being controls as shown in Table.

Group 1	*Pre-test*	*Treatment*	*Post-test*
E_1	O_1	X	O_2
E_2		X	O_3
C_1	O_4		O_5
C_2			O_6

Source: Gall et al. (1996).

The research design: -

There were Four Groups of Subjects: the experimental group one (E_1) the experimental group two (E_2), the control group one (C_1) and the control group two (C_2) which were used. Group E_1 and E_2 formed the experimental groups while C_1 and C_2 formed the control groups. Group E_1 and C_1 received a pre-test (O_1 and O_4) to ascertain whether or not the groups under study had comparable characteristics while E_1 and E_2 got treatment (X), that was an exposure to mathematical creativity enhancing strategy. All groups in this study received a post-test that facilitated comparisons between them.

Sampling Procedure and Sample Size

The target population was Form two mathematics students aged 16 years from provincial public secondary schools within Nakuru Municipality, Kenya. This ensured that the academic ability of the students was comparable because of the same cut-off points of entry into public provincial secondary schools. Four schools two experimental and two controls were sampled with an average population of 40 students per school. This gave approximately 160 subjects as the sample size for the study. The form two learners in the two experimental schools were taught by use of mathematical creativity enhancing teaching strategy. The other form two students in control groups were taught the same topic by use of conventional teaching methods.

Instrumentation

The mathematics achievement Test (MAT), was used to measure students' mathematics achievement. It was pilot tested among mathematics educators for face and content validity and its reliability found to be coefficient alpha=0.84.

Mathematical Creativity Enhancing Teaching Module on the Mathematics Topic 'Quadratic Expressions and Equations in Form Two Mathematics

The researchers developed a teaching module for the topic "Quadratic expressions and Equations". Teachers guide on the learners' development of mathematical creativity in four dimensions during instruction was used to induct mathematics teachers in experimental schools on how to enhance the development of the four dimensions of mathematical creativity among learners', namely: fluency, flexibility, originality and elaboration (Horrance, 1995, Haylock 1997; Krutetskij; 1976) as they taught the topic: 'Quadratic Expressions and Equations'. This training took one week. When teaching to enhance flexibility for example, learners were asked questions like 'How many different ways would you solve this equation? Fluency required the learner to provide many different ways of expanding a mathematical expression; elaboration required answering questions like 'what else….' that is, extending, improving methods of solving an equation while originality required answering questions like why or what is it, that is requiring the students to provide novel, unobvious responses.

RESULTS

Results of the Pre-Test Analysis of Scores on MAT

The aim of pre-testing was to ascertain whether the students who participated in the study had comparable achievement in mathematics before the teaching of the topic "Quadratic Expressions and equations" by engaging learners in mathematical creativity enhancing activities during instruction. To achieve this aim, the students in groups E_1 and C_1 were pre-tested on MAT. Table 2 presents gender composition of respondents at the pre-test phase.

Table 2. Gender composition of respondents

Gender	*Frequency*	*Percent*	*Valid percent*	*Cumulative percent*
Boys	82	50.6	50.6	50.6
Girls	80	49.4	49.4	100.0
Total	162	100	100.0	

Table 2 shows that out or the 162 students 82 were boys and 80 were girls. This translates to 50.6% boys and 49.4% girls in the study.

Table 3. Shows the group in the control and experimental/groups of the study

Group	*Frequency*	*Percent*	*Valid percent*	*Cumulative percent*
Control 1	40	24.7	24.7	24.7
Control 2	40	24.7	24.7	49.4
Experimental 1	42	25.9	25.9	75.0
Experimental 2	40	24.7	24.7	100.0
Total	162	100.0	100.0	

There were 40 respondents in control group one (C_1), 40 in control group two (C_2), 42 in experimental group one (E_1) and 40 in experimental group two (E_2). This translates to 24.7%, 24.7%, 25.9% and 24.7% in those groups respectively.

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Table 4. Pre-test on students' MAT scores

Group	*N*	*x*	*S.D.*	*Df*	*t-test*	*p-value*
C_1	40	42.2750	16.14992	80	983	0.329 (ns)
E_1	42	45.9524	17.65517			

ns – not significant at P <0.05 level

An examination of the results on Table 4 indicates that the mean scores for both E_1 and C_1 groups are not statistically different, t (80) = 0.293, P>0.05. This is an indication that the groups in question were comparable, had similar behavior, and hence homogeneous. These characteristics made them suitable for the study.

Table 5 indicates the pre-test mean scores of both male and female students for MAT by gender

Table 5. Independent sample t-test of the pre-test scores on MAT by gender

Variable	*Gender*	*Mean*	*SD*	*Df*	*t-value*	*P-value*
MAT	Male	47.86927	16.08927	79	0.511	0.477 (ns)
	Female	39.7027	17.28497			

ns- not significant of P<0.05 level

Table 5 indicates that pre-test mean scores of male and female students are not statistically different in MAT, t(79) = 0.511, p>0.05.

A comparison of students' pre-test MAT scores for groups E_1 and C_1 revealed insignificant differences. This shows that the groups used in the study were comparable, had similar entry abilities in the topic and hence homogeneous. These characteristics made them suitable for the study.

Effects of Mathematical Creativity Enhancing Teaching Strategies (MCETS) On Students' Achievement in Mathematics

Hypothesis HO_1 sought to find out whether there was statistically significant difference in mathematics achievement between students exposed to MCETS and those taught through the conventional teaching methods. To test the hypothesis, analyses of the students' post-test MAT scores was carried out. Table 6 shows the MAT post-test mean scores obtained by the four groups

Table 6. MAT post-test scores obtained by the students in four groups

	N	*Mean score*	*SD*
C_1	40	44.30000	16.53466
C_2	40	37.30000	17.37992
E_1	42	50.61190	18.42447
E_2	40	50.8500	15.19877
Total	162	45.8272	17.68341

Table 6 shows that the post-test mean scores for groups E_1 and E_2 and that of C_1 and C_2 respectively, were quite similar. One way ANOVA was carried out to find out whether these means were significantly different and the results are shown on Table 7.

Table 7. ANOVA for the post-test scores on MAT

	Sum of squares	*Df*	*Mean squares*	*F-value*	*P-value*
Between groups	4975.356	3	1658.452	5.776	0.01
Within groups	453369.805	158	287.151		
Total	50345.160	161			

Table 7 indicates that the difference of the MAT post-test mean scores among the groups were statistically significant, $F(3,158) = 5.776$, $P<0.05$. Least Square Difference (LSD) Post-Hoc comparisons test was used to find out whether there were significant differences of mean scores between the different pairs of groups. The results of LSD Post-Hoc comparisons test are shown on Table 8.

Table 8. LSD Post-Hoc Comparisons of the post-test of MAT means for the four groups

(I) Group	*(J) Group*	*Mean Difference (I-J)*	*P - value*
E_1	C_1	9.375*	0.018
	C_2	9.500*	0.016
	E_2	0.773	0.769
C_1	E_1	-9.375*	0.018
	E_2	-8.602*	0.024
	C_2	0.1250*	0.975
E_1	E_1	-0.773	0.769
	C_1	8.602*	0.024
	C_2	8.727*	0.022
C_2	E_1	-9.500*	0.016
	E_2	-8.727*	0.022
	C_1	-0.1250	0.975

*The mean difference is significant at $P<0.05$

Analysis on Table 8 reveals that the pairs of MAT mean scores of groups E_1 and C_1, E_1 and C_2,E2 and C_1, and E_2 and C_2 were significantly different at the 0.05 significance level. However, the mean scores of groups E_1 and E_2, C_1 and C_2 were not significantly different. Since the pre-test scores indicated that there was no significant difference between the entry levels of the groups involved in the study then it was not necessary to confirm the post-test results by performing analysis of covariance (ANCOVA)

Effect of Mathematical Creativity Enhancing Teaching Strategy MCETS on Gender Difference in Mathematics Achievement

HO_2 sought to find out whether there was a statistically significant gender difference in achievement of students taught through MCETS. An Independent samples t-test was carried out in order to test this hypothesis.

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Table 9. Independent samples t-test of the post-test MAT scores of both males and females

Gender	*N*	*Mean score*	*SD*	*Df*	*t-value*	*P-value*
Male	82	49.5610	17.11695	159	2.769	0.006*
Female	79	41.9747	17.64825			

The results on Table 9 indicated that the difference in MAT post-test mean scores between male and female students was statistically significant, t (159) = 2.769, P<0.05 with males students having higher mean scores than female students. This means that gender has an effect on learner's mathematics achievement.

Table 10. Independent samples t-test of the post-test MAT scores of the four groups by Gender

Groups	*Gender*	*N*	*Mean*	*SD*	*Df*	*t-value*	*P-value*
C_1	Male	20	44.4000	15.11848	38	0.038	0.970
	Female	20	42.2000	18.23704			
C_2	Male	19	41.3158	17.71394	38	1.407	0.167
	Female	21	33.6667	16.65633			
E_1	Male	24	56.7917	18.04097	39	2.631	0.012*
	Female	17	42.2941	16.38507			
E_2	Male	19	54.1053	12.43604	38	1.300	0.201
	Female	21	47.9048	17.09065			

The t-test results indicated that the difference between male and female students on achievement were not statistically significant in the two control groups. The results for the two experimental groups E1 and E2 were contradictory and hence inconclusive because the mean score differences by gender were significant for E1 but not for E2. Both male and female students in experimental groups had however higher mean scores than those in the control groups.

Hypothesis HO_2 that stated that there was no statistically significant gender difference in achievement between students taught through MCETS and those taught through conventional methods was therefore inconclusive.

DISCUSSIONS

Students' Mathematics Academic Achievement

Hypothesis HO_1 sought to find out whether there was statistically significant difference in mathematics achievement between students exposed to MCETS and those taught through the conventional teaching methods. The study found out that students who were taught through MCETS achieved significantly higher scores in the MAT than those who were taught through the conventional teaching methods. This is an indicator that the MCETS was more effective in improving students' achievement in the mathematics topic of the study compared to the conventional teaching methods.

Previous research studies (Kadir & maker, 2011; Brunkala, 2009; Mann, 2006) had found significant relationship between mathematical creativity and achievement in mathematics. They concluded creative activities in mathematics classrooms affect learners' mathematics achievement positively. In this study a mathematical creativity enhancing activity were practiced in experimental schools and was not used in the two control schools in mathematics classrooms. Learners in experimental schools had higher achievement mean scores than those in control schools

Gender Difference in Students' Mathematics Achievement

Hypothesis HO_2 stated that there was no statistically significant gender difference in the achievement of students taught through MCETS and those not exposed to it. The findings of this study however show that gender differences in achievement scores in experimental groups were not conclusive .The results also indicated that both male and female students taught through the MCETS performed significantly better than corresponding groups taught through the conventional teaching methods. Therefore, MCETS proved to be more effective in enhancing mathematics for learners than when conventional teaching methods are used. MCTES is likely to improve the current under-achievement of female students at KCSE mathematics examinations. This would lead to better female representation to scientific and technological fields currently dominated by men.

A similar study (Ndeke, 2003) in Kenya on form three biology 17 year old students support the results of this study. A study in Hong Kong on learner's mathematics performance (Wang, Ham and HO, 2003) also support the results of this study that MCETS improves learners achievement in mathematics and reduces the gap of gender differences in mathematics achievement.

CONCLUSIONS

This study has demonstrated that mathematical creativity enhancing teaching strategy in which learners engage in creative activities in solving mathematical problems in mathematics classrooms results in higher learners' mathematics achievement for both boys and girls. There was however no conclusive results on gender difference in mathematics achievement when MCETS was practiced in mathematics classrooms. Earlier studies (Pooner, 2012; Ganihar, et.al. 2009) indicated that while girls surpass boys in flexibility dimension of mathematical creativity, in general there is no gender difference in mathematical creativity. Those studies are supported by Palaniapan, (2000) and Ai (1999) who found out that while girls surpass boys in some dimensions of mathematical creativity boys surpass girls in other dimensions thereby giving inconclusive results.

IMPLICATIONS OF THE STUDY

The results of this study indicate that the MCETS was more effective in improving students' achievement as compared to the conventional teaching strategies. This implies that use of MCETS increases students' ability to solve mathematical problems and hence higher mathematics achievement. It also implies that when the MCETS is used, it is likely to improve the current under-achievement of female students at K.C.S.E national mathematics examinations.

It is therefore recommended that Mathematical Creativity Enhancing Teaching Strategies be incorporated in teacher education programs, in-service courses for mathematics teachers, and in mathematics classrooms.

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