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EFFECTIVENESS OF INTEGRATING SCIENCE PROCESS-SKILLS IN TEACHING MATHEMATICS ON STUDENTS' PROBLEM-SOLVING ABILITIES AND ACHIEVEMENT BY GENDER IN SECONDARY SCHOOLS IN THARAKA-NITHI COUNTY, KENYA

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ABSTRACT

Mathematics is a product of man's inquiry on natural phenomena which awakens logical thinking contrary to accumulation of facts to satisfy man's curiosity to subdue the environment. Inadequacy of qualified personnel especially in mathematics and scientific fields implies insufficiency in food production, insecurity, poor health services and may slow technological upbeat in a country. Science process skills are basic concepts which do nurture cognitive and affective skills akin to problem solving abilities, creativity and favourable attitudes towards mathematics and science. The study investigated the Effectiveness of Integrating Science Process-Skills in Teaching Mathematics on Students' Problem Solving Abilities and Achievement by Gender in Secondary Schools in Tharaka-Nithi County. Solomon Four Group Design was utilized where eight schools participated with four Boys' schools and four Girls' schools. Piloting was done in Embu County in a school not participating in the main study to ascertain the reliability and validity of instruments. Data analysis was facilitated using a Statistical Package for Social Sciences (SPSS) Version 19.0. Descriptive statistics and inferential statistics such as t-test, and ANOVA were utilized. Hypotheses were tested at $\alpha = 0.05$ level of significance. The findings established that integration of science process-skills in teaching mathematics significantly improved the students' abilities irrespective of gender. The study findings recommend all stakeholders, policy makers, curriculum developers and teachers to embrace integration of science process skills for meaningful learning towards technological realignments in Kenya. Suggestions are made on how adopt and appreciate integration of science process skills in teaching to nurture students' potentiality in creativity, problem solving and empower their computational skills.

Keywords: Science-Process Skills, Problem-Solving Abilities, Achievement, and Gender Parity

INTRODUCTION

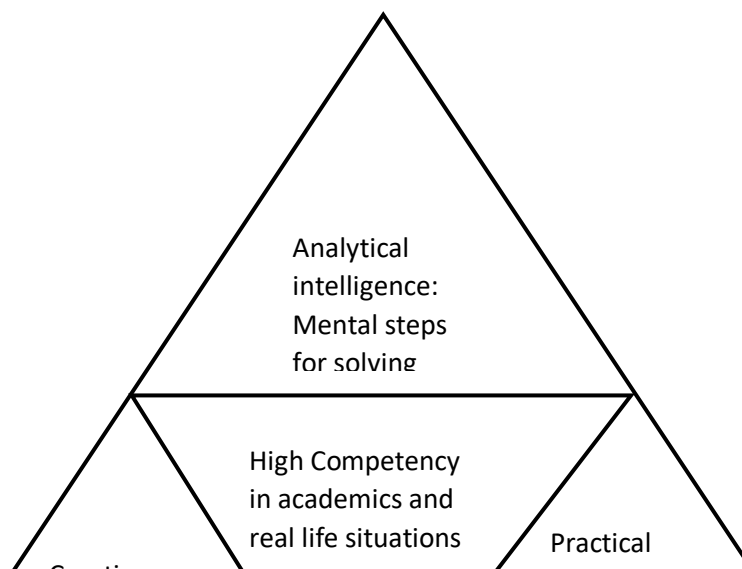
Education provide standards to good citizenry in search for solutions to social problems inclusive of corruption, gender discrimination and emerging issues like global warming, religious radicalization and terrorism (Cakiroglu, 2007; Frykholm & Glasson, 2005). Modern civilization and technologies are yearning for problem solving abilities and creativity to underpin in provisions of holistic and quality education that promotes cognitive and affective domains of the learners to meet the demand of 21st century (Republic of Kenya, 2007). Mathematics education is imperative towards sustainable technological growth without compromising the safety and sustainability of natural environment

(Aydogdu, 2014). Mathematics is conceptualized as the nature of numbers, patterns, procedures and relationships of functions empirically (Fresham, 2002). It is well utilized in banking, medicine, aviation, climatic-change monitoring and demographic feasibility studies (Gedik, Ertepinar & Geban, 2002). Acquisition of computational and algorithmic skills makes a strong foundation for learners not only in secondary but also higher learning institutions. Science process skills are broad transferable abilities which scientist utilizes when studying or investigating natural phenomena. American Association for the Advancement of Science (AAAS, 2001) identified at least twelve science process skills which include: observing, measuring, classifying, communicating, predicting, inferring, questioning, controlling variables, hypothesizing, formulating models, designing experiment and interpreting data. Integration of Science Process-Skills in teaching methods has been noted to improve students' performance in chemistry and biology (Chebii, 2008 & Myers 2004). They stir student cognitive abilities towards problem solving and improving their perception and understanding of concepts in learning irrespective of gender (Ozgelen, 2012). Problem solving abilities empowers the learner to formulate logical axioms in probing and analyzing problems encountered'

Theoretical Framework

The study was anchored on two theorems: Polya's Theorem of Problem Solving and Sternberg's Triarchic Theory of Intelligence. Polya postulated a four steps theorem in 1954. In the first step the learners pinpoint the problem to be worked out in question, check on conditions and limiting bounds. In the second step, the learner devises a plan or path to be taken before inclining to a single possibility of direct reasoning and application. Third step calls for planning and the execution of plan layout. Once the plan layout matures it is written down and carried out carefully observing necessary skills. Flexibility of mind and persistent trials to the problem from different viewpoints is encouraged. In the fourth step Polya proposed a need of looking back for the result to be verified or checked against the original problem. Polya posits that problem solving is a means of developing the logical aspect of thinking in development of the intelligence and abilities to solve everyday problems. By adopting Polya's Theorem researcher integrates science process skills to develop the learners' logical thinking in solving problems encouraging divergent thinking to understand mathematics concepts.

The Sternberg's Triarchic Theory of Intelligence is framed on Cognitive Psychology and was formulated in 1985. Sternberg advocated for integration of intelligence and creativity in adapting and modifying environment to fit human needs. Triarchic Theory is composed of three fundamental principles: analytical, creative, and practical intelligence. Analytical intelligence involved essential abilities to problem-solving: designing experiments, collecting data, analyzing data given, comparing and contrasting new ideas. Analytical intelligence calls for skilled critical thinking when handling problems. The learner is able to pick the correct formula, tools, and necessary equipment to tackle the problem at hand. Sternberg Triarchic Intelligence Theory has great implications in teaching and learning in mathematics especially in high school as it encourages the development of multisensory learning approaches. The current study contextualized Sternberg's Triarchic Theory to reflect in learning mathematics to blend environments within one's socio-cultural experiences. Analytical ability was applied as a relative abstract idea for academic achievement through analyzing, evaluating, and contrasting information in solving problem. Creative ability was applied in novel tasks and unique situations in learning. Practical abilities were applied in everyday adaptations, and selections strategies to solve problems. Analytical, creative, and practical abilities were integrated depending on problem being solved. Figure1 shows the interactions of Analytical, Creative, and Practical abilities in meaningful learning as adapted from Sternberg (2000). The study investigated the effectiveness of integrating Science Process Skills in teaching mathematics on students' problem solving abilities and achievement by Gender in Tharaka Nithi County.



LITERATURE REVIEW

Meaningful education is a construct of knowledge-based development in human resource and technology advancement for optimum utilization of natural resources to solve socioeconomic. It enhances solutions to problems such as corruption, gender discrimination and emerging issues like religious radicalization and terrorism (Cakiroglu, 2007; Frykholm & Glasson, 2005; Davis & Krajcik, 2005). The importance of mathematics education is imperative in countries anticipating sustaining technological growth without a compromise on environmental safety (Aydogdu, 2014). Acquisition of computational skills and algorithmic skills at secondary level make a strong foundation for higher education. Mathematics permeates through human life as father of sciences and technology. It is closely related to one's daily life (Saha 2007).

Science process skills are broad transferable abilities which scientist utilizes when studying or investigating natural phenomena. Integration of Science Process-Skills in teaching methods has been noted to improve students' performance in chemistry and biology (Chebii, 2008 & Myers 2004). They awaken and stir student reasoning levels towards problem solving hence improving their perception and assimilation of concepts in learning (Ozgelen, 2012). Science process skills form the basis on which creativity is anchored (Fah, 2004). Creativity is learner's ability to be sensitive to a problem, recognise relationship among concepts and being flexible in thinking in search of a solution to a given problem. According to a study carried out by Aktamis and Ergin (2008) on the influence of science process skills towards creativity, attitudes and academic achievements in Turkey reported that acquisition of science process skills had positive effects on students' achievement levels. Acquisition of science process skills improve not only students' perceptions on problems they encounter in daily life but also improving self- image concept fostering divergent thinking while learning. Achievement in mathematics may be demonstrated by learner's abilities to recall, comprehend, and analyse problems in learning experiences or in examinations. Integrating of science process skills in teaching may not only improve learner's metacognitive skills but also a remedy to foster problem solving abilities, creativity, favourable attitudes and academic achievement according to Catherine, Setlthomo, Calvin and Holmes (2011).

Methodology

The study applied Solomon Four Group Design. The figure 2 shows Solomon's Four Group Design as adapted from Shuttleworth (2009).

Group	Pre test	Treatment	Post test
Experimental- E ₁	O ₁	X	O ₂
Control - C ₁	O ₃	-	O ₄
Experimental- E ₂	-	X	O ₅
Control C ₂	-	-	O ₆

Figure 2: Solomon's Four Non-Equivalent Control Group Design

- E₁ & E₂ .Experimental groups
- C₁ & C₂ . Control groups
- (O₁O₂) Observations at pretest phase
- O₃ O₄ O₅ O₆) Observations at post-test phase
- (X) Indicates treatment

(----) Indicates the use of non-equivalent groups.

The schools were randomly assigned to four groups. Groups E₁ and E₂ taught through integrated science process skills module while groups C₁ and C₂ were taught conventionally. Prior to treatment groups E₁ and C₁ were exposed to pre-test (O₁ and O₃). After five weeks of instructions all the groups were post-tested (O₂ O₄, O₅ and O₆). The post-test O₅ and O₆ assisted in ruling out any interaction between pre-testing and treatment.

Study Population

The study targeted student population in public secondary school in Tharaka-Nithi County and accessible population was 4068 Form three students.

Sampling Procedure and Sample Size

Stratified random sampling was used to draw the eight schools involved of which four were Boys' only schools and other four Girls' only schools. Simple random sampling was applied to assign the schools to experimental groups (E₁ & E₂) and control groups (C₁& C₂). In schools with more than one stream in form three, all students participated but a simple random sampling was once again used to select one of the streams for data analysis. Table 1 shows the summary of the sample Size.

Table 1: Summary of the Sample Size:

Group	Group Type	Boys	Girls	Total
I	Experimental	49	34	83
II	Control	43	36	79
III	Experimental	51	46	97
IV	Control	34	35	69
Total	177	151	328	

Results of ISPS on Student's Problem Solving Abilities

The first objective of the study was to determine the effectiveness of integrating science process skills in teaching mathematics on students' problem solving abilities in secondary schools. In the study Integrating Science Process Skills (ISPS) referred to confluences of basic scientific concepts and ideas during learning experiences in mathematics. They include: measuring, graphing, observing, hypothesizing, communicating, controlling, comparing predicting and inferring. To find out the effects of integrating science process skills on problem solving abilities, students were subjected to PST after five weeks of treatment. The scoring of PST was structured from 0 to 25. The score attained by a participant was converted to 100%. PST post-test scores and standard deviation are presented in Table 2.

Table 2. Posttest Mean-scores and SD on PST

Group	N	Mean	Standard Deviation
E1	83	65.30	10.04
C1	79	41.33	12.63
E2	97	61.86	9.74
C2	69	38.70	10.93

Results presented in Table 2 indicate that group E1 and E2 achieved mean scores of 65.30 and 61.86 respectively while control groups C1 and C2 had 41.33 and 38.70 respectively. Higher performance by experimental groups could be attributed to intervention of ISPS. To determine whether the difference was statistically significant on problem solving abilities, analysis of variance (ANOVA) was run. Results are presented in Table 3.

Table 3. ANOVA on PST Post-test

	Sum of Squares	df	Mean Square	F	Sign.
Between Groups	45042.935	3	15014.312	128.349	0.000
Within Groups	37901.501	324	116.980		
Total	822944.436	327			

The information in Table 15 indicates that there was a significant difference between the means of four groups ($F_{(3,327)} = 128.349, p < 0.05$). This led to rejection of the first null hypothesis (H_01) which stated that there is no statistical significant difference in problem solving abilities between students exposed to science process-skills and those not exposed to it. To find out which group differed, Bonferroni test of multiple comparisons was carried out. Bonferroni test was preferred due to its ability of flexibility in manipulations, simplicity in computations and use with other types of statistical test like means, and t-tests and ANOVA. Bonferroni also assumes all tests have orthogonal traits and do not take into account whether the findings are consistent with past research (Keppel & Wickens, 2004). The results are shown in the Table 4.

The results in Table 4 show that the means difference on groups E1 against C1, and E1, against C2 are significant. On comparing C1 verses E1, E2 are significant. C2 verses E1 and E2 had a significant different. Also on comparing E2 verses C1 and C2 show significant different. Finally, when comparing C2 against E1 and C1 and E2 a significant different existed. This suggests that ISPS had significantly influenced students' problem solving ability in learning mathematics. ISPS treatment improved learners' problem solving abilities than CIA. ISPS can help close the gap in problem solving abilities in learning mathematics and provide students with the needed ability to solve problems in examinations. The findings of the present study are consistent with the results obtained by Fah (2008) in a study on influence of science process skills, logical thinking Abilities and attitudes towards science in Malaysia. Results indicated that there was a significant correlation among science process skills, logical thinking abilities. The present study is consistent with the findings by Ango (2002) in a study on extent of secondary teachers' mastery of science process skills and their use on enhancing positively students' abilities to solve problem in mathematics and other subjects. The report indicated that mastery of science process skills enhanced students' abilities to solve general problems in mathematics.

Table 4. Bonferroni Post Hoc on PST post-test

(I) Group	(J) Group	Mean D (I-J)	Std. Error	Sig.
E1	C1	23.97209*	1.70005	.000
	E2	3.44553	1.61721	.203
	C2	26.60555*	1.76203	.000
C1	E1	-23.97209*	1.70005	.000
	E2	-20.52656*	1.63913	.000
	C2	2.63346	1.78217	.843
E2	E1	-3.44553	1.61721	.203
	C1	20.52656*	1.63913	.000
	C2	23.16002*	1.70333	.000
C2	E1	-26.60555*	1.76203	.000
	C1	-2.63346	1.78217	.843
	E2	-23.16002*	1.70333	.000

*. The mean difference is significant at the 0.05 level

Effects of ISPS on Student's Achievement

In order to determine effects of integrating science process skills in teaching approaches on students' mathematics achievement posttest scores were analyzed as presented in Table 9

Table 9. Mean Scores and SD on MAT

Group	N	Mean	Standard deviation
E1	83	56.27	11.0112
C1	79	36.90	7.4809
E2	97	55.16	10.6592
C2	69	36.17	9.84132

Results shown in Table 9 indicate that groups E1 and E2 attained 56.27 and 55.16 respectively while groups C1 and C2 had 36.90 and 36.17 respectively. E1 and C1 gained 34.94 and 18.99 respectively in the posttest against pretest.

However experimental groups outperformed control groups. To determine whether difference was statistically significant, ANOVA was run. The results of in Table 10

Table 10: ANOVA on MAT

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	29738.587	3	9912.862	100.997	.000
Within Groups	31800.632	324	98.150		
Total	61539.220	327			

Results in Table 10 indicate that a statistically significant difference exists between the groups ($F_{3, 327} = 100.997$ $P < 0.05$). The results led to rejection of the fourth null hypothesis (H_04) which stated that there is no statistical significant difference in mathematics achievement between students exposed to science process-skills and those not exposed to it. To determine which groups differed Bonferroni test of multiple comparisons was run. Results are shown in Table 11.

The results in Table 11 show that the there existed significant differences in groups E1 Verses C1 and E verses C2 were significant. These results suggest that the intervention of ISPS had positive effects on students' achievement levels in learning mathematics. This implied that ISPS had positive effects in improving achievement among high students in mathematics. The students exposed to science process skills outperformed those not exposed. ISPS was effective in enhancing students' achievement in mathematics. Present research findings have indicated that science process skills do influence achievement in mathematics this concurs to the findings of a study by Fah (2008) on influence of science process skills, logical thinking abilities, attitudes towards science, and locus of control on science achievement among form four students in Malaysia who reported that science process skills highly influences academic achievement.

Table 11. Bonferroni Post Hoc on MAT

(I) Group	(J) Group	Mean D (I-J)	Std. Error	Sig.
E1	C1	19.36633*	1.55722	.000
	E2	1.10011	1.48135	1.000
	C2	20.09115*	1.61400	.000
C1	E1	-19.36633*	1.55722	.000
	E2	-18.26621*	1.50142	.000
	C2	.72482	1.63244	1.000
E2	E1	-1.10011	1.48135	1.000
	C1	18.26621*	1.50142	.000
	C2	18.99104*	1.56023	.000
C2	E1	-20.09115*	1.61400	.000
E1	C1	-.72482	1.63244	1.000
	E2	-18.99104*	1.56023	.000
	C1	19.36633*	1.55722	.000

* The mean difference is significant at the 0.05 level

The findings of the present study are parallel to the findings of Mei, Kaling, Xinyi, Sing and Khoon (2007), Lydia and Divina (2008) whose studies showed science process skills uplifted learners understanding of science concepts and problem solving abilities. The findings revealed that SPS had a significant effect on students' achievement in chemistry. However, the current study finding has showed that science process skills influence achievement in mathematics.

Effects ISPS on Student's Achievement by Gender

This study sought to determine whether there was a gender difference in achievement in mathematics among the students exposed to ISPS and those exposed to CIA. To make the inference whether ISPS instructions played a role in students' achievement by gender of the scores of MAT on the basis of gender. Information in Table 12 shows the mean cores of posttest obtained by students in MAT by gender in experimental and control groups.

Table 12. Pretest Mean scores and SD on MAT by Gender

Gender	N	Mean	Std. Deviation
Male	92	20.76	7.2602
Female	70	19.19	6.2119

Results in Table 12 show the mean scores obtained by male and female students were 20.76 and 19.19 respectively. To determine whether there was a significant difference in the mean scores before intervention independent t test was performed. Results of the t test are presented Table 13

Table 13: Independent t- test on MAT by Gender

	t	df	Sig (2 tailed)
Equal Variance Assumed	1.455	160	0.148
Equal Variance not Assumed	1.486	157.753	0.139

The results in Table 38 indicate that no significant difference existed in the mean scores of male and female students ($t(160) = 0.148$ $p < 0.05$). This implied that the level of achievement prior to treatment for the two groups was similar before the onset of ISPS. Analysis of the post test scores obtained by students in groups was done on the basis of gender. Table 14 shows the posttest mean and standard deviation of male and female students to MAT.

Table 14. Mean-scores and SD in MAT by Gender

Gender	N	Mean	Std. Deviation	Std. Error Mean
Male	100	56.76	10.08	1.008
Female	80	54.31	11.58	1.294

The results in Table 14 show that the mean score for males is 56.76 and that of female was 54.31. The boys scored higher than girls. An independent t- test was performed to determine whether this difference was significant. The results are shown in Table 15.

Table 15. Independent t-test on MAT by Gender

	t	df	Sig (2 tailed)
Equal Variance Assumed	1.515	178	0.131
Equal Variance not Assumed	1.492	157.58	0.138

Results in Table 15 show that there was no significant difference in the two means ($t_{(178)} = 0.131$ $p < 0.05$). This led to acceptance of the null hypothesis five (H_05) which stated that there is no statistically significant gender difference in mathematics achievement among the students exposed to ISPS. The findings indicate no significant difference between male and female students' achievement in mathematics when exposed to SPS learning mathematics. This suggests integrating Science Process Skills in teaching approaches improves learners' academic achievement irrespective of gender.

The findings of the present study are consistent with the findings of Zheng (2010) on a cross-cultural comparison of gender and math performance among college students in china and the United States. The findings showed that when common instructional approaches were used, there is no significant difference between male and female students in math performance, but rather significant differences occur on the basis of self-esteem and cultural based stereotypes. The present study has indicated that academic achievement is gender independent. This finding disagrees with the findings of a study by Sarah and Robinson (2013) on Girls' and Boys' Mathematics Achievement, Confidence, and Interest along with Experiences at Home and School. The report indicated that the gap between boys' and girls' performance in mathematics appeared soon after kindergarten and seemed to widen during elementary and secondary grades. Serap and Meltem (2004) carried out a study on Gender Differences in Academic Performance. The findings reported that smaller numbers of female students manage to enter the university. However, once admitted at university, they excelled in their studies as the same as the male students and at times outperform them. The finding supports the current studies which have revealed that boys and girls are equally competent in mathematics on fair play grounds.

SUMMARY OF THE FINDINGS

The findings of the study showed a statistically significant difference in problem solving abilities in mathematics between the students exposed to ISPS and those exposed to CIA. Results of the study show that experimental groups outperformed control groups in PST. This implied that ISPS is more effective than CIA in improving students' problem solving abilities in mathematics and science village and science process skills. ISPS enhanced learners' problem solving abilities in learning mathematics. Students stand to benefit more in learning mathematics when exposed to ISPS than CIA.

The findings of the present study showed a statistical significant difference between the experimental groups and control groups in acquisition of science process skills towards academic achievement in mathematics. Findings of the study have demonstrated that ISPS enhanced interplay of problem solving abilities, favouring academic achievement. When students are exposed to science process skills gains basic concept, skills and knowledge and know- how to apply them raises the chances of mental flexibilities in reasoning during learning experiences an essence achievement in mathematics.

The present study findings have revealed that male students equally performed as their female counterparts in science process skills acquisition. There was no statistical significant on academic achievement by gender. A big difference in mean gain existed on experimental groups exposed to the ISPS on PST, CAT MAT tests when compared to control groups exposed to CIA. This suggested that ISPS generally improved learners' problem solving abilities and individual achievement irrespective of gender more than those exposed to CIA. When science process skills were integrated in teaching methods students' curiosity was equally raised independent of gender. However, it is good to appreciate that differences between boys and girls in learning in mathematics may be attributed some other factors like stereotypes and socio-cultural blocks which tend to favour boys and yet girls are equally potentially competent.

CONCLUSION

The students' exposure to science process skills improved their acquisition of problem solving abilities in learning of mathematics. This implied that could teachers in secondary schools incorporate science process skills in teaching mathematics meaningful learning will be enhanced. This implies that students' exposure to science process skills will refine their computational skills not only their classrooms but also tackling examination questions and problems of novel situations. Acquisition of science process skills enhanced constructs of cognitive flexibility, recognition and sensitivity in solving problems mathematics during learning experiences. This implies that incorporation of science process skills in teaching methods presets mental frameworks on which critical thinking, logical and analytical reasoning are laid on. Divergence and multisensory viewpoints in learning mathematics is encouraged through brainstorming among secondary school students. This may improve their achievement in mathematics and competencies in science oriented courses at colleges and universities. Integration science process skills in teaching methods enhanced three-way interactions between teacher and learners and from learners to learners with mutual exchange of ideas. This implies that of ISPS formed a strong psychological and pedagogic web on which problem solving abilities interacts to uplift and improve favorable attitudes towards mathematics among learners irrespective of gender. Students' exposure to science process skills improved achievement in mathematics irrespective of gender hence incorporation of science process skills in teaching methods could mitigate the effects of cultural blocks which negates gender equity towards science oriented subjects like mathematics, chemistry, biology and geography among secondary school students. In nut shell integration of science process skills in teaching methods among secondary schools will result to meaningful learning, high achievement in national examination in preparation of students to colleges and universities. Inadequacy of science oriented professionals, food insecurity, and retarded technological growth will be reversed.

RECOMMENDATIONS

On the basis of the present study findings the following are recommendations.

- i) Teachers should adequately utilize ISPS in teaching of mathematics to achieve meaningful learning and improved problem solving abilities among the students. This could be reinforced through Ministry of Education in collaboration with KICD putting up guidelines for mathematics teachers on development of innovative instructional materials.
- ii). Universities and Teacher training colleges to design curriculums favouring integration of science process skills during development of instructional materials to enhance innovative pedagogies and teaching approaches which eliminate stereotypes, cultural blocks which may not encourage gender equity.

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