INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT

HR MARS MANAGEMENT ACADEMIC RESEARCH SOCIETY
EXPLORING INTELLECTUAL CAPITAL
www.hrmars.com
ISSN: 2226-6348

Effectiveness of Integrating Science Process-Skills in Teaching Mathematics on Students' Scientific Creativity in Secondary Schools in Tharaka-Nithi County, Kenya

Denis O. Kirimi and Mercy Wanja Njagi

To Link this Article: http://dx.doi.org/10.6007/IJARPED/v5-i4/2401 DOI: 10.6007/IJARPED/v5-i4/2401

Received: *12 October 2016,* ***Revised:*** *16 October 2016,* ***Accepted:*** *28 November 2016*

Published Online: 14 December 2016

In-Text Citation: (Kirimi & Njagi, 2016)

To Cite this Article: Kirimi, D. O., & Njagi, M. W. (2016). Effectiveness of Integrating Science Process-Skills in Teaching Mathematics on Students' Scientific Creativity in Secondary Schools in Tharaka-Nithi County, Kenya. *International Journal of Academic Research in Progressive Education and Development*, *5*(4), 112–124.

Vol. 5(4) 2016, Pg. 112 - 124

http://hrmars.com/index.php/pages/detail/IJARPED **JOURNAL HOMEPAGE**

INTERNATIONAL JOURNAL OF ACADEMIC RESEARCH IN PROGRESSIVE EDUCATION & DEVELOPMENT
www.hrmars.com
ISSN: 2226-6348

Effectiveness of Integrating Science Process-Skills in Teaching Mathematics on Students' Scientific Creativity in Secondary Schools in Tharaka-Nithi County, Kenya

Denis O. Kirimi and Dr. Mercy Wanja Njagi
Faculty of Education and Resources Development, Chuka University, Chuka - Kenya
Email: deniskirimi@gmail.com

Abstract
The study sought to investigate the Effectiveness of Integrating Science- Process-Skills (ISPS) in teaching mathematics on students' scientific creativity in secondary schools in Tharaka Nithi County Kenya. The research used quasi experimental design; the Solomon Four – Non-Equivalent Control Group Design. Data was collected from eight schools in Tharaka-Nithi County, Kenya with a sample size of 328 participants. Teachers in experimental groups were inducted on the use of ISPS before embarking on the study while participants in control groups were instructed through conventional approaches. Mathematics Creativity Assessment Test (CAT) and Classroom Creativity Observation Schedule (CCOS) were designed for data collection. Data analysis was accomplished by utilizing means, t-test and analysis of variance (ANOVA). Bonferroni post hoc test was used to shows where differences among the groups. Testing of hypotheses was done at alpha $\propto$ = 0.05 level of significance. The study finding indicated that students exposed to ISPS acquired higher meanscores than those not exposed to it in Scientific Creativity. Application of ISPS is more effective in improving students' Creativity than conventional instructional approaches. The study findings give insights on importance of inducting In-Service Teachers on ISPS in instructional approaches to improve their service delivery. From the study it is recommended that Teacher Training Colleges and Universities to incorporate science process skills in instructional methods and materials respectively.
Keywords: Integrating Science-Process Skills, Scientific Creativity, Secondary Schools and Achievement in Mathematics.

Introduction

The modern civilization and technologies are yearning for scientific creativity to underpin 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). According to Kaufman and Baer (2004) creativity fills in the missing links, disharmonies in search for solutions. Studies by Kwatra (2000); Driver (2001) indicated that science process skills, problem solving abilities and creativity are interconnected during learning processes.

Science process skills are broad transferable abilities which scientist utilizes when studying or investigating natural phenomena. These skills will inspire creativity and innovativeness during problem solving processes (Sevilay, 2011). 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. Bell (2008) noted that the fundamental aim of the mathematics curriculum is to educate students to be active thinking citizens who are able to interpret the world logically and critically in decision making.

Theoretical Framework

The current study was anchored on Okere's Model of Scientific Creativity formulated in 1986. The model asserts four tenets which include: sensitivity, recognition, flexibility and planning in finding solutions to given problems. Sensitivity is the ability to be aware of the problems and think of possible solutions to the identified problem. The ability to identify incorrect solutions, formula, fallacious arguments and statements is crucial in mathematics. Recognition is the position of identifying relationships, patterns and similarities among the concepts with farther generation of hypotheses based facts and ideas being observed. On flexibility, learners do to generate a variety of possible solutions a given problem though may not all be necessarily. In planning students follows correct criteria, procedures, or plans in pursuit of a solution to a problem or experiment. Along scientific creativity there exist creative intelligence which creates mental pictures and images of problems being solved. In mathematics students will use their imaginations, to note patterns, links to sequences, progressions and variable relationships. Students should be given opportunities to explore their learning environment during in teaching and learning of mathematics especially in high school as it encourages the development of multisensory perceptions.

On the hierarchy of science process skills there is observing, comparing, classifying, and communicating which are concurrently tied to scientific creative thinking with psychological attributes during learning experiences. Figure 1 show the interactions of psychological perceptions of creativity interconnections to science process skills in enhancing problem solving and achievement in mathematics.

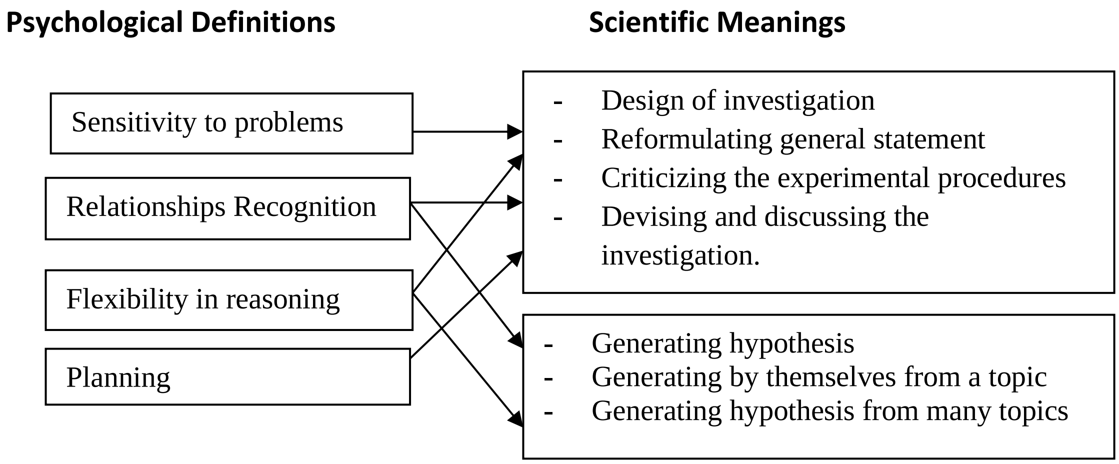

Figure 1: Psychological definition of creativity on Scientific Meaning adapted from Okere (1986).

Conflation of science process skills and scientific creativity into mathematics concepts results to distinctive intellectual activities in teaching and learning experiences. The limitations in conventional teaching approaches may be addressed by integrating science process to fill in the gaps existing in teaching.. Attempt to break from the existing limitations in teaching mathematics should be amplified in favour of students' self-exploration in efforts to improve their understanding and achievement in mathematics at secondary schools. The study investigated the effectiveness of integrating Science Process Skills in teaching mathematics on scientific creativity in Tharaka Nithi County.

Hypothesis of the Study

There is no statistical significant difference in Scientific Creativity between students exposed to Science Process-Skills and those not exposed to it.

Literature Review

Integration of science process-skills and scientific creativity enables students think critically and logically in solving problems in mathematics. Limiting the use of the of creativity in the classroom due to a set rules, formulae and algorithms denies the learners' opportunities of naturalistic mental curiosity. Many are misconceptions about scientific creativity among secondary school students. Some think it is a loose form of self-expression associated with indiscipline and lack of class control. However, creativity is a broad process of sensing a problem, drawing of hypotheses, testing and evaluating, and communicating the results to others Simonton (2004).

Chebii (2011) conducted a study on effects of science process skills mastery on secondary school students' achievement and acquisition of selected chemistry practical skills in Koibatek, Kenya. The report indicated that science process skills improved learners' creativity and that meaningful learning. Creative interaction should be encouraged and maintained in classroom during learning experiences. According to Jeffrey, Bob, Craft and Anna (2004) there are four major components of creativity in mathematics which include: Ability to sense and identify new problems, ability to transfer knowledge gained in one context to a novel situation in order to solve a problem and a resilience view on process focused on goals. Accuracy is important in mathematics; however strict emphasis on accuracy when assessing students understanding discourages the risk takers who apply their knowledge creatively to develop original solutions to a problem. Discouraging risk taking limits genuine mathematical activity and dampens the student's development of mathematical abilities (Driver, 2001; Aktamis & Ergin, 2008). In developed world, scientific and mathematical competence is viewed as a dimension of productive and democratic citizenship. Informed citizen contribute in making informed decision of the community. There is a growing recognition within the science education that scientific and mathematics literacy plays an important role for 21st Century society, not just for individuals only (European Commission, 2007).

In a study conducted by Brunkalla (2009) at Walsh University Ohio in USA, on how to increase mathematical creativity using Frobel's blocks reported that creativity was a major component in mathematics understanding and progress. When learners are exposed to science process skills, creativity is enhanced as a platform for innovativeness in solving real life problems. Aktamis and Ergin (2008) carried out a study on the Effect of Scientific Process Skills on Students' Scientific Creativity, Science Attitudes and Academic Achievements. The findings indicted that science process skills had positive effects on students' creativity. When students are taught without room for creativity, opportunities to appreciate and develop their talents is stiffed. Students may leave school with adequate skills but may not adequately apply them in solving problems. Exposing learners to science process skills enhances their creativity abilities and knowledge acquisition.

Teena (2014) carried out a study in Nagar district of Punjab India to investigate the relationship of science process skills, problem solving ability, and creativity in secondary schools. The findings showed chain if influence as creativity was influenced by problem solving abilities while science process skills assisted learners to reorganize and restate problem less error elimination. Rabari, Indoshi and Omusonga (2011) carried out study to investigate differences in divergent thinking among secondary school physics students in Nairobi Province Kenya. Report indicated that girls outshined boys in problem recognition and sensitivity while boys did better on spontaneous fluency and cognitive flexibility. Ndeke (2003) investigated the level of scientific creativity amongst form three biology students in Nakuru Kenya. The report indicated that the general level of creativity in biology at form three was not satisfactory and was affecting the learner achievement in biology. Due to limited information on effects of science process skills in learning mathematics in respect to creativity in secondary schools, prompted an investigation on effect of integrating science process-skills in teaching mathematics on student's scientific creativity in secondary schools in Tharaka Nithi County, Kenya.

Methodology

The study applied Solomon Four Group Design. The design assessed the effects of the experimental treatment relative to control conditions, interaction between pre-test and treatment conditions. The figure 2 shows Solomon's Four Group Design as adapted from (Shuttleworth, 2009).

Group	Pre test	Treatment	Post test
xperimental- E_1	01	X	02
:ontrol - C_1	03	_	04
xperimental- E_2	_	X	05
:ontrol C_2	_	_	06

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

E_1 & E_2 - Experimental groups
C_1 & C_2 - Control groups
(O_1O_2) - Observations at pretest phase
O_3 O_4 O_5 O_6) - Observations at post-test phase
(X) - Indicates treatment
(----) - Indicates the use of non-equivalent groups.

The schools were randomly assigned to four groups. Groups E_1 and E_2 taught through integrated science process skills module while groups C_1 and C_2 were taught conventionally. Prior to treatment groups E_1 and C_1 were exposed to pre-test (O_1 and O_3). After five weeks of instructions all the groups were post-tested (O_2 O_4, O_5 and O_6). The post-test 0_5 and O_6 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 were 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 (E_1 & E_2) and control groups (C_1& C_2). 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

Data Analysis

The data collected from pretest and posttests was organized, categorized and coded for analysis using both descriptive (means & standard deviations) and inferential statistics (t-test & ANOVA). Hypotheses were tested at alpha $\alpha = 0.05$ level of significance. The t-test and ANOVA were applied to find out if there is any difference between the means by gender of those exposed to teaching integrated with science process skills and those not. Table 2 shows independent samples t-test on CAT.

Table 2
Independent Samples t-test on CAT:

Test		t	df	Sig 2-tailed
CAT	Equal Variances Assumed	0.963	160	0.337
	Equal Variances not Assumed	0.963	158.99	0.337

The information in Table 9 show that the differences in meanscores attained by E1 and C1 were not statistically significant ($t_{160} = 0.963$ $P>0.05$). This implied that the students' characteristics were similar in terms of creativity abilities in both groups hence suitable for the study

Results and Discussion

In the current study scientific creativity referred to the level at which a learner is sensitive to a problem, recognised relationship among the concepts and being flexible in thinking when solving a mathematical problem. Creativity Assessment Test (CAT) and Classroom Creativity Observation Schedule (CCOS) assessed levels creativity against ISPS. CAT was set on the basis on metacognitive abilities while CCOS was set to pick on observable reactions during mathematics in lessons. After five week intervention with ISPS and CIA, students responded to CAT composed of eight items with varied difficulty levels. The CAT results were converted to percentage for easier comparisons. Table 3 presents the frequencies of students' psychological reactions on creativity attributes

Table 3:
Analysis of Students Frequencies in CCOS

Array	Students Activities during Learning Experiences when the Teacher Invites Comments/Questions which were answered by:	Frequencies Levels			
		E1	C1	E2	C2
R_1	Recalling facts, principles, formulas	51.29	32.05	47.44	33.34
R_2	Identifying patterns, relationships and similarities	48.72	37.18	42.31	35.34
R_3	Associating earlier experiences with current ones	53.18	35.90	46.16	33.34
R_4	Citing related ideas from other topics	43.59	38.47	43.59	32.77
R_5	Generalisation of patterns and variations	52.57	32.06	50.00	38.46
S_1	Identifying errors and omissions in calculations	48.72	34.62	51.28	36.34
S_2	Seeking for clarities	64.11	35.90	44.87	42.31
S_3	Self notes taking as lesson progresses	48.98	37.91	45.76	39.11
S_4	Offers suggestions other formulas on BB.	43.32	29.11	40.76	36.23
S_5	Positive Criticisms and redefining of ideas	46.61	37.54	47.19	33.52
F_1	Suggest opinions to solve the problem on BB.	43.67	39.19	44.98	37.34
F_2	Making attempts despite thrice failures	51.28	42.31	56.41	35.91
F_3	Consults other students, teachers when stuck	47.69	37,43	46,74	31.21
F_4	Asking logical questions not within the topic	37.54	34.97	47.81	36.86
F_5	Explaining other learners what one is doing on BB	54.18	41.03	55.13	51.28
P_1	Neat subdivisions of notebooks into columns	43.59	43.59	53.85	43.46
P_2	Logical arrangement of work in their notes books	55.13	34.62	53.85	48.59
P_3	Use rulers, different colours in writing notes	44.88	33.34	50.00	46.16

P_4	Planning on how to conduct simple experiments	57.44	35.90	44.87	44.47
P_5	Setting up equipments logically for experiments	52.57	41.03	42.31	39.18
Total		49.45	36.67	47.82	38.76

Key: Ri-Recognition Arrays, Si -Sensitivity Arrays, Fi -Flexibility Arrays, and Pi -Planning Arrays

Data presented in Table 17 indicates the frequencies of students' observable reactions during the learning experiences. Experimental groups E1 had a frequency of 49.45 and E2 recorded, 47.82. Groups C1 and C2 recorded 36.67 and 38.76 respectively. Experimental groups recorded higher frequencies than the control groups. The use of manual (Appendix A) could have made learners in the experimental groups to be more systematic and active in comparison to those in the control groups. The Classroom Creativity Observation schedule (CCOS) supplemented the quantitative data collected by CAT. The qualitative data described the students' activities during learning experiences in order to provide a deeper understanding of creativity tenets (Recognition, Sensitivity, Flexibility and Planning) on those areas which were not easily amenable to quantitative of data. Instructional approaches when integrated with science process skills increased interactions between students to students, and students to teacher in learning experiences. Teachers should encourage brainstorming, self discovery and inquiries during learning experiences.

This finding agrees with reports by SMASSE (2000) on baseline studies which posited that the learner should be offered opportunities for hands on activities during learning experiences. The scores on CCOS show that in groups where teachers integrated science process skills in teaching methods more class activities were registered than in groups instructed through CIA. The learners demonstrated self-discipline in solving problems, openness to new experience, confidence and concrete reasoning. They could analyze, evaluate, interpret and make arguments characterized by phrases like: I see .., This reminds me of ., I thought of .., The work resembles .., and awe short moments of silence in classroom. These findings are consistent with findings of Chebii (2011) on effects of science process skills mastery learning approach on secondary school students' achievement and acquisition of selected chemistry practical skills which indicated that science process skills improved learners' creativity resilience. The CAT scores were also analyzed. Table 4 shows the mean scores and standard deviation of analyzed CAT.

Table 4
Posttest Mean Scores and SD on CAT

Group	N	Mean	Sd
E1	83	57.89	10.18
C1	79	39.11	9.63
E2	97	56.19	8.92
C2	69	36.67	10.42

The information in Table 18 indicates that groups E1 and E2 achieved the means of 57.89 and 56.19 respectively while groups C1 and C2 had 39.11 and 36.67 respectively. Experimental groups had higher meanscores in compared to control groups. This could be attributed to intervention of ISPS. The improvement in group E1 tripled while group C1 doubled after treatment. These results suggest that group E1 instructed with ISPS on teaching method achieved more than group C1 instructed conventionally. To determine whether the difference was statistically significant analysis of variance (ANOVA) was run. The results are presented in Table 5.

Table5:
ANOVA) on CAT Posttest

	Sum of Squares	df	Mean Square	F	Sig
Between Groups	29668.688	3	9889.563	104.148	.000
Within Groups	30765.992	324	94.957		
Total	60434.680	327			

The results in Table 19 show that a significant difference between the mean scores. $F_{(3,327)} = 104.148$ $P>0.05$). This implies that there was a significant different on the means of groups instructed by ISPS and CIA. This led to the rejection of the second null hypothesis (H_02) which stated that there is no statistical significant difference in creativity between students exposed to science process-skills and those not exposed. To investigate which groups differed significantly *Bonferroni post hoc* test was run. Results are shown in Table 6

Table 6:
Bonferroni post hoc test on CAT

(I) Group	(J) Group	Mean D (I-J)	Std. Error	Sig.
E1	C1	18.77764*	1.53168	.000
	E2	1.70600	1.45705	1.000
	C2	21.22490*	1.58753	.000
C1	E1	-18.77764*	1.53168	.000
	E2	-17.07164*	1.47679	.000
	C2	2.44726	1.60567	.771
E2	E1	-1.70600	1.45705	1.000
	C1	17.07164*	1.47679	.000
	C2	19.51890*	1.53464	.000
C2	E1	-21.22490*	1.58753	.000
	C1	-2.44726	1.60567	.771
	E2	-19.51890*	1.53464	.000

*. The mean difference is significant at the 0.05 level

The results in Table 20 indicate that the mean difference in groups E1 Verses C1, and C2 were significant α = 0.05 significance levels. In groups C1 verses E1 and E2 were also significant at α = 0.05 levels and so was in groups E2 verses C1 and C2 were significant at α = 0.05 levels. Finally in groups C2 verse E1 and E2 was significant at $\alpha = 0.05$ levels. This suggests that the difference was due to ISPS intervention which had superior effects on students' creativity levels in learning mathematics than CIA.

The findings of the present study have pointed out that experimental group exposed to ISPS improved more in creativity abilities than control group in post-test. These findings are consistent with the findings of Aktamis and Ergin (2008) on effects of science process skills on students' creativity which pointed out that science process skills acquisition enhanced creativity among the students. Findings of the present study concurs with findings of a study carried out by Teena (2014) in India on the effects of science process skills on problem solving ability and creativity in secondary schools showed that acquisition of science process skills enhanced problem solving abilities and creativity. The finding of the present study is consistent with the results obtained by Arokoyu and Nna (2012) in Nigeria on acquisition of science process skills was greatly correlated to creativity abilities. Proficiency in utilization of science process skills will strengthen capability to execute empirical–inductive reasoning amongst the secondary school students as a basis of creativity.

Conclusion

The students' exposure to science process skills improved their acquisition of scientific creativity in learning of mathematics. This implies that students' exposure to science process skills will refine their flexibility in computational skills not only in classrooms but also when tackling examination questions and in novel situations. Acquisition of science process skills enhanced creativity constructs of cognitive flexibility, recognition and sensitivity in solving problems in learning experiences. This implies that critical thinking, logical and analytical reasoning are laid on and cultivated. When students are exposed to science process skills gains basic concept, skills and knowledge they could apply in learning to broaden their mental flexibilities in reasoning, the essence achievement in mathematics. In nut shell integration of science process skills in teaching methods among secondary schools will result to meaningful learning, high achievement in preparation of students to colleges and universities. Inadequacy of scienceoriented professionals, food insecurity, and retarded technological growth could be reversed especially in less developed countries.

Recommendations

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

i) Secondary teachers should create and maintain conducive learning environment favouring freedom of expression for learners to articulate and brainstorm during learning experiences.

ii) The National and County Ministries of Education should collaborate to improve on funding of secondary school to acquire learning materials and facilities which encourages hands on activities in and out of classrooms.

iii) 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 for meaningful learning.

References

AAAS. (2001). American Association for the Advancement of Science, Project 2001: Science for all Americans. Washington D.C.

Aktamis H., Ergin, O. (2008): The Effect of Scientific Process Skills Education on Students' Scientific Creativity, Science Attitudes and Academic Achievements. *Asia-Pacific Forum on Science Learning and Teaching*, 9(1), article 4.

Arokoyu, A. A., and Nna, P. J. (2012). Creativity and Process Skills for Self- Reliance Using Demonstration Approach of Teaching Chemistry, Department of Curriculum Studies and Educational Technology, University of Port Harcourt, Nigeria.

Bell, R. L. (2008). Teaching the Nature of Science Trough Process-Skills: Activities for grades 3-8. New York: Allyn and Bacon/Longman.

Brunkalla, K. (2009). *To Increase Mathematical Creativity*- An Experiment How. Published by Montana Mathematics Enthusiast, ISSN 1551-3440, Vol. 6, nos.1and2, pp.257- 266 Walsh University, Ohio

Chebii, R. J. (2008). Effects of Science Process Skills Mastery Learning Approach on Secondary School Students' Achievement and Acquisition of Selected chemistry Practical Skills in Koibatek District Schools, Kenya

Driver, M. (2001). Fostering Creativity in Business Education: Developing Creative Classroom Environments to Provide students with Critical Workplace Competencies. *Journal of Education for Business*, 77 (1), 28-33.

European Commission. (2007a). *Gender equality law in the European Union*. Luxembourg: Office for Official Publications of the European Communities.

Kaufman, J. C., and Baer, J. (2004). Sure, I'm Creative-But in Mathematics: Self-reported Creativity in Diverse Domains. Empirical Studies of the Arts, 22(2), 143-55.

Kwatra, A. (2000). Understanding of Science Process in Relation to Scientific Creativity Intelligence and Problem Solving Ability of Middle School Students of Bhopal Division (Ph.D Thesis). Baraktullaha University, India.

Ndeke, G. C. W. (2003). The Effect of Gender Knowledge and Learning Opportunities on Scientific Creativity Amongst Form Three Biology Students. Unpublished M.Ed Thesis Egerton University.

Rabari, J. A., Indoshi, F. C., Omusonga T. O. (2011): Differences in Divergent Thinking among Secondary School Physics Students. Department of Educational Communication, Technology and Curriculum Studies, Maseno University, Kenya

Republic of Kenya. (2007): Kenya Vision 2030: A globally competitive and prosperous Kenya. Nairobi: Government printers. Nairobi.

Sevilay, K. (2011). Improving the science process skills: ability of science student teachers using i diagrams. *Eurasia journal of physics & chemistry education 3, 26-38: uk.*

Simonton, D. K. (2004). Creativity in science: Chance, logic, genius, and zeitgeist. NY: Cambridge University Press.

Smasse. (2000). Strengthening of Mathematics and Sciences in Secondary Education. 1st cycle. Meru South District.

Teena, D. (2014) Problem Solving Ability and Science Process Skills as the Influential factors of Scientific Creativity International Journal of Research Pedagogy and Technology in Education and Movement Sciences (IJEMS) Vol.02.Issue 04-2014 Punjab, India