Journal of Education and Practice
ISSN 2222-1735 (Paper) ISSN 2222-288X (Online)
Vol.5, No.15, 2014

Effect of Science Process Skills Teaching Strategy on Boys and Girls' Achievement in Chemistry in Nyando District, Kenya

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Abstract
Science process skills are central to the acquisition of scientific knowledge which is useful in solving problems in our society. This study was intended to compare the effect of science process skills teaching strategy (SPSTS) on boys and girls' achievement in chemistry. The study employed quasi-experimental design. The target population consisted of students in the secondary schools in Nyando District. Purposive sampling was used to obtain two district secondary schools to ensure that the number of boys and girls in each school was about the same. The samples consisted of 90 Form Three students drawn from two district secondary schools. The study covered two topics selected from the KCSE Chemistry syllabus, that is, Volumetric analysis (Titration) and Qualitative analysis. .Chemistry Achievement Test (CAT) consisting of simple calculations, True and False items, and Fill in blanks were used as a pre-test. After the administration of treatment, which lasted five weeks, the same test was administered to the two groups as a post-test. The CAT was adapted from the KCSE Chemistry practical past papers. The reliability coefficient of 0.88 was estimated for the CAT using Kuder-Richardson (K-R21). The data generated were analyzed using descriptive statistics, t-test, ANOVA, ANCOVA at $\alpha = 0.05$ level of significance. The results revealed that SPSTS made significant difference on achievement in chemistry between boys and girls.
Keywords: science process skills, achievement, chemistry, gender

1. Introduction

The main reasons for having science education at secondary school are to create awareness on the effect of scientific knowledge in everyday life, to promote technological and socio-economic development in society. The practical activities carried out by students in class provide the foundation of technological development and prepare them for the pursuit of science related courses at higher levels. Hodson (1990) suggested that when students' interests are captured through hands-on activities, the consequence is that they will do better in the subject. Jenkins (1989) reinforced the foregoing statement by arguing that scientific knowledge presented through practical activities can be appealing and accessible to students. However, the influence of gender on students' achievement in science has for a long time been a concern to many researchers and science educators.

Studies carried out in the United States overwhelmingly show the image of a scientist as a white, bespectacled male wearing a laboratory coat and holding a test tube. Most of the illustrative diagrams and pictures in the science textbooks show males doing experiments (Bazler & Simons, 1991; Blubaum, 1994; & Edgar, 1999; 2004). Even girls who had been taught by a female science teacher rarely drew a female figure when asked to address the masculine stereotype of scientists (Kahle, 1987). In fact the messages conveyed about science as male preserve may demoralize the girls and make them switch off from science. For instance, during experiments in science lessons, boys may dominate girls in carrying out the activities thereby acting as though boys have monopoly of apparatus. Boys tend to gain more than their share of teachers' attention and ridicule girls' attempts to work, to the extent that girls act as boys' helpers/assistants. These behavioral attitudes and representations reinforce the masculine image of science (Versey, 1990).

However, many studies have been carried out to find whether male superiority is real, but the results obtained are varied. The investigation carried out by Dawson (2000) on gender imbalance revealed that the gap between boys' and girls' interests in the physical sciences had widened, with boys' interest in this area being far greater than that of girls. Jones, Howe and Rue (2000) Research report concurs with Dawson findings in that little change has taken place in girls' and boys' attitudes and perceptions towards science, with boys reporting a wider range of science interests and out-of-school experiences with science than girls. Adamson, Foster, Roark and Reeds (1998) found that, there was a significant gender difference in the area of science, which students selected for projects, that is, girls chose to work in the area of social and biological sciences, and boys in the physical sciences. Dawson advocates for the need to change the direction of science teaching from preparing science specialists to that of science for all. In response to this disparity, the curriculum review panels, publishers and textbook authors have made attempts to counter the damaging notion of science as male preserve. The Hertfordshire (Secondary School Curriculum Review) Working Party Statistics indicate that attention paid to materials put in context can change girls' attitudes towards science (Versey, 1990). The statistics for Suffolk Co-ordinated Science indicate improved uptake of "A" level science by girls following their active learning approaches.

There is need therefore to demystify the perception of girls from this attitude. Science as a practical subject provides students with an opportunity to interact with science process skills that can be used to solve problems in everyday life and contribute to national development. Science process skills are activities, which students carry out in scientific investigations to enable the acquisition of scientific knowledge. The selected science process skills investigated in this study were observing, measuring, recording and interpreting. Hodson (1990) indicated that these activities contribute to the understanding of abstract concepts in science, which would remain implicit if taught theoretically.

Hodson, (1990) reported that process skills would aid the understanding of the theoretical scientific knowledge if practical learning opportunities were put in place. The prospects of involving students in science practical activities may improve the mastery of science process skills and enhance the ability to understand the scientific concepts.

In Kenya both boys and girls in secondary schools find science concepts difficult to understand, this is reflected in the low scores obtained in KCSE by the candidates (KNEC, 2013), see Tables 1 and 2.

Table 1 shows the national overall performance of students in Chemistry, Biology and Physics at KCSE in the period 2008-2012. The average percentage performance in Chemistry was lower than Biology and Physics.

Table 1

The KCSE Chemistry, Biology, Physics National overall Performance (2008-2012)Percentage Mean Score

Year	Chemistry	Biology	Physics
2008	22.71	30.32	36.71
2009	19.17	27.15	31.31
2010	24.89	29.19	35.11
2011	23.66	32.44	36.64
2012	27.93	26.21	37.86

Source:- KNEC (2009 - 2013)

Table 2 shows the performance in Chemistry, Biology and Physics practical papers in the period 2008-2012. The mean score of the candidates was lower in Chemistry than Biology and Physics.

Table 2

Performance in Chemistry, Biology, and Physics Practical papers (2008-2012)Percentage Mean Score

Year	Chemistry	Biology	Physics
2008	28.72	43.25	49.80
2009	27.15	39.65	38.05
2010	37.15	46.05	55.90
2011	29.75	47.01	55.62
2012	40.85	29.80	43.60

Source:- KNEC (2009 - 2013)

Table 3 shows the national overall performance in Chemistry, Biology and Physics at KCSE by gender in the period 2011-2012. The average percentage mean score in Chemistry of girls was low compared to that of boys in the two year period. Similarly Chemistry was poorly performed by the girls than Biology and Physics.

Table 3

The KCSE Chemistry, Biology, Physics National overall Performance by Gender (2011-2012)Percentage Mean Score

	2011			2012		
	All	Female	Male	All	Female	Male
Chemistry	23.66	21.47	25.42	27.93	25.95	29.54
Biology	32.44	30.07	34.53	26.21	24.36	27.86
Physics	36.64	34.55	37.42	37.87	36.22	38.48

Source:- KNEC (2012 - 2013)

From the data displayed in Table 3, it is appropriate to adopt teaching strategies that stimulate girls' interests in science to alleviate this gender imbalance.

1.1 Statement of the Problem

The acquisition of scientific knowledge and process skills is significant in finding solutions to many problems in society. Chemistry as a practical subject in the secondary school curriculum plays significant role in preparing students for the challenges in the immediate environment. The importance attached to activity-based instructional methods by the chemistry teachers in Kenya is underscored by Abungu (2014) research findings, which reported that science process skills teaching approach enhances students' achievement in chemistry. However, it is not clear whether the enhancement of students' achievement in chemistry by science process skills

is affected by gender. It is on this basis that the study was designed to establish the effect of science process skills teaching strategy on boys and girls' achievement in Chemistry.

Objective

To find out the effect of science process skills teaching strategy on achievement in Chemistry with regard to gender.

Hypothesis

There is no statistically significant difference in achievement between secondary school boys and girls who are taught Chemistry through science process skills teaching strategy.

2. Methodology

Quasi-experimental design was used where the Form Three classes involved remained intact, as the school authorities would not allow randomization process by reconstituting and disrupting classes during the administration of the treatment (Coolican, 1999). The students in the two experimental (treatment) groups received instructional practical sessions on two-selected topic areas using SPSTA. The study was conducted in two district secondary schools in Nyando District in Kisumu County, Kenya. The target population for the study was about 3500 students of the Form Three classes in the secondary schools in Nyando District. The accessible population was composed of Form Three students in the sixty-three district schools. The sample consisted of Form Three students drawn from two district schools purposively sampled.

Purposive sampling technique was preferred to enable selection of schools with about the same number of boys and girls and adequate resources for teaching Chemistry. The sample size was ninety (90), with each school having approximately forty students. The optimum sample size required for each participating group in an experimental research as recommended by Coolican (1999), Gall, Borg and Gall (1996) is thirty respondents. This number compared very well with the proposed sample size employed in this study. The recommended class size for secondary schools in Kenya is approximately forty students.

Chemistry Achievement Test (CAT) was developed and used as a pre-test and post-test. It had 60 items consisting of simple calculations, True and False, and Fill in blanks. It covered two topic areas, that is, Volumetric analysis (Titration) and Qualitative analysis selected from Form Three KCSE Chemistry syllabus. The test was scored on the basis of correct or incorrect responses. Each correct and incorrect response was scored one and zero marks respectively. The Chemistry knowledge tested was validated by experts from science education department, Egerton University and two examiners in Chemistry registered with KNEC. Kuder-Richardson 21 formula (K-R21) was used to calculate the reliability coefficient of the CAT, which was found to be 0.88.

2.1 Intervention

The two groups received treatment conducted by the Chemistry teacher for a period of five weeks. Four sessions of practical work were organized, each session lasting eighty minutes. The students carried out experiments on the following content areas.

(i) Volumetric analysis (Titration of a base with an acid)
(ii) Qualitative analysis (detection of cations and anions)

During the practical sessions, the students were divided into five groups with about eight students each. Before the beginning of each session, the teacher informed and instructed the students on the objectives and procedures of working. The materials, apparatus and instructions for the experiment for each practical session were provided. The students did all the activities and the teacher visited the groups and posed guiding questions intended to lead them to an appropriate direction.

The pre-test (CAT) was administered to the students in one group (Experimental Group 1) to measure the initial chemistry knowledge of both boys and girls. The post-test was administered to the two groups at the end of treatment period. CAT was used to obtain students' achievement in Chemistry. The students' scores from the test were recorded and used for data analysis. The data were analyzed using both descriptive and inferential statistics. The mean and standard deviation were used to describe and compare students' achievement in Chemistry from the boys and girls. The hypothesis was tested using the following statistical tests for significance, t-test and ANCOVA. The post-test results were correlated with the co-variate, using KCPE results. The level of significance was set at $\alpha = 0.05$ to guide in the rejection or acceptance of null hypothesis.

3. Results and Discussion

Table 6 shows the t-test of the pre-test mean scores on CAT based on students' gender for Experimental Group 1.The purpose was to establish if the boys and girls in this group were of the same abilities in chemistry at the starting point.

Table 6:
Independent Samples t-test of the Pre-test Mean Scores on CAT based on Students Gender in Experimental Group 1

Exptal 1	N	Mean	Std Deviation	t	df	Sig.(2-tailed)
Boys	39	.45	.16	1.47	48	.148
Girls	11	.37	.13			

The results showed that in the Experimental Group 1 the boys obtained higher mean score than the girls in the CAT pre test, but there was no statistically significant difference in the pre- test mean scores between the boys and girls in the Experimental Group 1; t (48) = 1.47, p>0.05. This means that the boys and girls were of equal abilities in chemistry at the starting point.

Table 7 shows the t-test of the post-test mean scores on CAT based on gender for Experimental Groups 1 and 2 combined. The two groups were exposed to SPSTA and an independent samples t-test was carried out to test the null hypothesis.

Table 7
Independent Samples t-test of the Post-test Mean Scores on CAT Based on Gender for Experimental 1 and 2 Groups Combined.

Gender	N	Mean	Std Deviation	t	df	Sig.(2-tailed
Boys	63	.55	.14	2.62	88	.010
Girls	27	.47	.12			

After the application of SPSTA, an instructional intervention, there was an improvement on the performance of boys and girls on CAT as compared to the performance on the pre test. But generally the boys performed slightly better than the girls. There was statistically significant difference in the mean scores between boys and girls in the experimental groups; t (88) = 2.62, p<0.05, leading to the rejection of the null hypothesis. Since this study involved non-equivalent control group design, it was necessary to carry out analysis of covariance with KCPE score as covariate, to take into account any pre-existing differences that might have occurred due to other factors.

Table 8 shows the adjusted post-test mean scores of CAT based on gender for Experimental Groups 1 and 2 combined using KCPE as covariate.

Table 81:
Adjusted Post-test Mean Scores of CAT based on Gender for Experimental Groups 1 and 2 combined using KCPE as covariate.

Gender	N	Mean	Std. Error
Boys	62	.54[a]	.02
Girls	25	.50[a]	.03

a. Covariates appearing in the model are evaluated at the following values: covariate = 303.47.

The adjusted CAT post-test mean scores of boys and girls in the ANCOVA showed that boys performed better than the girls.

Table 9 shows the analysis of covariance of the Post-test mean scores of Boys and Girls in Experimental Groups 1 and 2 combined using KCPE as covariate.

Table 9:
Analysis of Covariance (ANCOVA) of the Post-test CAT Mean Scores of Boys and Girls for Experimental Groups 1 and 2 Combined.

Source	Sum of Squares	df	Mean Square	F	Sig.(2-tailed)
KCPE	.36	1	.36	12.18	.000
Gender	.02	1	.02	1.36	.000
Error	1.24	84	.02		

The findings of ANCOVA test showed that there was statistically significant difference between the mean scores of boys and girls in experimental groups, F (1, 84) = 1.36, p<0.05 (Table 9). These results compare very well with the findings of the Independent Samples t-test of the Post-test Mean Scores on CAT Based on Gender for Experimental Groups 1 and 2 Combined (see Table 7); therefore the null hypothesis is rejected.

3.1 Discussion

The t-test showed significant difference between the post-test mean scores of boys and girls on CAT in the experimental groups, t (1, 88) = 2.62, p<0.05. The results from ANCOVA showed the same trend F (1, 84) = 1.36, p<0.05. Other research studies have reported findings, which agree with the results in this study. Studies carried out in Nigeria with secondary school students by Nwosu and Okeke (1995), Alexoponlou (1997), Okpala and Onocha (1998) and Adeoye (2000) found that there was gender difference in favour of boys in relation to practical skills in science. Shaibu and Marri (1997), Ahiakwo (1988) findings showed that girls performed better

than boys in chemistry. Trigwell (1990) and Opara (2011) found that boys performed better than the girls in chemistry and biology respectively. However, these studies were done in different contexts. The former investigated the abilities of the students to solve quantitative problems in chemistry when exposed to an alternative science degree programme in Australia while the latter was carried out with secondary school students in River State in Nigeria. Studies carried out by International Evaluation of Educational Achievement (IEA) from a cross cultural survey revealed that sex differences have been found in every subject area in the written test, and that boys outperformed girls in Biology, Chemistry and Physics at all levels (Amunga et al., 2011). In Uganda the trend in academic excellence in the secondary schools final examination has shown that boys perform better than girls in Chemistry (Ssempala, 2005). In Kenya similar results are evident as shown by a study carried out by the Institute of Policy Analysis and Research (IPAR) (2003) as reported in Amunga et al., that boys performed better than girls in Chemistry, Physics and Biology in KCSE. A study carried out by Amunga et al. (2011) in secondary schools in Western Province, Kenya, indicated that boys performed better than girls in Chemistry. The outcome of a study carried out by Nyakan (2008) in Kenya revealed that there was significant difference between the performance of boys and girls in physics. This finding was not surprising considering that physics is the least popular with secondary school girls.

However, studies carried out by Shaw and Doan (1990); Inyang and Jegede (1991); Balogun (994) showed no significant difference on the achievement of boys and girls in chemistry. The outcome of Wachanga (2002) investigation on the effect of cooperative class experiment (CCE) on the achievement of boys and girls in chemistry disagree with the findings of this study. It showed that there was no significant difference between the achievement of boys and girls who were taught chemistry through CCE methods. Other studies carried out by Wambugu and Changeiywo (2008) in Kenya, Nwagbo and Uzoamaka (Online) in Nigeria with secondary school students showed similar results in Physics and Biology subjects respectively. Oludipe (2012) carried out a study to investigate the influence of gender on junior secondary school students' academic achievement in basic sciences using cooperative learning-teaching strategy. His findings revealed that there was no significant difference in academic achievement of male and female students. A study carried out by Olatoye, Aderogba and Aanu (2011) in Ogun State, Nigeria, on the effect of cooperative and individualized teaching methods on senior secondary school students' achievement in organic chemistry showed no significant difference between the achievement of boys and girls. Nonetheless the findings of this study have indicated that boys and girls exposed to science process skills teaching approach show significant difference in chemistry achievement. This is supported by research studies carried out by Raimi (2002), Akale and Usman (1993) and Iroegbu (1998) in Nigeria with secondary school students, which reported gender differences among students that were exposed to practical oriented activities in the classroom. Therefore, science process skills teaching approach does enhance the achievement in chemistry in both boys and girls but at different levels. Most of the studies reported in this study indicate that there are disparities in boys and girls achievement in chemistry in secondary schools. The information obtained from this study reinforces the notion of male dominance in science learning and the view that science careers being predominantly male preserve.

KNEC (2001) report shows that the take-up of Chemistry by girls in the KCSE examination indicates that 43% of the total number of candidates who registered for Chemistry in 2000, were girls compared to 58% who took biology, 29% who took physics. However, the number of candidates who took physical science was fifty-fifty. The scenario begs for a number of questions that we need to ask ourselves. Why is science in general and Chemistry in particular less popular with girls in secondary schools? How do we get more girls to do Chemistry? How do we set about developing and fostering the interest of girls in Chemistry?

In the UK, right from primary school to GCSE level, Chemistry does appear to offer girls and boys a more gender-fair approach than is offered by physics, that is, Chemistry is the science subject that shows the least sex differentiation in terms of candidates' enrolment (Whitelegg, 1992). However, in Kenya, girls' and boys' attitudes to science in general influence their view of Chemistry in particular.

The 8.4.4 curriculum has popularized Chemistry to girls by encouraging active learning approaches and use of relevant contexts. Planning activities that involve girls in related chores and everyday activities may influence girls' attitudes towards Chemistry. Some publishers have produced Chemistry textbooks, which display on their covers and inside pages, pictures showing girls as well as boys doing the experiments. A close examination of Chemistry textbooks authored locally display illustrations depicting girls as showing more active roles (Mbaka & Wamae, 2004; KIE, 2001). The other recommended strategy that may influence girls interests in Chemistry involve the non-use of gender biased illustrations in class showing girls performing less conventional tasks. The need to establish an appropriate teaching method, which would encourage active participation of girls in the learning of Chemistry is relevant in this study because a lot of literature show disparities in the performance of science in general and chemistry in particular between boys and girls in secondary schools.

4. Conclusion, Implications and Recommendations

Gender affects the students' achievement in chemistry when they are taught through science process skills

teaching strategy, with boys attaining significantly higher mean scores in chemistry than the girls. Since chemistry occupies a middle position between biology and physics in the secondary school curriculum, the difference in performance of boys and girls in chemistry evident in this study in favour of boys may disadvantage female students from pursuing courses at the tertiary level of education with bias to the physical and biological orientation and reinforce the view held by many educators that such courses as Engineering, Information Communication and Technology (ICT), Agriculture and Medicine are exclusively boys preserve. It is therefore recommended that science process skills teaching strategy be implemented in a manner that would bridge the gender gap in chemistry achievement by providing equal opportunities for both boys and girls to interact with the teachers, amongst themselves and the resources.

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