Fostering Students' Learning in the 21st Century: Effect of Inquiry-Based Learning on Students' Achievement of Science Process Skills in Biology Subject

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Abstract

The study investigated the effectiveness of Inquiry-Based Learning Approach (IBL) on students' achievement of Science Process Skills (SPS) among secondary level Biology students. Globally there is still a challenge in determining which teaching method equips students with both knowledge and skills which are not only useful for the realization of sustainable development goals (SDGs), but are also required for the 21st century. The Solomon Fourfold Non-Equivalent control group design was employed in the study. The study was carried out in Wareng sub county of Uasin Gishu County, Kenya where there has been persistent low achievement in Biology subject. The study sample comprised of 220 students selected from form three students in four different mixed day secondary schools. The sampling techniques used were stratified, systematic and simple random sampling. The experimental groups received instructions through IBL approach and control groups using the Traditional Learning (TL) method. Biology Science Process Skills Achievement Test (BSPSAT) was used for data collection. The results of the study indicated that students in the experimental groups outperformed the control groups in the achievement of selected Science Process Skills. It was concluded that IBL had a positive output on students' achievement in BSPSAT than the Traditional Learning (TL) method. Teachers of Biology in Kenya should be encouraged to incorporate IBL in teaching so as to enhance the development of Science Process Skills among secondary school students.

Keywords: Inquiry-Based Learning (IBL); Achievement of Biology Science Process Skills; Biology Science Process Skill Achievement Test (BSPSAT); Biology subject; Wareng Sub County.

INTRODUCTION

Learning of Science can be best achieved when the teaching-learning approach allows students to be actively involved in the learning process (Chebii, 2011). Globally there is still a challenge on establishing which instructional approach shall equip students with both the knowledge and skills required for this 21st century and for the realization of SDGs. According to the Student Achievement Division (2013), educators worldwide encounter the daunting challenge and responsibility of winning students over while learning in order for them to develop the skills and knowledge needed to survive in today's world.

The learner of the 21st century should be able to communicate effectively and collaborate with others; research on new ideas; collect, synthesize, and analyze information; develop new products and apply varied bodies of knowledge to novel problems that arise in the 21st century (Boix-Mansilla & Jackson, 2011). A demand of the 21st century for learners of Science is to acquire and develop SPS (Chebii, 2011). Biology is a practical subject that equips students with concepts and skills that are useful in solving daily issues of life (KIE, 2002; Ngesu, Gunga, Wachira & Kaluku, 2014). Biology also plays a major role in industrialization and in other sectors of the Kenyan economy (Muraya & Kimamo, 2011) hence Biology subject occupies a fundamental position in the Science curriculum. The Kenya National Examination Council (KNEC) statistics (2016) indicate that candidates recorded low mean percentages in the Kenya Certificate of Secondary Examination (KCSE) in Biology subject over the years. The Kenya Institute of Curriculum Development (KICD), (formally known as the Kenya Institute of Education-KIE) strongly recommends the use of discovery methods in achieving the objectives of Biology subject (KIE, 2002). Science Process Skills are among the skills that separate students who are prepared for increasingly complex life and work environments in the 21st century and those who are not (Saavedra & Opfer, 2012).

Objective of the Study

The objective of this study was to establish the difference between students' achievement of Science Process Skills when taught using IBL approach and TL approach in Biology subject among form three students in Wareng sub-county of Uasin-Gishu County, Kenya.

Hypothesis of the Study

The following null hypothesis tested at $\alpha = 0.05$ level of significance guided the study:
There is no significant difference between students' achievement of Science Process Skills when taught using Inquiry-Based Learning approach and Traditional Learning approach in Biology subject.

Limitations of the Study

The study was limited by the use of intact groups and the Solomon Fourfold Non-Equivalent control design as a quasi-experiment which led to a small study sample that may not necessarily be representative of the study population.

METHODOLOGY

Research Design

The study adapted the Solomon Fourfold Non-Equivalent control group design as a quasi-experiment. This implied that there was no randomisation because secondary school students in Kenya are placed in intact groups as classes. The school administration does not permit the reorganisation or randomisation of these groups for the purpose of research (Shadish, Cook & Campbell, 2002). Solomon Fourfold Non-Equivalent control group design allows for the comparison of the effect of a treatment on natural settings (Cohen, Manion & Marrison, 2007) and can control some major threats to internal validity. Maturation was controlled by selecting students from the same class. History was controlled by determining the students past experiences using a pre-test.

Study population

The target population of this study was selected from the mixed day school category; because students from this category are disadvantaged compared to those in boarding and single sex schools with reference to their achievement in Biology. Wareng sub-county (currently split into Kesses and Kapsaret sub-counties) was chosen because of its dismal performance in Biology – mean of 3.248 (SCEO-Wareng, 2015) – compared to the other two sub-counties within Uasin – Gishu County (formerly Eldoret West and Eldoret East) which recorded a mean of 4.021 and 4.201 respectively in their term one joint examinations (SCEO-Eldoret West, 2015; SCEO-Eldoret East, 2015). The total number of students that were used in the study was 220 students.

Table 1: Number of respondents used in the Study

Group	Gender		No. of students
	Male	Female	
Experimental group 1	30	22	52
Experimental group 2	29	27	56
Control group 1	37	27	64
Control group 2	27	21	48
Total	123	97	220

Source: Research Data, 2016 N= 220

Solomon Fourfold Non-Equivalent control group design involves forming two experimental and two control groups for the study. Table 2 illustrates the details of activities that were carried out in the four groups.

Table 2: Activities in the Solomon Fourfold Non-Equivalent control group design used in the study

Group	Pre-test	Treatment	Post-test	Questionnaire
Experimental group 1	Administered	IBL	Administered	Administered
Control group 1	Administered	TL	Administered	Not Administered
Experimental group 2	Not Administered	IBL	Administered	Administered
Control group 2	Not Administered	TL	Administered	Not Administered

Sampling

Stratified sampling was used to select the mixed day schools. At the time of the study, the then Wareng sub-county consisted of a total of 41 mixed sex schools. Out of these 41 schools, only 25 schools had students up to third form. Systematic sampling was used to select four mixed day schools from the 25 schools because of the preferred Solomon Fourfold Non-Equivalent Group Control Design. A list of the 25 mixed day schools was generated randomly to provide a sampling frame; after picking the first school on the list, every eighth school in the list was selected up to a total of four schools were selected from the list. Simple random sampling was used to select the stream to participate in the study in schools where the streams where more than one. Division of the four classes (participants) into the Control and experimental groups was also done using simple random sampling.

Instrumentation

BSPSAT was constructed by the researcher for the purpose of this research. Instrumentation was controlled by determining the instrument's validity; questions in the BSPSAT were validated by KNEC, KCSE examiners of Biology subject, for validity. Reliability was tested using Kuder Richardson-20. The reliability estimate for the BSPSAT was found to be 0.86 and was considered to be adequate as a measure of internal consistency.

Data Collection Procedures

Permission was sought from relevant authorities to conduct the research. Four teachers of Biology from the selected schools were trained as research assistants on conducting lessons using the IBL approach. The training took a period of five days. The use of IBL approach was explained to the teachers. A pre-test was administered to experimental group 1 and control group 1 so as to determine students' prior knowledge on SPS before treatment was administered. In the experimental groups, IBL was used while in the control groups, TL was used. The researcher supervised the teaching and learning process for the experimental groups. The treatment period lasted four weeks. After the treatment period, a post-test was administered to all the four groups. The researcher scored both the pre-test and post-test.

RESULTS

Pre-test

A pre-test was administered to experimental group 1 and control group 1. This was done so as to assess the initial group difference between both groups (experimental and control group) and also to determine whether the two groups were similar on the level of Biological concepts in terms of applying SPS before treatment was administered. The results of the pre-test are shown in Table 3.

Table 3: Pre-test Means and Standard Deviations in BSPSAT

Variable	Group	N	Mean	Std Dev.	Std Error Mean
BSPSAT	Experimental Group 1	52	36.02	13.154	1.824
	Control Group 1	64	35.94	11.967	1.496

Source: Biology Science Process Skills Achievement Test (Pre-test) N= 116

The experimental group 1 and control group 1 were given a pre-test. The means of experimental group 1 and control group 1 were 36.02 and 35.94 respectively (Table 3). The means were rather low. A further observation of Table 4 shows that the two groups were almost equivalent on the level of Biological concepts in terms of applying SPS before the treatment. This is revealed by the difference (0.082) of the pre-test means between experimental group 1 and control group 1. This can also be observed by comparing the means of the two groups in the pre-test scores. To establish whether this difference was significant, an independent samples *t*-test was carried out, at a significance level of alpha (α) 0.05. The findings are shown in Table 4.

Table 4: T-test for Equality of Pre-test means Between Experimental Group 1 and Control Group 1

Variable	t-test for Equality of Means				
BSPSAT	*t*	*df*	Sig. (2-tailed)	Mean Difference	Std Error Difference
	.035	114	.972	.082	2.336

Source: Biology Science Process Skills Achievement Test (Pre-test) N= 116

The results of the independent samples *t*-test revealed that the difference in the students' scores in the BSPSAT were not statistically significant t (116) = .035, $p < 0.05$. This indicates that experimental group 1 and control group 1 showed similar characteristics. Hence, it was concluded that no group was better than the other in the pre-test, that is, the entry behavior of experimental group 1 and control group 1 was of the same level.

Effect of Inquiry-Based Learning on Students Achievement of Science Process Skills

The hypothesis of the study sought to establish whether there was a significant difference in the scores of the achievement of the SPS (observing, classifying, measuring, communicating, inferring and interpreting data) between students who were taught using IBL and those who were taught using TL. Before treatment, the difference in the mean scores was not statistically significant (Table 4). At the end of the treatment

period, all the groups did a post-test to determine their achievement in SPS. Data was analysed using *t*-test and analysis of variance (ANOVA) test. Table 5 shows the post-test mean score obtained in the BSPSAT for the four groups. The experimental groups outscored the control groups as illustrated in Table 5.

Table 5: BSPSAT Post-test Means and Standard Deviations

Groups	N	Mean	Standard Deviation
Experimental group 1	52	60.58	13.17
Experimental group 2	56	59.25	12.87
Control group 1	64	47.13	9.73
Control group 2	48	41.20	13.89
All	220	52.04	12.415

Source: Biology Science Process Skills Achievement Test (Post-test) N= 220

Results from Table 5 indicate that experimental group 1 recorded the highest mean, followed by experimental group 2, then control group 1 and lastly control group 2. A further observation made was that, the experimental groups scored higher marks than the control groups as depicted by their means. The higher scores obtained by students in the experimental groups could be attributed to the exposure to the IBL approach. The gain in the means between post-test and pre-test in the experimental group 1 was large (24.56) and control group 1 was small (11.19), but on making a critical observation, the mean gain in the experimental group 1 was larger than in control group 1 (Table 6). Presenting the pre-test and post-test means of experimental group 1 and control group 1 graphically helps visualise the mean difference within and between the two groups. The large difference in the group means is an indication that the treatment, that is, the IBL approach had a greater effect on the post-test mean score when compared to the pre-test mean score. The mean difference between experimental group 1 and control group 1 was also large (13.17), this confirms that the experimental group 1 (which was exposed to IBL after pre-test) had a higher achievement in the BSPSAT. This observation indicates that IBL as a teaching-learning approach improved the performance of students in SPS compared to TL approach.

Table 6: Pre-test and Post-test Means and Standard Deviations of Experimental Group 1 and Control group 1

	PRE-TEST			POST-TEST		
Groups	N	Mean	Std. Dev.	Mean	Std. Dev.	Mean Gain
Experimental group 1	52	36.02	13.15	60.58	13.17	24.56
Control group 1	64	35.94	11.97	47.13	9.73	11.19
Mean Difference						13.37

Source: Biology Science Process Skills Achievement Test (Pre-test and Post-test) N= 220

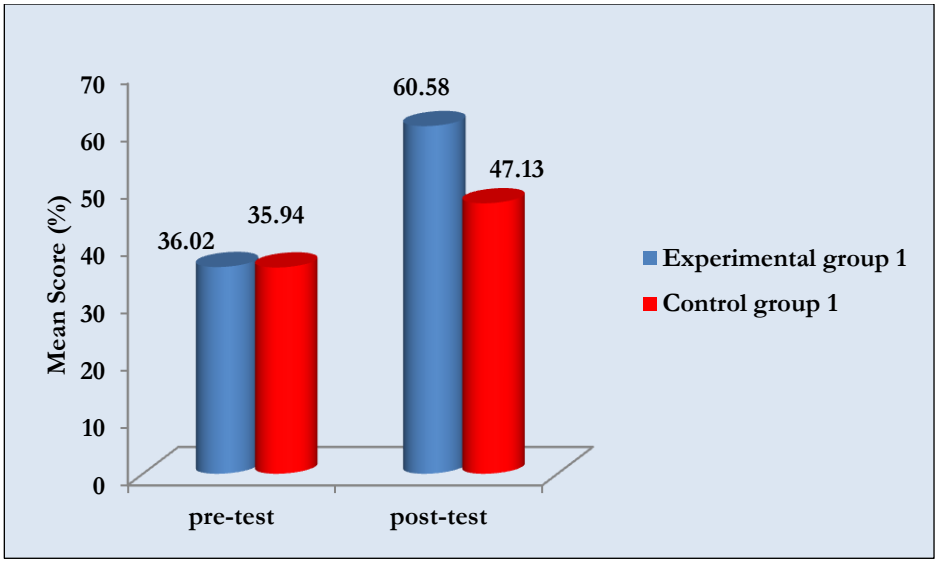

Figure 1: Pre-test and Post-test Means of Experimental Group I and Control Group I

The hypothesis of the study was "There is no significant difference between students' achievement of Science Process Skills when taught using inquiry-based learning approach and traditional learning approach in Biology subject." One-way ANOVA test was conducted to determine the significant difference between the two groups (i.e. experimental and control group). The results of the data analysis to test the hypothesis are presented in Table 7.

Table 7: ANOVA of Post-test Scores on BSPSAT

Source of Variation	Sum of Squares	*df*	Mean of Squares	*F*	*p*-value
Between Groups	13877.691	3	4625.897	30.293	.000
Within Groups	32984.109	216	152.704		
Total	46861.800	219			

Source: Biology Science Process Skills Achievement Test (Post-test) N= 220

Table 7 shows that a statistically significant difference existed between the mean scores of the experimental and control groups F (3, 216) = 30.293, $p < 0.05$. A decision was made to reject the null hypothesis. It was concluded there is enough evidence that the mean scores of students from the groups were not all equal (Table 5). It was necessary to conduct a post-hoc test to establish where the difference occurred. The test was then carried out using Least Significant Difference (LSD) procedure at $p < 0.05$ level.

Table 8: Post-Hoc comparison of the post-test of BSPSAT means for the four groups

(I) Group	(J) Group	Mean Difference (I-J)	Std. Error	Sig.
Experimental Group 1	Control Group 1	13.452*	2.307	.000
	Experimental Group 2	1.327	2.380	.578
	Control Group 2	19.369*	2.473	.000
Control Group 1	Experimental Group 1	-13.452*	2.307	.000
	Experimental Group 2	-12.125*	2.261	.000
	Control Group 2	5.917*	2.360	.013
Experimental Group 2	Experimental Group 1	-1.327	2.380	.578
	Control Group 1	12.125*	2.261	.000
	Control Group 2	18.042*	2.431	.000
Control Group 2	Experimental Group 1	-19.369*	2.473	.000
	Control Group I	-5.917*	2.360	.013
	Experimental Group 2	-18.042*	2.431	.000

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

Source: Biology Science Process Skills Achievement Test (Post-test) N= 220

Post-hoc comparison of the post-test shows that the mean difference between the experimental group 1, control group 1 and control group 2 were statistically significant. Experimental group 2 also showed a statistically significant difference with control group 1 and control group 2. Findings from the study reveal that experimental groups are the groups that received treatment and they outperformed students in the control groups. The post-hoc results on comparison of means confirm that IBL had a positive effect on students' achievement in BSPSAT; hence the null hypothesis guiding the study was rejected. Therefore, it can be concluded that IBL teaching approach that was used to teach the experimental groups contributed to the relatively higher achievement in SPS in learning ecology topic compared to those who were taught using TL approach. Students in the experimental groups were able to master selected basic SPS better than students in the control groups.

DISCUSSION

This study established that the difference between the experimental groups and control groups was statistically significant on the post-test scores of BSPSAT (p-value is 0.000, less than $\alpha = 0.05$) and F calculated, F (3, 216) is 30.293. The findings also indicated that the students in the experimental groups achieved higher mean scores (60.58, 59.25) in the BSPSAT than those students taught using TL (47.13, 41.20). These findings support observations made by KNEC, (2013), which noted that the low mean percentages recorded by candidates were attributed to: instruction that did not go beyond the classroom, but was based on mere transfer of factual information, lack of creativity for topics with abstract content, simple memorization of biological facts. Findings of this study are consistent with earlier studies conducted on IBL. A study conducted by Ajaja (2013) on the effects of 5E learning cycle on students' achievement in Biology, established that the use of 5E learning cycle led to enhanced achievement in the 5E learning cycle group than those taught with the regular lecture method. Another study conducted by Khan and Iqbal (2011) on the effectiveness of inquiry-based teaching in the development of Science Process Skills, observed that inquiry-based teaching had a positive effect on students' development of SPS in the treatment group.

CONCLUSION AND RECOMMENDATIONS

Inquiry-Based Learning manifested a significant difference in students' achievement in the BSPSAT compared to those exposed to conventional traditional method. This study concluded that IBL is more effective in the achievement of SPS than TL. Inquiry-based learning leads to higher gains in the application of SPS; IBL also provides an environment that encourages learners to become active participants while they take responsibility for their learning (Spronken-Smith, 2010). This fosters acquisition of skills that are relevant for the 21st century learner, IBL should therefore be employed so as to help the Ministry of Education Science and Technology to achieve the intention of ensuring learners improves their performance in Biology subject.

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