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Original Paper

Integration of Investigative Science Process Skills Teaching Strategy on Students' Achievement at Secondary School Level Physics in Embu County, Kenya

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Abstract

One of the challenges facing Kenya in the teaching of Physics in secondary schools is how to make learners acquire knowledge, build up capacity for critical thinking in solving problems in any situation and make an effort to enable them understand the application of content in real life situations and careers. Based on this challenge, the present study was designed to determine the effect of investigative science process skill teaching strategy on students' achievement in Physics. The study was guided by the following objectives: To determine students' achievement in school physics when using Investigative Science Process Skill (ISPS) teaching strategy. Theoretical framework of the study was based on constructivist theories of learning. Quasi- Experimental design was used. The research was carried out in eight schools in Embu County. Stratified random sampling technique was used to select participating schools, then simple random sampling was used to select and assign participating schools in experimental and control group. The sample was form three students. Research instrument used was: Physics Achievement Test (PAT) on the topic of Electricity (II). The research instrument was pilot-tested for validity and reliability. The reliability coefficient was calculated using Kunder-Richardson (KR-Formula20). A coefficient value of 0.768 was considered suitable for reliability of the instrument. Data was analysed using the analysis of variance (ANOVA) and chi-square and t-test. Hypotheses was tested at alpha (α) value of 0 .05 level of significance using a computer Statistical Package for Social Sciences (SPSS) for Windows. The findings of the study demonstrated that ISPS enhanced academic achievement in learning. It is hoped that the results of the study provide useful information to Physics teachers, curriculum developers, Quality Assurance and Standards Officer (QASO) and teacher-trainers.

Keywords

investigative science process skills, conventional methods, academic achievement and physics

1. Introduction

Integration of Investigative Science Process Skills (ISPS) is a teaching approach based on hands on activity where the teacher is just a guide. It is student centred. It involves practical activities used as an approach to instruct students. Process skills make the duty of a teacher teaching (more authentic) to the students as opposed to non-figurative or hypothetical presentation of facts, main beliefs and laws of subject matter (Madera, 2001). ISPS are the basis of scientific investigation plus the increase of intellectual skills and attitude that are needed to gain knowledge of concepts (Wachanga, 2002). ISPS is very important for technological development and the understanding of scientific concept, scientific knowledge and particularly physics knowledge, is fundamental in food production, industrial growth, economic growth and health care facilities among other socio economic needs (Changeiywo, 2000; Okere, 2004).

1.1 Academic Achievement in Physics

Low academic achievement in Physics education exists in countries across the world. In Europe, a report by the European Commission (2010) indicated that more that 20% of young European students were not attaining a minimum level of basic skills in mathematics and sciences. In Africa, physics is the least chosen science subject compared to chemistry and biology. However, in the Kenyan context, student enrolment and performance in physics has been low compared to mathematics, biology and chemistry as shown in the table below.

Table 1. Performance and Enrolment in Mathematics and Science Subjects in the Years 2007-2013 in Embu County

Subject	**Mathematics**		**Biology**		**Chemistry**		**Physics**	
Year	**Enrol**	**M/S**	**Enrol**	**M/S**	**Enrol**	**M/S**	**Enrol**	**M/S**
2007	4392	2.048	4162	4.163	2500	3.961	**829**	**3.811**
2008	4367	2.177	4132	4.574	2611	4.45	**857**	**4.444**
2009	4098	2.709	2813	4.791	2400	4.624	**991**	**4.38**
2010	3935	2.678	3373	5.086	3498	4.462	**1053**	**4.313**
2011	4317	2.759	3110	5.103	3060	4.34	**1032**	**4.322**
2012	4364	2.821	3224	4.403	3169	3.718	**1173**	**3.699**
2013	4390	3.021	3310	4.502	3259	3.818	**1214**	**3.799**

Source: County Education Office (2013). 2013 (KCSE) Result Analysis. Sub-county Education Office: CEO.

Among the sciences, physics is the least chosen by students after form two as shown in Table 1. The mean score of mathematics is the lowest compared to chemistry, biology and physics implying that performance in mathematics is directly proportional to that of physics, as most concepts, laws and principles in physics are normally expressed in Mathematics. This means that there must be factors which have not been addressed as far as students' performance in physics is concerned. It is due to this low performance that this study of investigative science process skill teaching strategy on students' achievement, problem solving and motivation in secondary school physics in Embu County, Kenya was carried out.

1.2 Purpose of the Study

This article reports on research conducted to investigate integration of investigative science process skills on students' achievements at secondary school level physics in Embu County, Kenya. This entailed comparing the outcomes of ISPS and conventional instructional methods. It is paramount to determine whether ISPS would have helped in addressing low academic achievement in physics among Kenya secondary school students towards learning of Electricity II.

1.3 Hypothesis

The study was guided by the following null hypothesis:

Ho1: There is no significant difference between student's achievement scores in Electricity (II) of students who are exposed to Investigative Science Process Skills (ISPS) teaching strategy and those taught using conventional methods.

1.4 Literature Review

Meaningful learning takes place as soon as students can bear in mind and make meaning of structural knowledge and are capable of applying what they have well-read (Anderson & Krathwohl, 2001; Bransford, 2000). The capacity to relate information to a new state of affairs is determined by the extent to which students study Physics all through insight. To structure knowledge in Physics, lessons and teaching/learning activities need to be organised in such a way that students are inquisitive, the context is meaningful and of interest to the students. According to Wachanga and Mwangi (2004) learning occur when students look for information and relate it to pertinent existing new facts and principles in their cognitive formation. Noteworthy knowledge occurs progressively over time (Shuell, 2004). According to Hodson (2003), knowledge in a skill rich setting is significant if education is lively (controlling) productive, introspective intended and genuine (multifaceted and appropriate and helpful, concerted and chatty). Knowledge is significant, improved and liable to reassign to new situations especially in real-life (Hodson, 2003). Students, who have not acquired significant learning, learn by rote (Novak & Gowin, 2002). The main restrictions of rote knowledge are pitiable retention and repossession of new ideas, possible meddling in later learning of connected concepts and failure to use the new information to solve innovative problems. Wachanga and Mwangi (2004) assert that achievement in significant learning depends on three factors (Osborne, 2002). The context measures the degree of cognitive strategy employment independently from knowledge acquisition, the context permits the students to construct concepts through his /her own cognitive efforts and employ this knowledge in proposing solutions and making decisions. The context is in built on new knowledge. If these factors are not met then, memorization takes over. Learner skill–building for significant knowledge is a difficult process (Bransford, Brown, & Cocking, 2000). It requires a rational endeavour or action connecting diverse learner—centred actions.

To be precise, past knowledge is vital in knowledge—building processes. Students construct their logical knowledge in Physics ahead of what they previously recognize and accept as true. Students articulate new technical information by modifying and enlightening their present skills in Physics and adding up innovative concepts to previous ones. Learners moreover, construe data based on their potential and environments (Oyoo, 2007). For instance, learners who do not have hypothetical framework towards making-measurement, or tasks on how to evaluate, interpret, predict, and expected observation and analysis of what they do in experiment / practical work (Hodson, 2003).

An important goal of education is the development of learners who can be responsible for not only employing their existing knowledge but for creating new knowledge so as to do away with miss-conceptions that might hinder their capacity to find out new things (Brandsford et al., 2000). Ndirangu, Kathuri, and Mungai (2003) indicate that denotation is a mixture of reflection, language, understanding and interaction. The function of common experiences is essential in knowledge building and its growth (Anderson & Krathwohl, 2001). Student knowledge can be facilitated by others and can lead to the processing of information insides one's head before making generalization regarding the trend of data, making conclusions from observations or using experience and acquired knowledge (Song & Keller, 2001). In cooperation, student-teacher relations are crucial for significant learning which can be improved by cognitive kit as science process skills. In addition, valuable learning needs students to be able to manipulate their own learning in expression and self-evaluation (Brandsford et al., 2000).

A major impediment to students' relations to various principles of human learning, which include the necessity of having a logical relationship between the objectives of instruction, content to be taught, the practice and application exercises is what is used to develop learning and the evaluation methods used to assess mastery (Salim, Puteh, & Daud, 2011). The operational remembrance is often loaded with inward bound information in the course of experiments. Moreover, differences in assignments and assessment procedures will produce differences in students' study patterns and differences in what students' learn and retain. In science education, instruction involves conceptual change rather than infusion of information into a vacuum (Sadiq, 2003). This is due to prior knowledge that student brings to a learning situation and this prior knowledge establishes a framework within which new input is interpreted. When this knowledge brought to new learning situation is accurate, the results of learning are authentic. However, if prior knowledge includes misconceptions the results may be distortion or rejection of the new learning (Kim & chin, 2011).

In order for students to construct new meaning in Physics learning, they should then include science process skills to enable them adapt to inventiveness, problem solving, introspective thinking and creativity which are vital ingredients for logical and scientific growth of any country. Science process skills when learnt in the minds of students, helps students in construction of knowledge both in laboratories, social environs and classrooms. Science process skills are inseparable in practice as they form conceptual understanding involved in learning (meaningful) and applications in sciences and mathematics (Okere, 2004). Rational model, according to Nersessian (2003), happens mostly when learners get significant learning. This is only likely to happen when the misconceptions are well anchored in the student's personal experience and are not resistant to change. Knowledge of laws, theory and facts is nonetheless complicated (Juma & cheong, 2005). In order to fill the knowledge gap of imaginative learning so that students can visualize the ideas and hence have a better understanding (Wheeler, 2000) the evidence is obtained from an investigation of the performance on the skill by high school students, A-level and first year Bachelor of Education.

According to Okere (2004) Physics students for example 90 pupils out of 146 tested were unable to carry out an experiment on internal resistance of a cell. The low performance on the skill of the design of scientific investigations is partly due to the lack of practice on the skills of investigation. Moreover, science process skills approach enhances "science for all", pupils' attitudes towards learning of Physics and above all it is more flexible, and makes the knowledge more relevant to the pupils as it is more of hands on activity and it is hence motivating (Ndirangu et al., 2003). Even though, numerous problems continue to confront attainment of projected education goals as envisaged in the vision 2030 development strategic plan. One of the notable challenges is the poor performance in science examinations. Students are reported to have poor mastery of the content; poor scientific language; poor understanding of concepts and inability to relate Physics knowledge to real life situation (KNEC, 2013). Various modern approaches are adept to deal with the dilemma. In spite of the implementation of these diverse approaches to learners, achievement at KCSE examinations is nevertheless poor. Science process skill knowledge is a necessary component in various pedagogical models to facilitate meaningful Physics learning.

The use of investigative science process skill teaching strategy in this study intends to facilitate meaningful learning, peer interactions and assist students to comprehend the contents of Physics in order to fill this gap.

1.5 Conceptual Framework

Constructivists state that the instructor needs to guide the learners in an attempt to provide an environment conducive for students to construct meaning at individual and group level (Duit & Treagust, 2003). Knowledge is actively built by the students in collaboration with his/her world (Piaget, 1950). This intern brings about self-directed learning and ultimately facilitate the construction of new knowledge (Piaget, 1972). It should, however be noted that there is dispute about which of the activities in a physics lesson contribute to scientific achievement are skills which ones are processes.

To overcome this difficulty, it is convenient to refer to all those activities that contribute to scientific learning as process-skills (Okere, 2004). The use of investigative science process skill is linked to constructivist teaching because it involves activities that define the teacher as a facilitator and enables students to construct meaning that leads to scientific learning. Moreover, ISPS is a hands-on explorations that fuel the construction process, letting them discover by themselves, thus students come to make sense of their experience, gradually optimizing their interaction with the world. When you investigate, you gather information about a problem. Knowledge is not merely a commodity to be transmitted, encoded and reapplied but a personal experience to be constructed making the study to hold the view of knowledge construction as demanded by constructivist theorist. It involves using your senses and planning. The difference between experimenting and investigating is that in the former the ideas to be tested and the equipment to be used are provided; while in the latter the student has to think of the apparatus as well as the procedure to be used (Changeiywo, 2002). It is therefore significant that a study that involves students in investigative science process skill is likely to lead to meaningful learning as well as scientific achievement compared to conventional methods of learning. The link between the independent variable, intervening variables and dependent variables is diagrammatically represented in Figure 1 below.

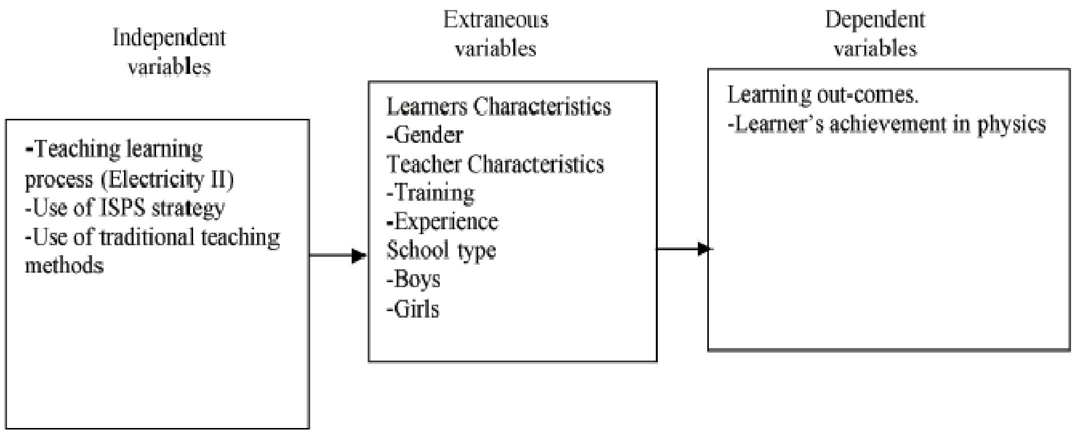

Figure 1. Conceptual Framework for the Use of ISPS and Achievement in Learning Physics

Scientific Learning is subjective to factors such as, teacher-methodology, learner's prior knowledge, resources available, individual differences and classroom environment. The factors are interconnected to facilitate the teaching/ learning procedure, which eventually influences the students' achievement and motivation in Physics. Teacher training and experience determine how effective a teacher is. The study will involve qualified Physics teachers with a minimum of five years teaching experience. It is assumed that these teachers will therefore teach in comparable ways (Fraenkel & Wallen, 2000).

2. Method

The study was carried out in Embu County which is in Kenya. The county was deemed appropriate for the study because the students' performance in physics has remained low as compared to mathematics and chemistry and also the enrolment has been low compared to other subjects.

2.1 Research Design

The study adapted a non-equivalent Solomon- Four Group Quasi-Experimental research design. Non-equivalent groups were used because classes in secondary schools once constituted existed as intact groups. The school authorities do not normally allow such classes to be broken up and reconstituted for research purposes. Thus it was possible to assign class randomly as required in true experimental designs. The schools selected were however assigned to the treatment and control conditions as intact groups. The quasi-experimental design was deemed appropriate for the study because it would allow for assessment of effects of integration of ISPS in teaching on achievement, problem solving abilities and motivation towards physics learning.

The research design was represented as follows:

Group I	(E1)	O_1	X	O_2
Group II	(C_1)	O_3	x	O_4
Group III	(E_2)		X	O_5
Group IV	(C_2)		x	0_6

Figure 3.1: Solomon-four Group, Non Equivalent Control Group Design

Source: (Borg and Gall, 1989).

Where O1 and O3 were pre-tests

O2 O4 O5 and o6 were post-tests.

X was the treatment where students would be taught by use of ISPS

– – – – Indicates non-equivalent groups

x Represented **no** treatment to the groups

C_1 Control 1

C_2 Control 2

Figure 2. Solomon-Four Group, Non Equivalent Control Group Design

2.2 Participants and Sampling Procedures

The research used stratified random sampling to select the eight schools that participated in the study four of which were girls' while the other four were boys' schools. Simple random sampling technique was used to group four schools to experimental and four others to control groups. Where schools had more than one stream all participated but simple random sampling was done to select one stream for data analysis.

The selection of four boys and four girls schools was deemed necessary to avoid excessive stratification that could result in complexities stemming out of logistics involved in handling many schools, types especiallyin a quasi-experimental design. The success of experimental and quasi-experimental designs normally relied on stringent control of extraneous variables (Fraenkel & Wallen, 2000). A challenge that could be minimized by reducing variation in characteristics of groups involved. A total of 320 students from eight schools participated in the study as shown in the population grid below:

Table 3. Categories of Schools and the Number of Respondents

Group	**Group type**	**Boys**	**Girls**	**Number of Respondents Total**
I	Experimental	40	40	80
II	Control	40	40	80
III	Experimental	40	40	80
IV	Control	40	40	80
Total		160	160	320

2.3 Research Instruments

Physics Achievement Test (PAT) was used to collect data on students' academic achievements in physics. Two assessment tests were used: the pre-test and the post-test. The pre-test was used to measure the student achievement in physics before the exposure of the treatment. The post-test was used to measure achievement after treatment. The questions of the pre-test and post-test were based on the topic from Form 3 physics syllabus on the topic of Current and Electricity II.

2.4 Data Collection Procedures

A research permit was obtained from National Council of Science Technology and Innovation (NACOSTI) and also a letter from District Educational Officer (DEO). In order to conduct research in the sample schools, the teachers were trained for one week on how to use ISPS. This enabled them to master the skills of using ISPS as a teacher's strategy. After this period a PAT and MSQ pre-test was administered to experimental group 1 and control group 2. This was followed by the exposure of ISPS. At the treatment period, the researcher assisted Physics teachers in sample schools to administer PAT post-test to all four groups followed by administration of MSQ. The researcher then scored and code collected data for analysis.

2.5 Data Analysis

The data was scored, coded and organized the data for analysis. Data was analyzed using both descriptive and inferential statistics. Raw data was analyzed using means, standard deviation and percentages so as to meaningfully describe the distribution of the measurements. Inferential statistics dealt with analysis, interpretation and decisions on the bases of the results (Changeiywo, 2002). Quantitative methods of data analysis involving the use of Analysis of variance (ANOVA) and t-test was used to list statistical significant difference within and among means in the posttest scores for the group exposed to ISPS and those exposed to regular teaching methods. When dealing with 2 means, a t-test was used because of its superior power of detecting the difference between 2 means. On the conceptualization of the topics on physics electricity (2) and also between the pre-tested groups and those not exposed to pretest. Hypothesis which was tested using the measures of central tendency. Computations were conducted using Statistical Package for Social Sciences (SPSS) version 18 for windows.

3. Results and Discussion

The results of the study were based on the following hypothesis:

Ho1: There is no significant difference between student's achievement scores in electricity (II) of student who are exposed to investigative Science Process Skills (ISPS) teaching strategy and those taught using conventional methods.

3.1 Normality Test

A plot of homogeneity of the average of student pre–test and the post test score for all learners studied showed deviations from the zero mark of the line of best fit not crossing probability lines (P < 0.05; thus homogeneity was accepted at 95% probabilities Figure 3.

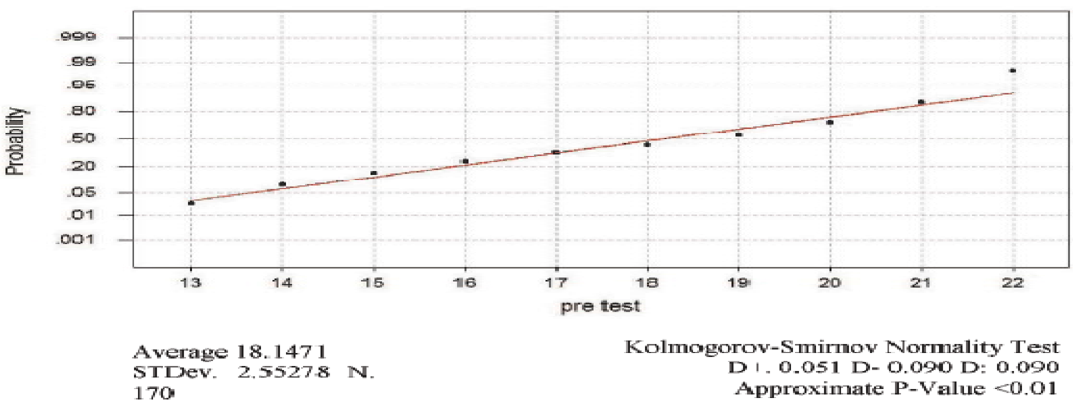

Figure 3. Normality Test for the Pre-test Results

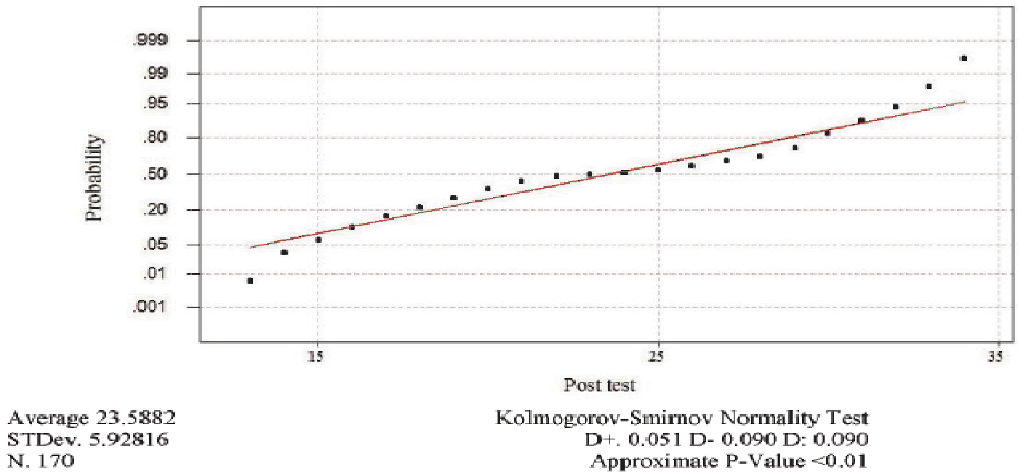

Figure 4. Normality Test for the Post-test Results

3.2 To Determine Students' Achievement in School Physics (Electricity II) When Using Investigative Science Process Skills Teaching Strategy

Students' achievement in the selected schools was determined when using Physics achievement test. The achievement in school physics (Electricity II) was recorded in four schools used as experimental and four schools as control group. To establish the effect of the use of ISPS, a pre-test was conducted in the schools. The resulting score from the students in the control was 18.05 ± 0.28 and in the experimental group was 18.24 ± 0.28 out of 40. Using two sample t-test, students' achievement in the control and experimental group of schools in Physics (Electricity II) before the experiment (pre-test) were not significantly different (t = 0.49, P = 0.623).

Table 3. Mean Achievement of the Students in Physics (Electricity II) (Pre-Test)

	Mean	Standard error (SE)	Minimum	Maximum
Control	18.05a	0.28	13.0	22.0
Experimental	18.24a	0.28	13.0	22.0
t-test	0.49			
P-value	0.623			

Mean values in the same column denoted by similar letters are not significantly different at $P \leq 0.05$. Means separated using Tukeys HSD test.

Students' achievements in pre-test and after the test were presented in Figures 5 and 6 respectively.

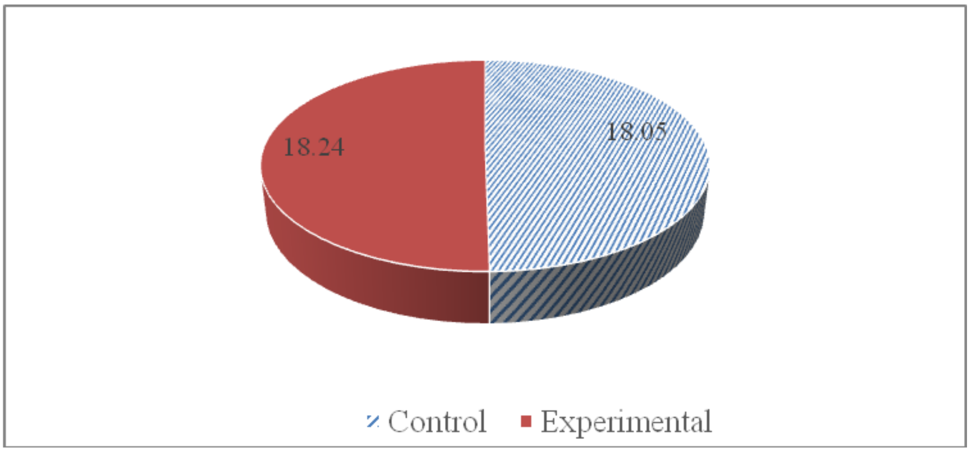

Figure 5. Pre-Test Achievements of the Students in Physics

In this study, same students who were given pre-test were subjected to a post -test to establish the effect of the use of ISPS. The resulting post-test score from the students in the control was 18.10 ± 0.26 (mean ± standard error) and the score for the experimental group was 28.83 ± 0.28. Using two sample t-test, these achievements in the control and experimental group of schools in Physics (Electricity II) after the experiment (post -test) were significantly different (t = 28.06, P = 0.0001).

Table 3. Mean Achievement of the Students in Physics (Electricity II) after Using ISPS (Post-Test)

	Mean	Standard error (SE)	Minimum	Maximum
Control	18.10a	0.26	13.0	22.0
Experimental	28b	0.28	23.0	34.0
t-test	28			
P-value	0.0001*			

Mean values in the same column denoted by similar letters are not significantly different at $P \leq 0.05$. *significant difference in the means

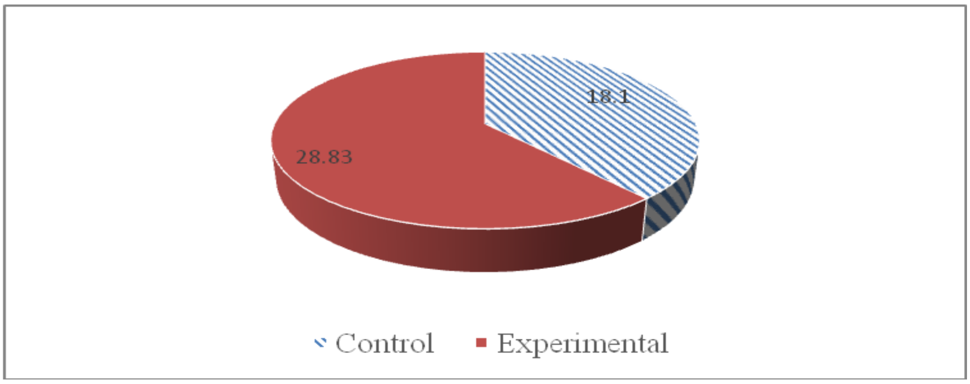

Figure 6. Post-Test Mean Achievements of the Students in Physics Electricity II

Students' achievements before the experiment (pre-test) were compared to their achievements after the use of ISPS (post-test). Mean score post-test (mean 23.59 ± 0.46) was significantly higher than the students' mean score pre-test (mean 18.15± 0.20), t = 11.73, P = 0.0001. This showed that Investigative Science Process Skills teaching strategy (ISPS) resulted into a significant improvement of the individual students score in Physics (Electricity II) teaching.

Table 3. Mean Achievement of the Students in Physics (Electricity II) before (pre-Test) and after Test (Post-Test)

	Mean score	Standard error (SE)	Minimum	Maximum
Pre-test	18.15a	0.20	13	22
Post test	23.59b	0.46	13	34
t-test	11.73			
P-value	0.0001*			

Mean values in the same column denoted by similar letters are not significantly different at $P \leq 0.05$.
*significant difference in the means

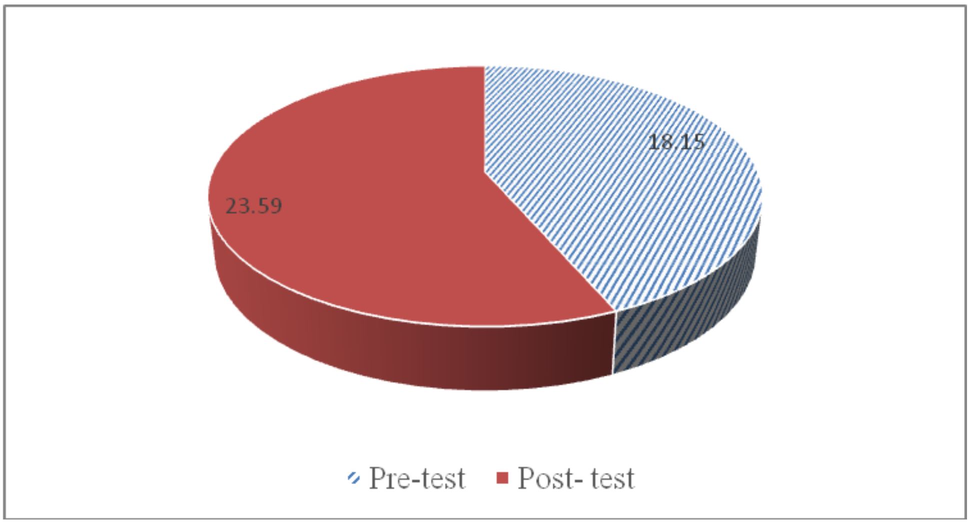

Figure 7. Mean Achievement of the Students in Physics Electricity II before Pre-Test and after Post-Test

When related to the null hypothesis of the study which was stated as follows:

Ho1: There is no significant difference between achievement scores in Electricity (II) of students who are exposed to Investigative Science Process Skills (ISPS) teaching strategy and those taught using conventional methods.

In testing this hypothesis, using t-test, the result showed that Science Process Skills teaching strategy (ISPS) significantly improved individual students score in Physics (Electricity II) learning (t = 11.73, P

= 0.0001). The null hypothesis is therefore rejected; "There is a significant difference between achievement scores in Electricity (II) of students who are exposed to Investigative Science Process Skills (ISPS) teaching strategy from those taught using conventional methods. The result of the study shows that ISPS teaching strategy indeed affect students' achievement as compared to conventional methods. This gives the answer to the research question.

Investigative Science Process Skill, as an instructional strategy influences learners understanding of concepts as significant learning takes place as students make meaning of structural knowledge and are able to apply what they have well –read. The results are in line with the argument of Wachanga and Mwangi (2004) that significant learning occur when students look for information and relate it to new facts and principles in their cognition. Students are able to articulate new information by modifying and enlightening their present skills in physics and adding up innovative concepts to previous ones (Oyoo, 2007). The findings are in line with results of Okere, ((2002) who views that in an evaluation exercise groups in the experimental groups after the intervention always attained better scores in subjects tested than the control groups. This also improves the retention rate of learners and creates interest in the learning process.

4. Conclusion and Recommendations

The summary of the study indicated that there was a significant difference between achievement scores in the topic of electricity (II) of students, who were exposed to investigative science process skills (ISPS) teaching strategy and those taught using conventional methods. This implied that Investigative Science Process Skill(ISPS) is more effective than conventional teaching approaches in improving students learning in electricity (II) in physics. It is hoped that the results of the study provide useful information to Physics teachers, curriculum developers, Quality Assurance and Standards Officer (QASO) and teacher-trainers.

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