EFFECTS OF PROBLEM-BASED LEARNING ON LEARNERS' ACQUISITION OF CORE CRITICAL THINKING SKILLS OF ANALYZING IN SECONDARY SCHOOL PHYSICS

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Abstract
Progressive research recognizes the importance of teaching thinking skills through appropriate methodology as key to developing learners' problem solving ability. This study investigated the effects of Problem–Based Learning (PBL) instruction on learners' acquisition of core critical thinking skills (CT) of analyzing in secondary school physics in Nakuru, Kenya. Solomon Four non-equivalent Control Group design was used. A sample of 139 students from four schools obtained through stratified random sampling was used in the study. Independent variables for the study were PBL mode of instruction and the conventional teaching methods, while dependent variablewas learners' core critical thinking skill of analyzing in physics. The instrument for data collection was the Core Critical Thinking Skills Physics Achievement Test (CCTSPAT).Data collected was analyzed using both descriptive and inferential statistics. Differences between means of the four groups were analyzed using t-test and ANOVA.Tests on hypothesis was done at α=0.05level of significance. The study established that there was no statistically significant difference in achievement of core critical thinking skills of analyzing between students taught using PBLand those taught using conventionalmethods.The results of the study could benefit teachers by providing insight, knowledge and need for fundamental preparation skills and practices on effective implementation of PBL to enhance development of analyzing skills in learners.

Keywords: *Problem–Based Learning (PBL), Core Critical Thinking Skills (CT) of analyzing in Physics, Conventional TeachingMethods*

1. Introduction

Knowledge of physics provides solutions to many of the problems that occur in today's world (Radido, 2017; Hmelo-Silver, 2004; Zahoyao, 2002**)**. To solve the problems, adequate and well developed critical thinking skills have also been recognized as essential (Veloo, 2015; Moore, 2009; Hmelo-Silver, 2004; Okere, 1996, 2006). That is why contemporary thought regarding effectiveness in physics instruction favours instructional methods that are likely to enable learners to acquire critical thinking skills and inquiry so as to enhance their problem-solving ability in everyday life (Hmelo-Silver, 2004; Okere, 2006).

It is through knowledge of physics that innovations such as the optical fibre, satellite links, radar systems and the internet have been developed and utilized in the realization of great advancements and refinements in modern communication (Hall, 2008). For knowledge of physics to provide a strong foundation for development of communication systems, adequate critical thinking skills are necessary (Hall, 2008).Growing demand for quality and competitiveness especially in industry, medicine, agriculture and communication requires effective use of knowledge of physics in solving problems of society (Sovacool, 2010). Such expertise is possible when learners' critical thinking skills are well developed. Lack of expertise in physics has often been attributed to inadequate development of learners' critical thinking skills (Hmelo-Silver, 2004; Okere 2006).That is why the teaching of critical thinking skills should be a fundamental part of curriculum that should involve methodology that ensure that the skills are transferable (Okere, 2006).

The UNESCO/ICSU World Conference on Science has documented the perennial problems that affect the teaching of physics in schools (UNESCO, 1999). Most important are its abstract nature, lack of visualizable elements and mathematical presentation. These problems are also the reasons why learners often find physics subject matter to be complex and somewhat distant from their everyday life concerns (KIE, 2006, 2009;Kiboss, 2002; Okere, 1996). Unless physics instruction is made congruent and responsive to learners' social, physical and emotional needs, there is a high likelihood that many learners may fail to grasp the relevance of the subject in life and to society.

Clarity of relevance of physics in life to learners is necessary for sustained learner interest and motivation in the subject (Ali& Awan, 2013). Many learners may tend to shy away from the subject when they encounter difficulties in their studies and pressure in their pursuit of good grades (Changeiywo, 2001; Nyakan, 2008). The persistent poor performance in physics in Kenyan schools may be attributed to this absence of clarity of significance of physics in

lives of learners and their lack of core critical thinking skills(Kenya National Examinations Council [KNEC], 2010; KIE, 2009). Table 1below showsthe national mean scores for physics in Kenya Certificate of Secondary Education (KCSE) between 2009 and 2017.

Table 1: Mean in KCSE Physics from Year 2009 To 2017

Year	2009	2010	2011	2012	2013	2014	2015	2016	2017
Mean score (%)	35.31	38.52	39.74	38.64	40.10	38.84	43.68	39.77	35.05
Grade	D+	D+	D+	D+	C-	D+	C-	D+	D+

Source: KNEC Examination report, (KNEC,2010,2013, 2015, 2018)

As shown in Table 1 above, over the last nine years, all the mean scores for physics in KCSE exams were between 35.0 and40.0% (equivalent to a grade of D+) except in the year 2015 and 2013. Compared to the maximum aggregate of 100% (equivalent to a grade of A), the means show progressive dismal performance in secondary physics in Kenyan schools (KNEC, 2010, 2013, 2015, 2018). The subject has also been less popular among students as compared to other science subjects (Wambugu & Changeiywo, 2008; KNEC, 2015, 2016, 2017).

Although there are many causes that have been advanced to explain the poor performance, the quality of physics instruction remains the central theme in most of them (CEMASTEA, 2004, 2017;KIE; 2006).The Kenya Institute of Education has described clearly the situation in Kenyan education.It vividly indicates that the 8-4-4 curriculum is visibly deficient on aspects related to innovation and technology (KIE, 2006) due to lack of expertise in physics, a problem that has often been attributed to inadequate development of learners' critical thinking (CT) skills (Hmelo-Silver, 2004; Okere 2006; KIE, 2006).It is therefore important that physics instruction beimproved so as to provide adequate development of thinking skills especially the core critical thinking skills in learners (Okere 2006).

Core critical thinking skills refer to the range of critical thinking skills that contribute most towards problem solving. A number of critical thinking skills have been recognized as core in the learning of physics. These include analyzing, synthesizing, evaluating, applying, generating idea and solving problems (Valentino, 2000;Okere, 2006; CEMASTEA, 2017). For secondary school learners, analyzing and applying skills are the most applied critical thinking skills in the learning of physics in a physics lesson (KIE, 2006; CEMASTEA, 2017).

Analyzing Skills refers to the ability of a learner to separate a complex idea into its constituent parts. The skills are manifested through communication of understanding of the organization and relationship between parts of a complex idea or design (Moore, 2009; Okere, 2006). Analyzing skills may be recognized in situations where learners express awareness of logical fallacies in reasoning, relationships between elements and, through comparison and contrast of alternatives in procedures (Srivastava &Kumari, 2005; Rani, 2004; Okere, 2006).

Problem-Based learning (PBL) pedagogy, has been found effective in development of critical thinking skills and problem solving ability in learners at any levels of learning (Gerace& Beatty, 2005; Hmelo-Silver, 2004; Barrett & Moore, 2011). In many contexts where PBL has been applied, it has affected learners positively; it has enhanced students' problem-solving skills, increased their motivation to reflect on learning and also enhanced their self-directed learning skills (Hmelo-Silver, 2004; Barrett & Moore, 2011; Sungur&Tekkaya, 2006). Other key benefits of PBL cited in research literature include fostering critical thinking, conceptual understanding and intrinsic motivation towards becoming self-directed learners (Hmelo-Silver, 2004; Barrett & Moore, 2011). This study investigated the effect of PBL on development of Critical Thinking (CT) skill of analyzing in physics learners' at secondary school level in Nakuru East and Nakuru West Sub-counties schools in Kenya where performance of physics has been poor, a problem that has been linked to inadequate development of learners CT.

1.1 Purpose of the Study

The purpose of the study wasto investigate the effects of PBL instruction on learners' core CT skill of Analyzing in secondary school physics in Nakuru County Secondary Schools, Kenya.

1.2 Research Objective

The study was guided by the following objective:

To compare the acquisition of analyzing skills in the topic of heating effect of electric current by learners taught using PBL and those taught using conventional instruction

1.3 Research Hypothesis

The following null hypothesis was tested:

Ho1 There is no statistically significant difference in learners' achievement of analyzing skills in the topic of heating effect of electric current between the

students taught using PBL and those taught using conventional teaching methods.

2. Research Methodology

The study was a quasi-experimental pretest-posttest research based on Solomon Four Non-Equivalent Control Group Design. The method was preferred because of its suitability for investigation of cause-effect relationship between variables involved in a study (Mugenda&Mugenda, 2008; Fraenkel&Wallen, 2006). The design was particularly appropriate for Kenyan secondary schools given that learners are taught in intact groups and re-arrangement into groups for a study may not be granted by the authorities in host institutions.

The sampling frames consisted of the 16 stratified sampled established mixed day public secondary schools in Nakuru East and Nakuru West sub-counties.The sample comprised 147 subjects, in which139(respondents) representing 95.5%, participated in the study. Stratifying was necessitated by the need to minimize experimental contamination through interaction between study groups.The four schoolswere randomly sampled from the 16 schools and assigned to the treatment and control groups through simple random assignment. E_1 (an experimental group) and C_1 (a control group) were given both the pre-test and the post-test while E_2 (experimental group) and C_2(control group) received only the post-test. In addition, each of the experimental groups received the treatment which comprised the PBL instruction.The Core Critical Thinking Skills Physics Achievement Test (CCTSPAT) was used in measuring achievement of learners in analyzing skills. The tests consisted of 25-marks questions drawn from the physics topic “heating effect of electric current” in form three physic syllabus.Figure 1 shows the representation of the Solomon Four Non-Equivalent Control Group design used in the study.

	Pre-Test	Treatment	Post-Test
E_1	O_1	X	O_2
C_1	O_3		O_4
E_2		X	O_5
C_2			O_6

Key: pre-test: O_1 and O_3; Post-tests: O_2, O_4, O_5 and O_6; X is the PBL treatment.

E1, E2: the experimental groups; C1, C2: Control groups

Figure 1: Solomon four non-equivalent control group research design

2.1 Results and Discussions

Scores of learners in CCTSPAT instrument were recorded and compared between the groups and used for data analysis. The level of acquisition of the analyzing skills in learners taught using PBL was compared to that of learners taught using conventional teaching methods in Nakuru East and Nakuru West Sub-counties.

2.1.1 Pre-test Analysis of students score in Analyzing Skills

Experimental group $E_1$and the control group C_1were pre-tested on analyzing skills. The pretest was administered to estimate the magnitude of homogeneity between the groups before treatments so that learners' growth as a result of the treatments could be tracked (Kelly, 2017). The levene's and t-test results of the pretest is as shown in table 2.

Table 2: Pre-test Students Mean Scores on Analyzing Skills

				Levene's Test for Equality of Variances		t-test for Equality of Means		
Sample Group	N	Mean	Std. Dev	F	Sig.	T	Df	Sig. (2-tailed)
E1	41	2.488	2.158	.188	.666	.328 Equal var.	70	.744
C_1	38	2.817	2.680			.329 unequal var.	69.505	.743

Results in Table 2 shows the pre-test analysis of scores obtained on the CCTSPATon analyzing skills. Out of a maximum of 25marks, the mean score was ($\bar{X}$=2.488, SD=2. 158)for E_1 and($\bar{X}$= 2.817, SD=2.062)for C_1. Results in Table 2 also gives the independent t-test analysis of the pre-test scores on analyzing skills between E_1 and C_1. First, the Levene's statistics indicated that the samples were of equal variability given that p was greater than the chosen α (α=0.05) level of significance (Lee *et al*., 2015). On t-test, it was observed that the

p-value obtained was greater than the chosen significance level α=0.05. The results indicate a non-statisticallysignificant difference in pre-test means on analyzing skills of learners between those in the experimental group and those in the control group. The study henceforth established that C_1 and E_1 were at same level in analyzing skills before treatment.

2.1.2 Learners' acquisition of analyzing skills by instructional method

The effect of PBL learning on learners' core critical thinking skills of analyzing was established through a post-testCCTSPAT on all groupsnamely E_1, E_2, C_1 and C_2. The experimental groups were first exposed to the treatment (taught using PBL) while the control groups were taught using the conventional teaching methods. A post-test was then administered to all groups to measure their respective performance. Descriptive statistics of the post-test on learners' level of achievement of analyzing skills are presented in Table 3.

Table 3: Post-test Means of students score on Analyzing Skills

T	N	Mean	Std. Deviation
E_1	38	7.079	3.035
E_2	33	6.576	2.807
C_1	34	6.353	2.662
C_2	34	5.794	3.374

Table 3 shows the post-test means attained in the CCTSPAT by learners on analyzing skills. The means were ($\bar{X}$=7.079, SD=3.035)for E_1,($\bar{X}$=6.576, SD=2.807) for E_2, ($\bar{X}$=6.353, SD=2.662) for C_1 and ($\bar{X}$=5.794, SD=3.374)for C_2. Generally, the Experimental groups attained higher mean scores than the control groups. Group E_1 and E_2 were taught using PBL while group C_1 and C_1 are taught using conventional teaching methods.

From the results obtained, learners in the experimental groups taught through PBL acquired better scores in analyzing skills than those in the control groups who were taught using conventional teaching methods. To test whether the difference in scores between the experimental and control groups were statistically significant, one way ANOVA test was carried out. The results are as indicated in Table 4.

Table4: One-Way ANOVA on Post Test Scores on Analyzing Skills

Effect of treatments on Analyzing Skills

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	30.457	3	10.152	1.140	.335
Within Groups	1202.147	135	8.905		
Total	1232.604	138			

df (3,135); F_t=2.42) α>0.05

It was observed fromTable 4 that the calculated value of F (F (3,135) =1.140) was less than table valuesF_t at α=0.05level of significance with α>0.05. This indicated that there was no statistically significant difference between learners taught using PBL and those taught using conventional teaching methodsin achievement of analyzing skills in the topic of 'heating effect of electric current.

The results supportedthe null hypothesis that there exists no statistically significant difference in achievement of analyzing skills in learners between those taught using PBL and those taught using conventional teaching methods.This finding was contrary to thegenerally perceptionabout PBL. According to most studies, PBL has been recognized to have a well-established promise of increasing problem solving ability of learners at all levels (Belland, French &Ertmer, 2009; Hmelo-Silver, 2004). Other studies have shown that PBL has affected learners positively, enhancing their critical thinking, conceptual understanding and intrinsic motivation towards becoming self-directed learners (Hmelo-Silver, 2004; Barrett & Moore, 2011; Sungur&Tekkaya, 2006).

To rule out on the possibility that the lack of statistical significant differences could be as a result of initial differences in groups, KCPE scores of the learners studied were taken as covariate. Adjusted mean scores of the groups with KCPE mean score as covariate are given in Table5.

According to Table 5, the adjusted means of experimental group E_1 (7.138^a), and group E_2 (6.566^a) were greater than those of the control counter parts group C_1 (5.822^a) and group C_2 (6.268^a). The results indicate that learners taught using PBL scored highly in analyzing skills than those taught using conventional teaching methods.

Table 5: Adjusted Post –Test CCSCPAT Mean Score Using KCPE Marks

Dependent Variable: Analyzing Skills

Sample Group	Adjusted Mean	Std. Error	95% Confidence Interval	
			Lower Bound	Upper Bound
E_1	7.138[a]	0.495	6.159	8.117
E2	6.566[a]	0.521	5.536	7.597
C_1	5.822[a]	0.515	4.803	6.841
C_2	6.268[a]	0.532	5.215	7.321

Pair-wise comparison of the adjusted means was further done to establish the nature of the differences between the group means. Table 6 shows the results of the comparison.

Table6: Comparison of Adjusted Post-Test CCSCPAT Mean Score

Dependent Variable: CCSCPAT Score

(I) Mean Score	(J) Mean Score	Mean Difference (I-J)	Std. Error	Sig.[a]
E_1	E_2	.572	.721	1.000
E_1	O_1	1.316	.708	.392
E_1	O_2	.870	.746	1.000
E_2	O_1	.744	.734	1.000
E_2	O_2	.298	.742	1.000
O_1	O_4	.446	.750	1.000

Table 6 illustrates the differences between group means after covariate adjustment. The purpose of the adjustment was to neutralize the effect of any initial differences prior to treatments in order to establish the true effect of the treatment. The results indicate that experimental groups scored higher in analyzing skills than control groups.

Further comparison of the adjusted mean scores was done using ANCOVA to establish whether the differences between the means were statistically significant or not. Results of the test are shown in Table 7.

Table7: ANCOVA Test of theAdjusted Post-Test CCSCPAT Mean Score

Dependent Variable: CCSCPAT Score						
	Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Contrast	32.344	3	10.781	1.205	.311	.026
Error	1198.94	134	8.947			

Table 7 shows the ANCOVA result for the differences in adjusted means on analyzing skills between those of experimental and the control groups. The ANCOVA results (F [3,134] = 1.205, p>0.05) indicated that the achievement of analyzing skills by students taught by PBLwas not statistically significantly different from that of students taught using conventional teaching methods. Hence on the basis of above results,the hypothesis that there exists no significant difference in achievement of analyzing skills in learners between those taught using PBL and those taught using conventional teaching methods was accepted.

These findings agree with those of Du and Han on medical Students taught with PBL bilingual method and those taught with the bilingual method alone (Du &Han, 2016). They found out that there was no statistical significant difference between the two teaching methods with respect to critical thinking and problem-solving skills. The same study however found that the students taught by PBL bilingual scored significantly higher in basic knowledge, case analysis and treatment selection than students taught with the bilingual method alone.In a number of meta-analyses on the effectiveness of PBL, research findings show that PBL is more effective than traditional approaches when the measurement of learning out-comes are focused on long-term knowledge retention, performance or skill-based assessment, and mixed knowledge and skills(Yew& Goh, 2016).

The reason for lack ofstatistically significant difference in achievement of analyzing skills by learners exposed to PBL and those taught using conventional instruction in the current study could be mostlikely due to lack of familiarity onPBL by teachers and learners. In the PBL process, a teacher has a critical role (Gwee, 2009).Success or failure of PBL is largely determined by the commitment and tutoring skills of the teacher (Albanese, 2004). In Gwee'sview, the tutor is the one that sets the pulse and tone of discussionsin the learning process (Gwee, 2009).

3. Conclusion

The study established that there was no statistically significant difference in achievement of analyzing skills by learners between those taught using PBL and those taught by conventional teaching methods in the topic of 'heating effect of electric current' in secondary school physics.Even though the post-test mean scores of the students in experimental groups who were taught using PBL were higher than for those taught using conventional teaching method, achievement of analyzing skills by learners taught using PBL was not statisticallysignificantly higher than that of learners taught by using conventional teaching methods. This is contrary to the long held perception that PBL would improve the analyzing skills in learners.

The reason for lack ofstatistically significant difference in achievement of analyzing skills by learners exposed to PBL and those taught using conventional teaching methodsin the current study could mostlikely bedue to lack of familiarity to PBL methods of instruction by teachers in experimental groups.To realize positive impact of PBL, effective training programs for both students and teachers should precede its implementation (Albanese, 2004). Efficient and effective implementation of PBL that realizes skills development requires many factors in place; prior knowledge activation, well-constructed problems, competent tutors, students' self-determination, well-constructed teams and group dynamics. A number of these factors require significant time to develop.It was therefore concluded that the basic training for teachers and preliminary orientation of learners for PBLcould not have adequately prepared them for effective implementation.

Following the findings, similar studies on the effects of PBL on Critical thinking skill of analyzing in learners should be conducted to determine whether there would be similarities with the findings of the current study. Attention should be taken to intensifying training of teachers and students on PBL to ensure that participants have acquired a favorable and appropriate mind set ahead of the treatments.

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