

Comparison of the Learning Effectiveness of Problem-Based Learning (PBL) and Conventional Method of Teaching Algebra.

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Abstract

This study was undertaken to find out the effect of Problem-Based Learning (PBL) approach on senior secondary school students' achievement in algebra. The design of the study was quasi-experimental pre test – post test control group. Four hundred and forty seven senior secondary one (SS I) students of six grant-aided and government schools sampled using multistage sampling were involved in the study. Two hundred and eleven students were assigned to the experimental group while two hundred and thirty six students were assigned to the control group. Students' Algebra Achievement Test (SAAT) constructed by the researchers was the main instrument used for data collection. Four hypotheses were raised for the study and tested using Analysis of Covariance (ANCOVA) at .05 level of significance. Findings of the study showed that students taught using PBL achieved significantly higher in the post test than those taught algebra using conventional method. The interaction effects on achievement due to methods and gender was not significant (at $p < .05$). The study proved the efficacy of PBL. The strategy is therefore recommended for use by mathematics teachers to enhance students' achievement.

Key words: Problem-based learning, achievement, algebra, gender.

Introduction

The student-centred active learning process within which the teacher is merely a guide is the focal point of contemporary education systems. Active learning is a learning process in which the learner takes the responsibility of his/her learning and he/she is given the opportunity to make decisions about various dimensions of the learning process and to perform self-regulation. In active learning process, learning is no longer a standard process, but it transforms into a personalized process. Here, the skills of problem-solving, critical thinking and learning to learn are developed. Humans face various problems in their lives and they try to find particular ways to solve these problems. In this respect, it is important for students to be prepared for the future by facing real problems in their learning environment and producing appropriate solutions to these problems. What is expected from education is to enable individuals to become effective problem solvers in their actual lives.

Literature Review

The present day teaching and learning of mathematics is far from being satisfactory. Ali, Hukamdad, Akhter and Khan (2010) observed that mathematics is one of the most poorly taught, widely hated and poorly understood subjects in our schools. Okereke (2006) had blamed this on a number of factors, which range from the students' perception that mathematics is difficult, shortage of qualified mathematics teachers and lack of mathematics laboratory. Some scholars (Bassey, Joshua & Asim, 2007) blamed the colonizers of Africa for applying direct transfer of Western Science curricula, examinations and teaching methods, which have failed to address the continental challenges of Africa. The result of this direct transfer of western curricula is a science and mathematics education, in most African countries, exemplified by de-contextualized knowledge being transmitted by poorly trained teachers in under-resourced and sometimes overcrowded classrooms.

The consequence is the deplorably low academic performance of students in mathematics. The persistent poor performance of secondary school students in mathematics examinations both in teacher-made tests and external examinations is now a global issue. The Trend in International Mathematics and Science Study (TIMSS) ranked American students either last or close to the last in nearly every category in assessment of students in nearly 25 industrialized nations (Havenhill & Crist 2006). Similar analysis of students' achievement in mathematics (Maduabum & Odili, 2006; FRN, 2007), shows that the performance of Nigerian students is not encouraging. Nigerian students like the Americans now compete for the last position instead of the first in Senior School Certificate Examination (SSCE) mathematics among the eleven English speaking West African countries (Achor, Imoko & Uloko, 2009). The students' low performance in mathematics is an indication of low mastery of the subject. This poor result calls for serious concern and this has made researchers in mathematics education to consider a number of factors. One of the factors as examined in this study is that of appropriate method of teaching.

Ali (2006) noted that very little work has been done on how achievement in mathematics can be improved by focusing attention on the students from which efforts at improvement should emanate. Others, according to Ali have suggested the improvement of the cognitive demand levels of the secondary school curriculum in

mathematics. Many non-professional and in-experienced teachers present topics in mathematics to the student in such ways that the students find it difficult to grasp some mathematics concepts (Iji, 2002, Onose, 2007). According to Odili, (2006) many teachers cling to traditional methods in which answers to the previous day's home works are first given, then the teacher directed explanations are used to present materials for the new lesson. The powers of thinking and understanding are thus not developed in the students. One of the many strategies that have the potentials to put learners at the centre of their own learning is through problem-based learning.

With problem-based learning (PBL), learning begins with a problem to solve, and the problem is posed in such a way that the students need to gain new knowledge before they can solve the problem (Roh, 2003). PBL as an instructional strategy based on constructivism, is the concept that learners construct their own understanding by relating concrete experience to existing knowledge where process of collaboration and reflection are involved. PBL is generally based on ideas that originated earlier and nurtured by different researchers like Dewey, Bruner, Piaget, Ausubel, Novak and Hanesian (Dorchy, Segers, Bossche & Gijbels, 2003). PBL was first applied to K-12 classrooms in the 1920's and 1930's and has gained particular attention in recent years due to the success of its application to medical problems at the University level (Smith & Ragan, 1999). PBL, as it is known today, originated in the 1950s and 1960s as it grew from dissatisfaction with the common medical education practice in Canada (Dorchy, Segers, Bossche & Gijbels, 2003).

Ali, Hukamdad, Akhter & Khan (2010) found that students taught through problem-based learning achieved better than those taught by traditional method did. The study also concluded that the significant difference between the achievement levels was due to PBL. Most of the researchers (Visser, 2002; Loggerenberg-Hattingh, 2003; Raimi & Adeoye, 2004; Mergendoller, Maxwell & Bellisimo, n.d) who worked on the implementation of the problem-based learning (PBL) agree that it is an effective teaching/learning method in the classroom.

Researches done in Texas, South Africa, Pakistan, Singapore, Malaysia, Canada and other western countries as reported by Camp (1996), Ward and Lee (2002), Loggerenberg-Hattingh (2003), Dorchy, Segers, Bossche and Gijbels (2003) and Gwee (2009) have shown positive links between PBL and students' achievement. The use of problem-based learning in the mathematics classroom may enhance the quality of mathematics teaching and learning in Nigeria. The purpose of this study is to shed light on this issue. Thus, the aim of the study reported here was to ascertain the extent to which problem-based learning (PBL) approach would affect the achievement and retention of students when teaching algebraic concepts in Nigerian secondary schools.

Algebra is a branch of mathematics in which symbols (usually letters) represents unknown numbers in mathematical equations (Microsoft Encarta, 2009). Topics in algebra are taught for its usefulness in other branches of mathematics, and in generalization of scientific truth, its power and verification of results in simpler and more satisfactory manner; and its practical value in trades and industries (Sidhu, 2006, Odili, 2006). Algebra also provides an effective way for expressing complicated relations and as a good instrument for mental training. Algebra was chosen because it inculcates power of analysis and provides a good instrument for mental learning (Sidhu, 2006). Furthermore WAEC (2007) reports that it is an aspect of mathematics that presents difficulties to students.

The key research question was:

To what extent will the mean achievement scores of students taught algebra using problem-based learning (PBL) approach differ from those taught using conventional lecture method? The study tested the following hypotheses at .05 level of significance.

Research Hypotheses

The following hypotheses were formulated and tested at $p < .05$:

H₀₁: There is no significant difference between the mean achievement scores of students taught algebra using problem-based learning (PBL) approach and those taught using conventional lecture method (CLM).

H₀₂: Group does not significantly interact with gender to influence students' achievement in algebra.

Research Design

The study utilized the non-randomized pre-test and post-test control group type of quasi-experimental design, because it was not possible to meet all the conditions of true experiment. Hence, intact classes were randomly assigned to experimental and control groups, without disrupting the school programmes. The choice of the design was also because the study intended to establish the nature and scope of cause-effect relationships between the use of problem-based learning (PBL) instruction and students' achievement in mathematics.

Four hundred and forty seven Senior Secondary 1 (SS I) students in 6 government owned and grant-aided schools in the education zone B of Benue State of Nigeria participated in the study. The students and schools were selected through multistage sampling. The students were divided into experimental and control groups. Students in three schools numbering 211 were assigned to experimental group while 236 in the other three schools were assigned to the control group.

Students Algebra Achievement Test (SAAT), constructed by the researchers was used for the collected data. SAAT was validated by two lecturers in mathematics education and a lecturer in science education. SAAT had 25 multiple choice (each with four options) and 7 essay items constructed from SS 1 mathematics curriculum. SAAT was scored out of 100 marks. Using Kuder–Richardson (KR – 20) formula, the internal consistency of the multiple-choice items was found to be 0.80. Similarly, an inter-rater coefficient of concordance ($W = 0.063$) was obtained to test the internal consistency of the essay items using Kendall tau b correlation. These values were considered reliable enough to be used for data collection in this study. SAAT was comprehensively developed based on a table of specification. The instrument was then administered on students as pre test before commencement of the teaching. After four weeks of teaching, SAAT was reshuffled and re administered on the students as post test.

Two types of lesson plans, one for the control group and another for the experimental group, were also used for the study. They were based on the SS2 Mathematics curriculum. The topics selected included change of subject formulae, substitution in formulae, direct, inverse, joint and partial variations, factorization, formation and word problems in quadratic equations. The items were spread from comprehension to evaluation levels of Bloom's levels of the cognitive domain. The psychometric indices of SAAT were also confirmed satisfactory before the experiment. Mathematics teachers of three years experience and above were trained to teach the experimental group using PBL approach while equally experienced mathematics teachers were trained to teach the control group using traditional methods. The training exercise was based on the purpose of the study, the topic to be taught, the use of the lesson plans, the use of the SAAT as well as general conduct of the study.

It was ensured that all the teachers used equal length of time (four weeks) to teach the topics to both groups. Throughout the exercise, the researchers went round to supervise and ensured smooth teaching in all classes. The hypotheses were tested using analysis of covariance (ANCOVA) at 0.05 level of significance.

Results

Table 1 reveals that the mean post-test scores of the students taught using PBL is 48.66 with standard deviation of 9.77, while that of the students taught using conventional method is 27.64 with standard deviation of 6.08. The difference between the post-test and pre-test mean scores for students taught using PBL method is (30.71), far above the mean gain of 10.08 for students in the conventional method. The difference between the mean post-test scores between the two groups is 21.02 and is in favour of the PBL group. This suggests that the PBL students have developed competence in essential skills of numeracy and a deeper understanding of the content knowledge of learnt materials than the conventional group students did.

From Table 2, the results of the main effects on the PBL and conventional methods indicated by $F(1, 442) = 736.974$ is significant at $P < .05$ with large effect size (eta squared = .625). That is, 63% of the difference is due to the method of instruction (PBL). This result affirms that there is a significant difference between the mean achievement scores of the students taught using PBL and those taught using conventional methods. Thus, the hypothesis of no significant difference is not retained. That is PBL group achieved higher in the post-test scores than the conventional group students. In testing for hypothesis 2, Table 2 equally reveals that F-ratio for interaction effects on achievement due to methods and gender is .082 at (1,442) degrees of freedom. This value (F-ratio) is not significant at $P < .05$, which suggests that gender and method of teaching do not jointly influence students' achievement, especially when PBL is used. Thus, the hypothesis of no significant interaction effects is not rejected.

Discussion and implications of the findings

The result of this study has shown that students taught algebra using PBL outperformed their counterparts taught using conventional method. The post-test mean scores of the PBL students were found to be significantly different from those of their colleagues in the conventional group. The finding revealed the efficacy of the use of PBL in enhancing students' achievement in algebra. This finding contradicts Visser (2002), who found that students in the lecture-based group performed significantly better than the PBL group in solving 'near-transform problems' in Illinois. The finding however corroborate that of Ali, Hukamdad, Akhter and Khan (2010) from Pakistan, Loggerenberg-Hattingh (2003) from South Africa as well as Raimi and Adeoye (2004) in Nigeria, who all attested that PBL students performed better than the conventional group students.

The use of problem-based learning technique either as a teaching strategy or self-learning device, was more effective in algebra than the conventional method. Furthermore, the superiority of problem-based learning strategy over the conventional method could be attributed to the logical and sequential manner with which instructions are presented in problem-based learning technique and practical skills in teaching. A student who is exposed to this type of strategy is more likely to possess a meaningful in-depth knowledge of the content area. Such students will be able to organize their thoughts in an orderly manner that is essential for problem solving and acquisition of basic practical skills in mathematics.

The likely explanations for this outcome may not be unconnected with the fact that PBL fosters a deeper understanding of content knowledge. In addition, students in the PBL group, through social negotiations with the

group members, had ample opportunities to compare and evaluate their understanding of subject matters with others' understanding. This could be explained from the point of view that self-directed learning, one of the attributes of PBL, entails competence in essential skills of literacy and numeracy, information location and retrieval. PBL method could also arouse interest and make students more focused leading to better understanding, translating to improved performance.

Conclusion and Recommendations

It is evident from the findings of this study that the use of problem based learning strategy could provide a good way for students to learn mathematics. Problem-based learning enhances students' achievement in algebra and is not dependent on gender. Performance in mathematics is a function of method rather than gender. Both sexes are capable of competing and collaborating in classroom activities. PBL should therefore be used as an additional teaching strategy to other traditional methods of teaching mathematics. This could help in improving students' achievement in the subject.

If this method, proposed by this study, is adopted in mathematics teaching and learning, it will boost the performance of students in skills acquisition, problem solving ability and development of the right type of attitude toward mathematics as a subject. The implication of the results of this study and the associated recommendations as it borders on mathematics education are as follows:

- Mathematics teacher trainees should be trained on the use of problem-based learning approach.
- Teachers of mathematics should use problem-based learning to improve the academic achievements of the students.
- Seminars and workshops should be organized for mathematics teachers in elementary and secondary schools to employ problem-based learning in the classrooms.

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Table 1 Mean Retention Scores and Standard Deviations of subjects in the experimental (PBL) and control groups

Group	N	Pre-Test		Post-Test		Mean Difference
		\bar{X}_{\square}	δ	\bar{X}_{\square}	δ	
Experimental	211	17.95	3.52	48.66	9.77	30.71
Control	236	15.56	4.37	27.64	6.08	10.08
Mean Difference		0.41		21.02		

Key: \bar{X} = mean scores; δ = standard deviation scores

Table 2 2-Way ANCOVA on the achievement scores of students in SAAT.

Sources of Variation	Sum of Squares	df	Mean Square	F	Sig	Eta Squared
Corrected Model	49294.106 ^a	4	12323.526	189.950	.000*	.632
Intercept	31718.142	1	31718.142	488.891	.000*	.525
Pre-test	4.813	1	4.813	.074	.785**	.000
Method	47813.183	1	47813.183	736.974	.000*	.625
Gender	5.296	1	5.296	.082	.775**	.000
Method * Gender	26.760	1	26.760	.412	.521**	.001
Error	8675.952	442	64.878			
Total	708628.00	447				
Corrected Total	77970.058	446				

Key: * Significant, ** not significant

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