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EFFECT OF PROBLEM-BASED LEARNING ON SENIOR SECONDARY SCHOOL STUDENTS' ACHIEVEMENTS IN FURTHER MATHEMATICS

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Abstract: The study investigated the effect of Problem-based learning (PBL) on senior secondary school students' achievements in Further Mathematics (FM) in Nigeria within the blueprint of pre-test-post-test non-equivalent control group quasi-experimental design. Intact classes were used and in all, 96 students participated in the study (42 in the experimental group taught with the PBL and 54 in the control group taught using the Traditional Method (TM)). One research instrument manipulated at two levels namely: Teacher-Made Test (TMT) and Researcher-Designed Test (RDT), was developed and used for the study and data collected were analysed using the descriptive statistics of mean and standard deviation which served as precursor to testing the two hypotheses for the study using an independent samples t-test. Results showed that there were statistically significant differences in the mean post-test achievement scores on TMT and mean post-test achievement scores on RDT between students exposed to the PBL and those exposed to the TM, all in favour of the PBL group. Based on the results, the study recommended that the PBL should be adopted as alternative instructional strategy to the TM in enhancing meaningful learning in Further Mathematics classrooms and efforts should be made to integrate the philosophy of PBL into the pre-service teachers' curriculum at the teacher-preparation institutions in Nigeria.

Key words: Problem-based learning, Further Mathematics, Achievements

1. Introduction

Much of the failure in school mathematics is associated with a tradition of teaching that is inappropriate to the way most students learn (National Research Council [NRC], 1989). The ineffective teaching and learning of mathematics due to the traditional method (TM) of teaching that has dominated the classroom worldwide has been associated with the dismal performances of students in mathematics (Van de Walt & Maree, 2007; Dossey, McCrone, Giordano & Weir, 2002). Traditional methods of teaching mathematics have been found to be very defective and full of many inadequacies that do not allow students to actively construct their own mathematical knowledge (Dubinsky, 1991; Mji, 2003). It has adversely affected effective learning at the different levels of education. Education is facing many challenges in terms of student performance particularly in the physical sciences (DoE, 2006) and this is as result of the introduction of new topics into the curriculum which the teachers perceive as difficult to teach (DoE, 2006). Mathematics as one of the physical sciences is not left out as the performances of students in this critical subject at both internal and external examinations have remained low in many countries (Van de Walt & Maree, 2007) including Nigeria. In Lesotho, at the Junior Certificate (J. C.) and the Cambridge Overseas School Certificate (COSC) levels, the number of students that obtained grades A through C in Mathematics were less than 10% (MOET, 2003). The Southern African Consortium for Monitoring Educational Quality (SACMEQ) Survey of sixth grade primary school students' performance in Reading and Mathematics conducted across 15 South and East African countries indicated that 2

Lesotho's mean score for Mathematics was below the SACMEQ average (Ratsatsi, 2005). In Namibia, the low performance of students raises national concern amongst curriculum developers, policy makers and even politicians each year. In the Primary and Secondary schools in the northern regions of Namibia, teacher shortages persisted especially in Mathematics, Science and English which made

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the level of teaching in these subjects very poor (Beukes, Visagie, & Kasanda, 2007). In South Africa, when apartheid ended, Mathematics was not offered and taken by learners in all schools. It was taught as an abstract, meaningless subject, only to be memorised (Khuzwayo, 2005). In Nigeria, 23.5% of the total number of candidates that sat for the Senior School Certificate Examination obtained a credit pass in Mathematics and English Language at the West African Senior School Certificate Examination (WASSCE) in 2008 while 25.99% obtained it in 2009. In May/June 2011, 540,250 candidates which represented 38.2% of the 1,587,630 candidates that sat for the examination, obtained credits and above in Mathematics (The Guardian Nigeria Newspaper, 2011). Thus, 61.8% of the candidates failed the Mathematics examination.

1.1. Theoretical Background

The observed annual poor performance of students in mathematics at these external examinations necessitates the concern of everyone who works in the mathematical sciences to find lasting solutions to this dilemma. Research-based strategies for helping students come to know mathematics and be confident in their ability to do the subject are on the daily increase (Awofala, Fatade & Ola-Oluwa, 2012) and the need for teachers to shift from traditional method of teaching to a learner-centred approach is inevitable. The recognition of the need for reform in mathematics curriculum and instruction is broad and deep, ranging from professional organizations to government agencies. Currently, the dominant method of teaching mathematics involves the rote learning of algorithms for solving a limited range of exercises (Van de Walle, 2007). The textbooks that nurture this method are repetitive and uninspiring in their content and the students who are its victims are generally unable to transfer their skills from the textbook exercises to problems of the real world. Enormous reactions emanated from the above approach of teaching mathematics and the reaction focuses attention on its major weaknesses, urging the development of relevance, application, modelling and problem solving. Some of the weaknesses of the traditional method are that teachers' focus is primarily on getting answers while students depend on the teacher to determine the validity of their answers. Students with this background are of the view that mathematics is a series of arbitrary rules, emanating from the teacher. These follow-the-rules, computation-dominated, answer-oriented view of mathematics is a gross distortion of what mathematics is really about (Van de Walle, 2007). The approach cannot be exciting to the learners. Few learners are good at learning rules and strive to obtain good grades but are not necessarily the thinkers in the classroom. The traditional system rewards the learning of rules but offers little opportunity actually to do mathematics.

According to Hiebert and Stigler (2004), one factor that is found in international studies which characterizes higher performing countries is the use of cognitively demanding tasks and having students engage in critical thinking and reasoning. Webb (2010) opined that there is a general agreement that students need to experience, engage and learn how to do mathematics tasks from a range of levels of cognitive demand. Clarke (1997) remarked that the call for reform draws its impetus from two main areas: (i) the changing needs of citizens for effective participation in an increasingly technological and global society, and (ii) increased research knowledge about the teaching and learning of mathematics. Curriculum reforms have been taking place in various countries across the world (Murphy, 2007). Some countries like Australia, China, Singapore, United States and United Kingdom are known to have recently altered their systems of education (Martio, 2009; Huang, 2004).

In Nigeria, the federal government reform in education, the need to attain the Millennium Development Goals (MDGs), and the critical targets of the National Economic Empowerment and Development Strategy (NEEDS) provided the needed impetus to review and re-align the existing curricula for senior secondary school to fit into the reform programme (Awofala, 2012; NERDC, 2008). The Nigerian Educational Research and Development Council (NERDC), on the directive of the National Council on Education carried out the overhauling of the existing curricula and mathematics became one of the five crosscutting core subject while further mathematics became a core subject in the science/mathematics field of study. One unique thing about the current curriculum reform in Nigeria is the advocacy for a learner-centred approach to instruction in schools. The Professional Standards for Teaching Mathematics assert that teachers must shift from a teacher-centred to a child-centred approach in their instruction (Van de Walle, 2007). The path towards the shift and reform is the adoption of modern methods of teaching whose focus is on students sharpening their problem-solving abilities, as well as their abilities to reason, communicate, connect ideas, and shift among representations of mathematical concepts and ideas (Dossey et al, 2002). Adler (1997) described participatory-inquiry approach as one of the alternative modern methods to the traditional method of teaching. Participatory-inquiry is a structured learner-centred strategy in which multiple perspectives are sought through a process of group inquiry within the context of helping learners organise their thinking in solving problems. Clarke (2004) described another modern method of teaching and called it Kikan-Shido, meaning, "walking between desks instruction" in Japanese. Kikan-Shido is a classroom strategy that organizes mathematics instructions around problem solving activities and affords students more opportunities to think critically, present their creative ideas and communicate with peers mathematically (Hiebert, Carpenter, Fennema, Fuson, Human, Murray, Olivier, & Weane, 1996). Problem-based learning (PBL) possesses some of the features in the participatory-inquiry and walking between desks instruction approaches as discussed by both Adler and Clarke and in addition has the learning trajectory that made it unique among other modern methods (Kyeong Ha, 2003).

Educational researchers like Sungur and Tekkaya (2006), Hallam and Ireson (2005) seem to agree with the idea that, among other factors, the teacher' s teaching style has some impact on student learning and the perceptions students develop about science learning and the work of scientists. In particular, Sungur and Tekkaya (2006) advocated the use of PBL as an instructional strategy to enhance students' performance in both the cognitive and non-cognitive outcomes. Though efforts have been concentrated on students' performances in mathematics for some years; there is however little or no research carried out on the effectiveness of PBL in Further Mathematics in Nigeria. The PBL is one of the modern methods of teaching that allows each learner to construct his/her own schema. The PBL mathematics classroom focuses on problem-solving and conceptual understanding rather than on computational drill. It also promotes students' confidence in their own mathematical abilities (Schifter & Fosnot, 1993). The PBL classroom is not in any way dominated by the fetish of the "one right way"- the teachers' way, the textbooks' way- to solve a problem that characterised the traditional method but has become a community where members explore mathematics problems together. A Problem-based learning classroom is one that could be called learners' community classroom. In this community, learners engage in discourse, dialogue and work in groups. Opportunity is given to each member of the community to express his/her ideas during the lesson. The teacher gives open-ended questions and tasks that allow multiple entries to solving the problems. Teachers in PBL classroom do not appear to possess solutions to problems. Evidence suggests that the high attrition rate in most physical science subjects and concomitant poor performance in the subjects at the senior secondary school level could be reduced to the barest minimum with the implementation of the PBL (Abraham etal, 2012; Burch, Sikakana, Yeld, Seggie & Schmidt, 2007).

This study is against the backdrop of increased high annual percentage of students that fail Mathematics and Further Mathematics in Nigeria at the West African Senior School Certificate Examination (WASSCE). Many factors could have been responsible for the students' high failure rate in these subjects such as Parents, Students, Teachers, and Government etc. The researchers however sought to examine teachers' method of approach in the Further Mathematics classroom. Table 1 illustrates the awful performance of candidates in the West African Senior School Certificate Examination in Further Mathematics from 1996 to 2010 in Nigeria.

The relatively low enrolment and general poor performance of students in Further Mathematics at the Senior School Certificate Examination in Nigeria is an indication of and invitation to serious future problems in producing skilled and knowledgeable engineers and scientists in the country. Teachers' poor method of teaching as earlier stated has been identified as one of the major factors responsible for students' low enrolment and poor performances in Further Mathematics. The search for an enduring, appropriate and effective method of teaching Further Mathematics is yet to be fruitful, and this constitutes a major problem. The study therefore, investigated the effect of PBL on senior secondary school students' achievements in Further Mathematics in Nigeria

Table 1. *Nigeria statistics of entries & results in Further Mathematics*

YEAR	TOTAL ENTRIES	NO PRESENT FOR EXAM.	NO. WITH CREDIT & ABOVE (%)		NO. FAILED(%)
1996	8758	6884	1578	(22.9)	5306 (77.1)
1997	10594	8618	1339	(15.5)	7279 (84.5)
1998	10571	8128	1290	(15.9)	6838 (84.1)
1999	12481	9684	2230	(23.0)	7454 (77.0)
2000	9292	7431	1724	(23.2)	5707 (76.8)
2001	37060	21978	2910	(13.2)	19068 (86.8)
2002	41852	22797	3926	(17.2)	18871 (82.8)
2003	30768	18520	3336	(18.1)	15194 (81.9)
2004	18618	12385	3518	(28.4)	8867 (71.6)
2005	29998	24385	7212	(29.6)	17173 (70.4)
2006	35208	28733	12552	(43.7)	16181 (56.3)
2007	40115	33021	9750	(29.5)	23271 (70.5)
2008	41699	35155	13293	(37.8)	21862 (62.2)
2009	44719	38233	11952	(31.3)	26281 (68.7)
2010	43543	37502	13829	(36.9)	23673 (73.1)

Source: Test Development Division West African Examinations Council (WAEC), Yaba, Lagos

1.2 Nature of Further Mathematics

Further Mathematics came into existence when Nigeria's educational system changed from 6-5-2-4 (six years at primary, five years at secondary, two years at A-level and 4 years at undergraduate level) to 6-3-3-4 (six years at primary, three years at junior secondary, three years at senior secondary and four years at undergraduate level). The subject was referred to as Additional Mathematics during the former system of education. The observed annual poor performance of undergraduates at first year Mathematics courses at the tertiary institutions culminated in the Mathematicians and Mathematics educators clamouring for a Mathematics curriculum that would be a bridge between senior secondary school Mathematics and the first year undergraduate Mathematics (FME, 1976). This led to the introduction of Further Mathematics curriculum at the secondary school level in 1985 and the subject was classified as an elective (optional) at the senior secondary school in the National Policy on Education (FRN, 2004). The contents of the 1985 Further Mathematics curriculum could be broadly classified into three themes namely Pure Mathematics, Statistics and Probability, and Vectors 10 and Mechanics. This curriculum was in use in the country for over two and a half decades without any meaningful review. The new Senior Secondary School Further Mathematics curriculum whose implementation started in September 2011 with the first set of graduates from the nine-year Basic Education Curriculum was a product of the reform initiatives of the Federal Government of Nigeria under the auspices of the Nigerian Educational Research and Development Council. This think tank of the Nigeria education carefully reviewed and re-aligned the old Further Mathematics curriculum with inputs from the teachers in the field to fit into the current education reform in the country. This new curriculum was planned to enable Senior Secondary School graduates cope with first year undergraduate Mathematics and Mathematics related courses. Unfortunately, students' enrolment in the subject has been very poor.

1.3 Content of the New Senior Secondary (SS) Further Mathematics Curriculum

The years at the Senior Secondary School are from SS year one to SS year three. The new curriculum which is spiral in nature was prepared to ensure continuity and flow of themes, topics and experiences from Senior Secondary year one to Senior Secondary year three. The new curriculum reflects depth, appropriateness, and interrelatedness of the curricula contents. The new curriculum pays particular attention to the achievement of the Millennium Development Goals (MDGs) and the critical elements of the National Economic Empowerment and Development Strategies (NEEDS). The new curriculum represents the total experiences to which all learners must be exposed; the contents, performance objectives, activities for both teachers and learners, teaching and learning materials and evaluation guide are provided. The new curriculum contains five themes: pure mathematics, vectors and mechanics, statistics and probability, coordinate geometry, and operation research and the different themes cut across the three levels of the Senior Secondary School in Nigeria. This is a radical departure from the old Senior Secondary School Further Mathematics curriculum whose implementation lasted 26years (1985-2011).

1.4 Research Questions

Based on the aforementioned problem, this study provided answers to the following research questions:

RQ1: Will there be any significant difference in the post-test achievement on TMT scores between students exposed to the PBL and those exposed to the TM?

RQ2: Will there be any significant difference between the post-test achievement scores on RDT between students exposed to the PBL and those exposed to the TM?

1.5 Null Hypotheses

The following null hypotheses were stated and tested at .05 level of significance in the study

$\mathbf{H_{o1:}}$ There is no significant difference in the post-test achievement scores on TMT between students exposed to the PBL and those exposed to the TM.

$\mathbf{H_{o2:}}$ There is no significant difference in the post-test achievement scores on RDT between students exposed to the PBL and those exposed to the TM.

2. Method

2.1. Research Design

The model of inquiry adopted for this study was a quantitative method (Creswell & Plano Clark, 2011) described as a systematic empirical investigation of social phenomena via statistical, mathematical or computational techniques (Bergma, 2008) within the blueprint of quasi-experimental design using pretest-posttest non-equivalent control groups (Bell, 2008). The quasi-experimental design allows identification of variables (Blaxter, Hughes & Tight, 1996) in the study. The quasi-independent variable-instructional strategy was manipulated at two levels (PBL & TM) and answering the research questions for the study required data that allowed assessment of the extent to which the PBL and TM influence students' achievements in Further Mathematics. This study relied on ratio (scores on Researcher-Design Test and Teacher-Made Test) data as the strongest form of quantification (Okpala, Onocha & Oyedeji, 1993). In this study, participants do not have control over which group (control or experimental) they belonged or of receiving or not receiving the treatment based on quasi-experimental design. One inherent advantage of this design is that it is typically easier to set up than true experimental designs (Shadish, Cook & Campbell, 2002) but lacks randomisation of subjects to treatment conditions (Bell, 2008). Adopting quasi-experimental design in this study allowed the investigation of intact group in real classroom settings since it was not necessary to randomly assemble students for any intervention during the school hours so as not to create artificial conditions. Students in control & experimental groups participated in the study in their natural classroom conditions.

2.2. Participants

The participants comprised 96 Senior Secondary School year one further mathematics students (52 males and 48 females). Puposive sampling was used to select one intact science class each from two equivalent coeducational secondary schools that were distantly located from one another within the city of Ijebu Ode in Ogun State, Nigeria. We randomly assigned one school to the PBL strategy and the remaining one school to the traditional method. The mean ages of the students in the PBL and traditional method schools were 15.4 years and 15.3 years respectively.

2.3. Instrumentation

2.3.1. Researcher-Designed Test (RDT)

The RDT is an essay (a constructed-response) test of four questions based on Indices and Logarithms, Sequences and Series, and Algebraic equations (FME, 1985). The RDT was used as pre- and post-test in both the control and experimental classes in the study. Initially, 10 questions were drawn from Stewart, Redllin, and Watson (2006), Dossey et al (2002) and WAEC (2007). The questions were in word problems that required students' higher- order cognitive skills: analysis, synthesis, and evaluation (Okpala, Onocha & Oyedeji, 1993). Test contents were organized in accordance with the Bloom's Taxonomy (Okpala, Onocha & Oyedeji, 1993) of higher-order cognitive domain as indicated in Table 2 below.

Table 2. *Test Item Specifications in Further Mathematics on RDT*

FM Contents	**Higher-Order Cognitive Domain of Bloom Taxonomy**			**Total**
	Analysis	**Synthesis**	**Evaluation**	
Indices & Logarithms	**1**			**1**
Sequences & Series		**2**		**1**
Algebraic Equations			**3, 4**	**2**
Total	**1 (25%)**	**1 (25%)**	**2 (50%)**	**4 (100%)**

Each of the four questions in the RDT showed discrimination index of more than 0.40 and item difficulty of 0.40 – 0.60. This supports the views of Ebel (1979) about the appropriateness of values. Cronbach alpha computed to determine the internal consistency and reliability of the test was 0.87. Thus, the four questions constituting the RDT were considered reliable and of moderate difficulty level. Each item on the RDT instrument attracted a score of 25marks. This gave a total of 100marks. Hence, a maximum score that could be obtained was 100marks.

The RDT might be considered as performance test in that it assessed how well students used foundational knowledge to perform complex tasks under more or less realistic conditions. Apart from the fact that the RDT contained ill-structured tasks which favour PBL for the study (Sungur & Tekkaya, 2006), the instrument was considered advantageous in ascertaining students' background knowledge (used as pre-test) in FM before treatment and in detecting the level of knowledge gained (used as post-test after questions re-arrangement) in FM after treatment. One other advantage of RDT was that the test items contained multiple solutions (Educational Testing Service, 2011), synonymous with real-world problems which called for critical thinking (Paul, & Elder, 2006) on the part of the students. Critical thinking is the process of thinking that questions assumptions and scrutinise viable facts to assess why they hold. This is in tandem with the constructivist approaches to setting of 'open-ended questions' as against the traditional way of setting questions that favours one pre-determined correct answer. Conversely, this inherent advantage of RDT could also constitute a disadvantage as the multiple solutions made RDT more difficult for students to solve, more tasking and time consuming for the researcher to grade. This potential disadvantage was reduced through the TMT, which followed the traditional way of setting essay questions (which both teachers and students were used to) that favoured one direct answer. Below is the full description of the TMT purposely used as pre- and post-test in the study.

2.3.2. Teacher-Made Test (TMT)

The TMT (used as pre- and post-test in both the control and experimental classes in this study) is an essay test of 10 questions based on the course contents for the study reflecting the cognitive level of Bloom taxonomy. The contents selected include Indices and Logarithms, Algebraic Equations, and Series and Sequences. These were chosen from the first term work of the Senior Secondary School year one Further Mathematics curriculum (FME, 1985). The mathematics studied at the Junior

Secondary School served as pre-requisites for the selected topics. Unlike the RDT, which was developed by the researcher, the TMT with initial items of 60 questions (20 questions each) set by three FM teachers from schools different from the ones selected for the study based on the instruction of the researcher, were drawn from Tuttuh-Adegun, Sivasubranmaniam and Adegoke (2002). Test contents were organized in accordance with Bloom's Taxonomy (Okpala, Onocha & Oyedeji, 1993) of cognitive domain as indicated in Table 3 below.

Table 3. *Test Item Specifications in Further Mathematics on TMT*

FM Contents	**Cognitive Levels**						**Total**
	K	**C**	**AP**	**A**	**S**	**E**	
Indices & Logarithms	**5**	**6**	**-**	**3**	**-**	**1**	**4**
Sequences & Series	**8, 9,10**	**-**	**7**	**-**	**-**	**-**	**4**
Algebraic Equations	**-**	**4**	**2**	**-**	**-**	**-**	**2**
Total	**4 (40%)**	**2 (20%)**	**2 (20%)**	**1 (10%)**	**-**	**1 (10%)**	**10 (100%)**

K-Knowledge, C- Comprehension, AP- Application, A- Analysis, S- Synthesis and E- Evaluation

For the TMT, each of the ten questions showed discrimination index of more than 0.40 and item difficulty of 0.40-0.60 thus, similar to suggestions as noted by Ebel (1979). Cronbach alpha was computed (using SPSS version 15) to determine the internal consistency and reliability of the test and a value of 0.88 was obtained. The ten questions then constituted the TMT. Each item on the TMT instrument attracted a score of 10 marks. This gave 100 marks. Hence, a maximum score that could be obtained was 100marks.

The request made by the researcher to the participating teachers to set questions for the TMT is not new. Researchers (Notar, Zeulke, Wilson & Yunker, 2004; Kadivar, Nejad & Emamzade, 2005) have used TMT in assessing students' achievements and grade point average (GPA). In general, teacher-made, or teacher-chosen, content-specific tests are templates for awarding course grades resulting in the computation of GPA which is often considered a standard of accountability (Notar, Zeulke, Wilson & Yunker, 2004). Apart from the fact that these teachers have been teaching and setting questions internally for students taking FM, which made them knowledgeable in setting questions, both the State and Federal Ministries of Education in Nigeria rely on experienced and practicing teachers in setting examination questions for students in various school subjects including FM.

More so, external examination bodies like WAEC and National Examination Council (NECO) at all times invite experienced and practicing graduate teachers to set questions on all subjects, including FM, into their question banks. It is from such question banks that the final selection of items for any particular examination is taken. In this study, the 60 items for TMT went through various stages of validation (Kimberlin & Winterstein, 2008). Thus, the harmonisation of the final items on the TMT resulted from a combination of experts' advice and recommendations. Apart from ease of construction by the teachers, the TMT was considered advantageous in terms of efficiency thereby enabling the teachers to ask many questions in a short period. The TMT also allowed speedy assessment of what might be called foundational knowledge as against the higher-order skills enacted in the RDT. The foundational knowledge refers to the basic information and cognitive skills (comprehension and application) that students need in order to do such high-level tasks as solved problems and create products (Stiggins, 1994). One disadvantage of the TMT was that it reflected the lowest level of Bloom's cognitive taxonomy (verbatim knowledge) as a result, students focused on verbatim memorization rather than on meaningful learning championed in the RDT. Another disadvantage of the TMT was that one only got some indication of what students knew, the test exposed nothing about what students could do with the knowledge. This shortcoming was among other factors that led to the development of the RDT.

2.4. Procedure

The study covered a period of three months. Prior to the commencement of teaching in the experimental and control classes, students were pre-tested on the TMT and RDT in that order. The essence of the pre-test was to ascertain the background knowledge of the participants in both the experimental and control classes before entering into the experiment/instruction. The attention of the regular mathematics graduate teacher in the control school was sought after the management of the school had given approval for the study to be conducted in the school. The details of the study were neither made known to him nor fully discussed with the school management as the study was presented to the duo as if the exercise was meant for the school alone. This was to prevent any form of bias and influence on the part of the teacher in the course of his teaching.

The participating teacher in the control school unlike his counterparts at the experimental school was not trained on the PBL approach but the researcher paid unscheduled visits to the control school during the school hours and this afforded the researcher the opportunity to observe the teacher while teaching. However, no attempt was made to discuss the classroom interaction pattern that prevailed between the teacher and the students in the classroom. He taught the students with the traditional method following the already prepared instructional plan within the context of the contents selected for the study. The teacher covered the topics related to the Indices and Logarithms, Algebraic Equations, and Series and Sequences. The instructional lesson plan in the control school differed only from that of the experimental school in the area of presentation. The presentation in the control school followed the routine traditional activities against the flowchart of problem solving process enacted in the experimental school. The traditional mathematics instruction involved lessons with lecture and questioning methods to teach the concepts related to indices and logarithms, algebraic equations, and series and sequences. The students studied the approved mathematics textbooks on their own before the class hour. The teacher structured the entire class as a unit, wrote notes on the chalkboard about definitions of concepts related to indices and logarithms, algebraic equations and sequences and series. The teacher worked examples on the chalkboard about indices and logarithms, algebraic equations and sequences and series, and, after his explanation, students discussed the concepts and examples with teacher-directed questions. For the majority of instructional time in the control school, students received instruction and engaged in discussions stemming from the teacher's explanations and questions. Thus, teaching in the control school was largely teacher-dominated and learning confined to the classroom. The classroom instruction in the control class was two periods of 40 minutes each per week in the afternoon on Tuesdays and Thursdays. The afternoon periods on these two days were uniform across the schools offering FM in the local government area of the study.

The researcher sought the consent of the management of the experimental school and an approval was given to conduct the study in the school. The nature and purpose of the research were then explained to the four teachers who showed willingness and readiness to participate in the study. The highlight of the weekly activities that would be carried out and the extent of their involvement were discussed with them. The teachers were given comprehensive orientation on the principle behind the PBL as an instructional strategy and content areas for the study discussed. They were free to ask questions and offer suggestions on how best this modern approach could successfully be implemented in the school. Because the PBL was a novel approach for participating teachers in the experimental group, one of the researchers (first author) taught students in the experimental group in order to ensure fidelity of treatment. The first author acted as both a teacher and a researcher in the experimental class based on the following reasons: Although many teachers are aware of problem solving, few teachers understand the difference between a traditional approach and problem-based approach. For those teachers who understand what problem-based approach entails, majority are neither sure of how to implement this approach in their classrooms nor are they interested in even to try it (due to their own valid reasons).

Prior to the actual implementations of PBL in the experimental classroom, one of the researchers in collaboration with the four participating mathematics graduate teachers grouped the 42 Further Mathematics students heterogeneously based on their performances at the JSS year 3 final examinations. The class was referred to by the researchers as Learners' Community Group (LCG) that consisted of six groups of seven students each. The sitting arrangement was re-constituted in a semi-circular form that made it possible for teachers to walk across the groups. The groups were coded as

LCG A, B, C, R, P, and Q. The students were asked to construct nametags that were used as a form of identification. The students coded numbers were LCGA 01-07, LCGB 01-07, LCGC 01-07, LCGR 01-07, LCGP 01-07 and LCGQ 01-07. The coded number for the students was used for 'blind' assessment.

The seats were arranged for all students to face the chalkboard. Files were provided for all the students with working sheets. Shipboard, cello tape, markers of different colours and exercise books were given to the participating teachers to note their remarks and observations. Two periods of forty minutes each were allocated to the teaching of Further Mathematics in a week. The periods were usually in the afternoon on Tuesdays and Thursdays as dictated by the government policy. Thus, the researchers had no control on the placement of FM in the afternoon on the school timetable. The rigidity of the timetable did not allow the researchers to create more instructional time in the teaching of the contents in the experimental class and more importantly, the school authority in compliance with the State Government's directives did not allow any extension of classroom activities beyond the closing time. This precluded any intruder in the PBL classroom that could have created an unusual atmosphere.

Four mathematics graduate teachers at the experimental school watched the researcher leading discussions in the Further Mathematics classroom using PBL in a scaffolding manner to suit the already prepared instructional lesson plan. The instructional plan consisted of Introduction, Objectives, Content, Presentation, Evaluation and Conclusion. In the experimental class, the PBL group process adopted consisted of five phases namely (i) identify the problem (ii) make assumptions (iii) formulate a model (iv) use the model and (v) evaluate the model. Aside the arrangement of students into heterogeneous ability groups, the flowchart on problem processes for PBL used in this study consisted of five phases: Identify the problem, Make assumption, Formulate a model, Use the model, and Evaluate the model.

In the first contact period of the third week in the PBL class, students were given orientation on the PBL and its associated problem-solving processes. This was followed by a diagnostic test on indices in which students were to investigate the correctness of the given equations: (i) $2^2 \text{ x } 3^3 = 6^6$? (ii) $(2^3)^4 = 2^7$; 6^4; 2^{12}; 16^3? (Pick the correct answers). Students were left to ruminate on the given tasks individually and in groups following the identified problem-solving processes while the teacher acted as a facilitator. One member each from the first three groups (LCG A, B & C) was selected by the teacher to make presentations on the chalkboard while other members of the learners' community group critiqued the presentations and this triggered off dialogue in the classroom. Thus, mixed feelings ensued among members of the learners' community group as some were in favour that the equality holds for the first equation, some were against this stand and obtained 6^5 as the solution while others were indifferent. In reaching consensus among the three opposing groups, the teacher interjected by calling the students attention to simplify the value on the right hand side of the equation and see whether it corresponds to the simplified value on the left hand side. This made the three opposing groups to recline on their decisions and agreed that the equality did not hold and stemming from the teacher's questions, a member of the class stated that the law of indices could not be applied to the given equation because the given numbers were not of the same base.

The entire class was in agreement with the final submission while another member of the class gave a brisk overview of the laws of indices. In the second given equation, students engaged in individual and group investigations of the task following the identified problem-solving processes and the same procedure as described above took place in arriving at final answers while the teacher acted as a facilitator. Similar procedure was adopted in teaching topics related to the logarithms in the fourth week, algebraic equations in the fifth and sixth weeks and sequences and series in the seventh, eighth and ninth weeks of the study. In each of the topics taught students were given ill-structured task as homework that demanded their visiting the libraries, and surfing the net in preparation for presentation in the next contact period.

3. Results

3.1 Research Question One: Will there be any significant difference in the post-test achievement on TMT scores between students exposed to the PBL and those exposed to the TM?

In Table 4 below, the mean marks obtained by students in the post-test TMT in the experimental and control classes, showed that the marks obtained by students in the experimental class were better than the marks obtained by students in the control class. The mean of the post-test achievement on the TMT for the experimental class *(M=43.79)* was higher than the mean of the control class *(M=34.96).* This connotes that students in the experimental class exposed to the PBL recorded better performance on the post-test TMT than did the students in the control class taught using the traditional method. This is in line with the submission that the PBL might have improved the performance of the experimental students. The standard deviation of the post-test achievement on the TMT for the experimental class (*S.D =14.46)* was higher than the standard deviation of the control class (*S.D=9.62).* This is an indication that students in the experimental class responded widely different to PBL even though their overall performance has improved better than their counterparts in the control group.

Table 4. *Results of statistical analysis of pre-test and post-test scores on TMT*

	Experimental Class		Control Class	
Test Occasion	Pre	Post	Pre	Post
Total score	100	100	100	100
Mean (M)	30.90	43.79	33.50	34.96
Std Deviation (SD)	14.07	14.46	9.59	9.62
Number of students	42	42	54	54

Evidently, the mean gain (12.89) in the experimental class on the post-test TMT was far above the mean gain (1.46) recorded in the control class. The low standard deviation observed in the pre-test showed that the 42 students in the experimental class started from the same low state of knowledge while the higher standard deviation recorded by the same set of students in the post-test after intervention showed otherwise. The mean difference of 2.60 between the control and experimental classes in the pre-test TMT was however not significant *(t=1.07, p=.286)* whereas the mean difference of 8.83 between the experimental and control classes after the intervention was significant *(t=-3.58, p=.001).* Thus, the results confirmed that there was a statistically significant difference in the post-test achievement on TMT scores between students exposed to the PBL and those exposed to the TM.

3.2. Null Hypothesis One: There is no statistically significant difference between the post-test achievement on TMT scores of students exposed to the PBL and those exposed to the TM

Further analysis of post-test achievement scores on TMT of students in both the experimental and control classes using one-way ANOVA as contained in Table 5 below showed that difference in means between the two classes was significant ($F_{(1,95)} = 12.82$; $p = .001$).

Table 5. One-way ANOVA on post-test achievement scores on TMT for Experimental and Control classes

	Sum of squares	Df	Mean Square	F	Sig.
Between groups	1838.992	1	1838.92	12.82	.001
Within groups	13482.997	94	143.436		
Total	15321.990	95			

Since the ANOVA generalises the t-test to more than two groups, it is apparent that the relation $F = t^2$ must hold when $t = -3.58$. However, the p value of 0.001 recorded on the ANOVA table above tallied with the p value obtained in the t-test. Thus, research hypothesis one was rejected. Hence, there was a statistically significant difference between the post-test achievement scores on TMT of students exposed to the PBL and those exposed to the TM.

3.3. Research Question Two:
Will there be any significant difference between the post-test achievement scores on RDT between students exposed to the PBL and those exposed to the TM?

In Table 6 below, a comparison of the mean marks obtained by students in the post-test RDT in the experimental and control classes showed that the marks obtained by students in the experimental class were better than the marks obtained by students in the control class. The post-test RDT achievement mean score for the experimental class *(M=2.43)* was higher than the mean score of the control class *(M=1.34)*. This is an indication that students in the experimental class when compared with their counterparts in the control class performed better after the intervention in the post-test RDT. The standard deviation of the post-test RDT achievement for the experimental class (*S.D =1.07)* was also higher than the standard deviation of the control class (*S.D=0.72)*.

Table 6. Results of statistical analysis of pre-test and post-test scores on RDT

	Experimental Class		Control Class	
Test Occasion	Pre	Post	Pre	Post
Total score	10	10	10	10
Mean (M)	1.05	2.43	1.06	1.34
Std Deviation (SD)	0.75	1.07	0.72	0.72
Number of students	42	42	54	54

The mean gain (1.38) in the experimental class was above the mean gain (0.28) recorded in the control class. The performance of the experimental students in both the pre- and post-RDT showed that less than 40% and 20% of the students respectively recorded raw scores above the mean marks in the pre- and post-tests. Similarly, less than 40% and more than 60% of the control students obtained raw scores above the mean marks in both the pre- and post-RDT respectively. The mean difference of 0.01 between the control and experimental classes pre-test RDT was however not significant *(t=0.05, p=.958)* whereas the mean difference of 1.09 between the experimental and control classes after the intervention was significant *(t=-5.92, p=.000)*. Thus, the results confirmed that there was a statistically significant difference in the post-test achievement on RDT scores between students exposed to the PBL and those exposed to the TM.

3.4. Null Hypothesis Two:
There is no statistically significant difference between the post-test achievement scores on RDT of students exposed to the PBL and those exposed to the TM

Further analysis of post-test achievement scores on RDT of students in both the experimental and control classes using one-way ANOVA as contained in Table 7 below showed that difference in means between the two classes was significant ($F_{(1,95)} = 35.06$; $p = .000$).

Table 7. One-way ANOVA on post-test achievement scores on RDT for Experimental and Control classes

	Sum of squares	**Df**	**Mean Square**	**F**	**Sig.**
Between groups	27.862	1	27.862	35.062	.000
Within groups	74.698	94	.795		
Total	102.560	95			

Since the ANOVA generalises the t-test to more than two groups, it is apparent that the relation $F = t^2$ must hold when t = -5.92. However, the p value of 0.000 recorded on the ANOVA table above tallied with the p value obtained in the t-test. Thus, research hypothesis two was rejected. Hence, there was a statistically significant difference between the post-test achievement scores on RDT of students exposed to the PBL and those exposed to the TM.

4. Discussion

At the outset, consideration was given to the selection of two schools with comparable characteristics in terms of achievement in FM, age, language etc so that the two groups that emerged from these schools would enter the instruction/experiment on relatively comparable strength. This was to ensure that if any observable significant difference is seen in the mean post-test scores of the two groups on either TMT or RDT then such difference would not be attributed to chance but the effect of the intervention. This set the stage for the discussion of results in respect of the two research questions and two null hypotheses analysed in the preceding section of the present study.

It was found out that the mean post-test scores on the TMT of the students in the experimental (PBL) group was statistically significantly at $p<0.05$ from that of the students in the control (TM) group in favour of the PBL group. This finding has shown that students who were exposed to PBL performed better in Further Mathematics thereby corroborating the views of PBL proponents that the strategy is effective in enhancing students' achievement and self-regulated learning (Sungur & Tekkaya, 2006; Wheijin, 2005). Sungur and Tekkaya (2006) found that PBL students, among others, achieved better. Similarly, Gordon, Rogers, Comfort, Gavula and McGee (2001) found that PBL students value the student-centred nature of PBL, including information seeking, high levels of challenge, group work, and personal relevance of the material. The finding of this study is also consistent with the PBL research in showing that PBL has a positive impact on students' acquisition of domain specific knowledge (Cognition and Technology Group at Vanderbilt, 1992; Gallagher & Stepien, 1996). When the students were exposed to the PBL classroom, their achievement scores increased more than those students who learned the same content in the traditional classroom. Williams, Pedersen and Liu (1998) found that both the computer-supported and paper based PBL were equally effective in enhancing students' achievement. Six Thinking Hats Results confirmed that pre-tutorial preparation, when measured by attendance and academic achievement, increased across all levels of the undergraduate program for the PBL groups that used scaffolding, when compared to PBL groups without scaffolding and lecture-based delivery groups. This study supports the inclusion of scaffolding during the brainstorming stage of PBL. In effect, in this study, students' achievement in further mathematics differed significantly in favour of those treated with the PBL.

In consonance to the preceding discussion on TMT, the discussion relating to the result of analysis of data for answering research question two and null hypothesis two stated in this study is given. It was revealed that a statistically significant difference in the mean post-test scores on the RDT between the students in the experimental group treated with the PBL and those that received instruction in the traditional method existed. This difference in favour of the experimental class showed the efficacy of the use of PBL in promoting students' high-order achievement in Further Mathematics thereby supporting previous research that indicated that the PBL is an effective strategy for stimulating students' learning outcomes (Williams, Pedersen & Liu, 1998; Sungur & Tekkaya, 2006; Iroegbu, 1998; Wheijin, 2005; Gordon, Rogers, Comfort, Gavula & McGee 2001; Gallagher & Stepien 1996) like other learner-centred instructional strategies (Awofala, Arigbabu & Awofala, 2013; Awofala, 2011; Awofala, Fatade & Ola-Oluwa, 2012). Although PBL may be beneficial for long-term retention of knowledge, more didactic forms of teaching achieve higher examination results (Strobel & van Barneveld, 2009),which is one possible reason why some academics refuse to spend time redeveloping the curriculum, if the potential gain in terms of academic achievement are minimal and, in some case, reduced (Albanese & Mitchell, 1993).

In the present study, it was found out that statistically significance difference existed in mean post-test scores on RDT between students exposed to the PBL and those treated with the traditional method. This finding suggests that the PBL class performed better in the further mathematics topics treated during instruction than did their traditional counterparts. In PBL classroom, students' were introduced to the problem before they had learned the necessary content knowledge. They then worked collaboratively to define the issues and their learning needs, locating relevant information, questioning and researching to build a deeper understanding, evaluating possible solutions to the problem, choosing a "best fit" solution and reflecting on both the process and the solutions (Delisle, 1997; Lambos, 2004; Torp & Sage, 2002). This was not the case in the traditional classroom. Thus, throughout the investigation, the PBL class "engaged in ongoing reflective activities such as journaling, self-evaluation, and group debriefings" (Ertmer & Simons, 2006). All these might have contributed to the better performance of the PBL class on the post-RDT.

5. Conclusion

In the course of the present study, it can be asserted that the PBL as a constructivist instructional strategy is more amenable to the teaching of Further Mathematics. Effective teaching and learning of Further Mathematics could only be achieved through introduction of various innovative strategies that are cognitively learner-centred, minds-on, hands-on, and peer-mediated like PBL in this study. As shown in this study PBL approach made students more creative, act purposefully, think rationally and relate effectively with their peers in the Further Mathematics classroom. The adoption of PBL prompted teachers to know when and how to apply scaffolding during the course of classroom teaching. It also assisted teachers through diagnostic test to ascertain students' level of preparedness before the introduction of PBL as an intervention strategy. The adoption of PBL in the Further Mathematics classroom could assist low achievers; enhance their interest in Further Mathematics at the Senior Secondary School Certificate Examinations.

The result from this study shows that mathematics teachers need in-service training regularly to make them competent in preparing the 21st century students to face global challenges in their chosen disciplines. Government should give greater emphasis to in-service education for teachers because no matter the efficiency of pre-service training, the constant change in society and resultant change in curriculum will necessitate continuous in-service training for mathematics teachers. The study has in no small dimension revealed that problem-based learning approach could improve students' achievement in Further Mathematics. There is need for mathematics teachers to be knowledgeable about problem-based learning approach before it can be introduced into the classrooms at all levels of education especially at the elementary and secondary levels. If PBL approach were to be adopted, significant changes would have to be effected in the classroom structure in the area of sitting arrangements, location and placement of all materials needed by the teacher. School time-table, curriculum, assessment orientations and a host of others would also have to be re-structured to favour PBL.

Textbook writers and Publishers would also have to incorporate this new technique in their write-ups for the benefit of both the teachers and the students. The Nigerian Educational Research and Development Council (NERDC) which is the think tank of the Nigerian education and whose part of its mandates is to develop, review, and produce the school-based subject curricula should consider it expedient to review the broad based and highly loaded Further Mathematics curriculum for students' active participation in class discussion and consequently improving their achievement. Professional bodies such as the Science Teachers' Association of Nigeria (STAN), Mathematics Association of Nigeria (MAN), and Nigeria Mathematical Society (NMS) would have to start thinking about how PBL approach could be integrated into their yearly Panel workshops and annual conferences as the case may be for thorough practical demonstration for all participants.

In view of the limitations of this study, suggestions are made for further studies. It may be a worthwhile effort for future researchers to engage in a longitudinal study of the effect of PBL on students' learning outcomes in Further Mathematics classrooms. One of the limitations of the present study is that it did not consider the moderating effect of variables such as gender, parental educational background, cognitive style, reading ability, locus of control etc that could influence the findings of this study. Future studies may consider these intervening variables with larger sample size. Efforts could also be made to consider the effect of PBL on students' higher-order cognitive skills. The feasibility of PBL in a computer-mediated environment could also be investigated.

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