ASEAN Journal of Science and Engineering Education 4(2) (2024) 193-210

ASEAN Journal of Science and Engineering Education

Journal homepage: http://ejournal.upi.edu/index.php/AJSEE/

Altering Students' Mindsets and Enhancing Engagement in Mathematics in a Problem-Based Learning

Adeneye Olarewaju A. Awofala, Sabainah O. Akinoso*

University of Lagos, Nigeria

*Correspondence: E-mail: aawofala@unilag.edu.ng

ABSTRACT

Teaching strategy is a foremost dynamic that influences not only students' mathematics mindset but also their engagement in learning mathematics. This study explored the effect of problem-based learning (PBL) in not only altering senior secondary school students' mathematics mindset but also improving their engagement in mathematics. The results of the study showed that students exposed to the PBL have meaningfully higher mathematics mindsets tilting towards a growth mindset than those taught through the TLM. In addition, students taught using the PBL recorded significantly higher mathematics engagement than those taught using the TLM. The researchers concluded that PBL is an effective strategy not only for altering students' mindset towards the growth zone but also for enhancing their engagement in learning mathematics; henceforth, mathematics teachers should integrate PBL into the repertoire of learner-centered strategies for teaching mathematics.

ARTICLE INFO

Article History:
Submitted/Received 03 Dec 2023
First Revised 09 Jan 2024
Accepted 06 Mar 2024
First Available online 13 Mar 2024
Publication Date 01 Sep 2024

Keyword:
Engagement,
Mathematics,
Mindset,
Problem-based learning strategy,
Senior secondary school,
Traditional lecture method.

1. INTRODUCTION

In Nigeria, mathematics teaching and learning are embroiled in detrimental and ubiquitous myths believed by a large population of people including schoolchildren, teachers, and other stakeholders in the education industry. Students often display these myths in their actions and thoughts leading to a meaningful reduction in their learning and achievement in school mathematics. One detrimental myth often confessed by students is that only a few people are born with a ''brain for mathematics precocity'' while a large population of people are not and that extraordinary attainment in mathematics is reserved for a handful of students. This myth can be dispelled based on the findings from recent advances in research.

First, the research in neuroscience, which shows the malleability of the brain, points to the fact that the brain can be cultivated and changed if fed with the right nourishment (Maguire *et al*., 2000). Second, research findings have indicated that mathematically resilient people (Awofala, 2021; Kooken *et al*., 2016) but poor in mathematics often change from a fixed mindset (rigid ability) to a growth mindset (malleable ability) to enhance their mathematics achievement. It is evident that students with a growth mindset accomplish extraordinarily in mathematics than those whose mindsets are fixated (Blackwell *et al*., 2007; Claro *et al*., 2016) and that when students move from a rigid mindset to a growing mindset their achievement in mathematics changes positively (Aronson *et al*., 2002; Good *et al*., 2003).

Another detrimental myth utterly displayed by students is the belief and conception that mathematics is fragmented rather than cohesive (Awofala *et al*., 2020; Crawford *et al*., 1998; Mji & Arigbabu, 2012). Students who hold fragmented conceptions see mathematics learning as entangling in rules, procedures, and full of memorization while those who hold cohesive conceptions see mathematics learning as embroiling in ideas, concepts, and creativity. Evidence suggests that students who hold a cohesive conception of mathematics attain higher in mathematics than those who hold a fragmented conception (Boaler & Zoido, 2016).

A third damaging myth and the last is that students hold the belief that worthy mathematics students should be fast intellectuals and thinkers when some of the world's famous mathematicians are slow and relaxed sages and intellectuals. However, these negative myths may have great consequences for students who are not engaged in mathematics learning. In Nigeria, a large population of school students, seem to be less engaged in mathematics learning as testified by the annual poor performance of students in Senior Secondary Certificate Examinations in mathematics (WAEC Chief Examiners' Reports, 2010-2018).

According to Skinner and Belmont (1993), "Engagement includes both behavioral and emotional components. Children who are engaged show sustained behavioral involvement in learning activities accompanied by a positive emotional tone. They select tasks at the border of their competencies, initiate action when given the opportunity, and exert intense effort and concentration in the implementation of learning tasks; they show generally positive emotions during ongoing action, including enthusiasm, optimism, curiosity, and interest" (p. 572).

Dynamic engagement in mathematics classes is not only paramount to students' academic attainment but a key helper in students' selection of college majors and professions in science, technology, engineering, and mathematics (STEM) (Maltese & Tai, 2010; Wang & Degol, 2014). The investigation has shown a reduction in secondary school students' engagement in mathematics with students from low socio-economic status and minority groups badly affected (Martin *et al*., 2015). Engagement in mathematics is conceptualized as a multifaceted construct consisting of four distinctive, but interconnected dimensions:

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

behavioral, emotional or affective, cognitive, and social engagement (Wang *et al*. 2016). Behavioral engagement is defined as a continuum of evolving involvement in educational activities and school governance, leading to acquiescence with school rules and classroom processes, and taking the initiative in the classroom with absolute repulsion of disrupting behavior (Fredricks *et al*., 2016; Kong *et al*., 2003).

Earlier empirical studies have assessed behavioral engagement using survey items that border on class participation, un-involvement, career plans, tardiness, classes skipped, attentiveness, assignment execution, and obedience to school and classroom rules and procedures. Affective or emotional engagement is defined as possessing a sense of belonging characterized by progressive passionate antiphons to teachers and colleagues and a welcome of the goals of schooling as well as showing interest in the classroom learning content (Finn, 1989; Voelkl, 1997; Kong *et al*., 2003). Prior empirical surveys have measured affective engagement with items that depict students' emotive reactions like enjoyment, perceived value of learning, anger, nervousness, sadness, curiosity, boredom, discouragement, excitement, and interest (Kong *et al*., 2003).

Cognitive engagement has been conceptualized concerning self-regulated learning, adopting profound learning strategies, and putting forth the essential rational and problem-solving strategies for the understanding of multifaceted ideas (Zimmerman, 1990). Previous studies have measured cognitive engagement with items that center on approaches to learning such as surface, deep, and achieving, self-regulation, preference for hard work vs. preference for easy work, independent vs. dependent work styles, flexible vs. rigid problem solving, and persistence (Biggs, 1978; Greene, 2015; Kong *et al*., 2003).

The component of social engagement is a new addition to the first three dimensions of engagement (Fredricks *et al*., 2016) and it is defined as the worth of social collaborations with earls and adults, as well as the readiness to engender the development and conservation of fruitful associations while learning (Wang *et al*., 2016; Fredricks *et al*., 2016). Prior investigation has indicated that students' engagement is a robust predictor of academic performance and choice (Hughes *et al*., 2008) in which students higher in behavioral and affective engagement are inclined to achieve higher grades and are desirous of tertiary education (Wang & Holcombe, 2010).

While engagement in mathematics is productive to the learning of mathematics, disengagement in mathematics is detrimental to the studying of mathematics and may pose a threat to students despite mathematics being a subject for all (Kong *et al*., 2003). However, it is a widespread conviction that the attainment of mathematical concepts entails having an exceptional gift, a belief, that negates the appearance of mathematics as a 'subject for all'. When students could not fathom the relevance of mathematics to their everyday living and could not withstand the rigor in its level of complexity, they would in no time become apathetic to, or fearful of, the subject. Most times, these students are likely to have a nasty inscription of mathematics permanently engraved in their memory after schooling (Kong *et al*., 2003).

One question that beckons for the answer is how can these detrimental myths be removed from mathematics teaching and learning to ensure students' engagement in the mathematics classroom. Answering this question would require mathematics teachers to change their didactic pedagogical approaches to teaching and learning mathematics in schools. Mathematics classrooms in Nigeria are bedeviled with and dominated by teachers' didactic instruction with the very diminutive prospect for students to be active participants in their learning (Ojaleye & Awofala, 2018) thereby undermining students' abilities and culpabilities to grow into autonomous learners (Awofala, 2012).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Thus, to accentuate students' engagement in mathematics and change students whose fixated mindset about mathematics is at its peak, it will be proper to identify effective pedagogy that teachers could adopt to support and shape students' engagement in mathematics and enable growth mindset in mathematics learning at the secondary school level. One pedagogical constructivist approach capable of turning students into active and self-determining learners in mathematics classrooms is problem-based learning (PBL) (Fatade *et al.*, 2014). Savery (2006) defined PBL this way:

PBL is an instructional (and curricular) learner-centered approach that empowers learners to conduct research, integrate theory and practice, and apply knowledge and skills to develop a viable solution to a defined problem. Critical to the success of the approach is the selection of ill-structured problems (often interdisciplinary) and a tutor who guides the learning process and conducts a thorough debriefing after the learning experience.

While Sungur and Tekkaya (2006) pushed for the deployment of PBL in schools to enhance student's performance in both the cognitive and the non-cognitive outcomes, PBL is conceptualized to be a learner-centered pedagogical approach that inspires students to learn via the controlled investigation of a research problem. As a dynamic learning strategy, PBL empowers students to become conscious of and define their learning necessities and problem-solving ability (Ajai, & Imoko, 2015) to make knowledge effective and engendering cooperative works in the face of ill-structured real-life problems (Akinoglu & Tandogan 2007). With PBL, students are empowered to take charge of their learning with minimal teacher interventions to become reflective thinkers. PBL is conducted with small, simplified groups embroiled in active discussion, learning with earls, and engaging in problem-solving (Hmelo-Silver, 2004).

The PBL classroom is not only different from the traditional classroom that is characterized by the fetish of the "one right way"- the teachers' way, the textbooks' way- to solve a problem rather is a community dominated by members exploring mathematics problems cooperatively (Fatade *et al*., 2013). In PBL, students have the purpose of attaining self-directed learning through examination, re-analysis, and resolution of problems (Ajai & Imoko, 2015). The PBL mathematics classroom centers on conceptual understanding and problem-solving rather than on computational drill (Fatade *et al*., 2013) which pervades traditional mathematics classrooms. In short, PBL promotes students' confidence in their mathematical ingenuities and abilities.

Although enormous empirical studies have been conducted on the effectiveness of PBL on cognitive outcomes in mathematics (Maulidia *et al.*, 2019; Siagian *et al.*, 2019; Ojaleye & Awofala, 2018; Olaoye & Adu, 2015; Ajai & Imoko, 2015; Bude *et al.*, 2009), few studies can be said to have been carried out on the non-cognitive outcomes in mathematics (Fatade *et al*., 2014; Sahin, 2009). To the author's knowledge few or no study had been conducted on the effect of PBL in improving engagement in mathematics and altering students' mindset in mathematics. While the engagement students experience in PBL leads to students' achievement as shown in structural equation models and lengthening ingenuity and intelligence in mathematics (MacMath *et al*., 2009), student engagement contributes both directly and indirectly to achievement (Schmidt & Moust, 1995).

The PBL is found more flexible and innovative than the traditional pedagogical approaches (Kaharuddin, 2018; Ojaleye & Awofala, 2018; Olaoye & Adu, 2015). The PBL is an important constructivist learning method that permits students to construct their own schema within a learner's community where they participate in discourse, negotiation and work in groups with group members having opportunity to express their ideas and reflect during lessons (Fatade

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

et al., 2013). Therefore, this study investigated the effect of PBL in altering students' mindsets about mathematics and improving their engagement in the learning of mathematics.

The two null hypotheses articulated and verified in the present study at α=.05 level of significance encompassed:

H_{o1}: PBL will not significantly alter students' mindset in mathematics.

H_{o2}: PBL will not significantly improve students' engagement in learning mathematics.

2. METHODS

2.1. Research Design

This study embraced the quantifiable research within the structure of the quasi-experimental design. The Solomon four non-equivalent control group design was employed to test the null hypothesis. The design was cautiously selected because it was not probable to randomize students to the groups and reasonably because the unit of sampling a class had already been formed and, consequently, it was wrong to re-organize one randomly. Besides, senior secondary school classes happen as intact groups with a fixed time for lessons and this may cause problems in re-instituting classes for research purposes (Awofala, 2016, 2017). Indeed, the research design is allegorically epitomized in **Figure 1**.

Group E_1	O_1	X	O_2
Group C_1	O_3	-	O_4
Group E_2		X	O_5
Group C_2		-	O_6

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

In continuation, O_1 and O_3 were pre-tests; O_2, O_4, O_5, and O_6 were the post-tests; X was the treatment where students were taught using the problem-based learning strategy. The flecked line denoted the involvement of entire groups and the design involved a random allocation of intact classes to four diverse groups. Group E_1 was the Experimental Group I and was exposed to the pre-test, the treatment X, and the post-test. Group C_1 was Control Group I, which was exposed to the pre-test, followed by the control condition and then the post-test. Group E_2 was Experimental Group II and was exposed to treatment X and post-test but was not given the pre-test. Group C_2 was the Control Group II and was given the post-test only because it was a control group. Group C_1 and Group C_2 were given the control condition of the lecture method while Groups E_1 and E_2 were treated with the experimental condition of problem-based learning.

This design outlawed all major threats to internal validity apart from those connected with interactions of selection and maturation, selection and instrumentation, and history. No major event was identified in any of the sampled schools that would have warranted interaction between selection and history. To control for interaction between selection and maturation, the schools were allocated randomly to the control and treatment groups. To control for interaction between selection and instrumentation, the situations under which the instruments were administered remained as similar as possible in all the schools (Awofala, 2016, 2017).

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

2.2. Participants

The target population for this study consisted of all senior secondary school year two students in Education District II of Lagos State in South-west, Nigeria. There are six Education Districts in Lagos State and through a simple random sampling Education District II was selected for the study. Four senior secondary schools were randomly selected from Education District II and one intact class of senior secondary school year two was randomly chosen to make four intact classes for the study. Each intact class of senior secondary school year two students in each of the four schools were arbitrarily allocated through a simple random sampling technique to experimental groups I and II and control groups I and II. In all, the sample consisted of 260 senior secondary school year two students (120 females and 140 males).

The mean age of students at this level was 16 years 2 months (SD=1 year 4 months). These students were considered suitable for this study because older students at senior secondary schools seem to benefit more from problem-based learning than younger students in junior secondary schools. This is accredited to the fact that older students possess more advanced schematics for handling information in a real-world context and taking on active roles in problem-based learning to increase social expertise is never a problem. **Table 1** displays the sharing of the students in the four groups of the design. Fraenkel and Wallen recommended at least 30 subjects per group. Hence, this number was adequate for the study.

Table 1. Distribution of students in the experimental and control groups by gender.

Treatment Group	Gender	N
Experimental group I	Male	40
	Female	30
	Total	70
Control group I	Male	30
	Female	30
	Total	60
Experimental group II	Male	30
	Female	30
	Total	60
Control group II	Male	40
	Female	30
	Total	70

2.3. Instrument for Data Collection

Two instruments were deployed for data collection in the study: The Mathematics Mindset Survey (MMS) and the Mathematics Engagement Scale (MES).

2.3.1. Mathematics Engagement Scale (MES)

The MES adopted from Wang *et al*. (2016), consisted of 33 items anchored on a modified five-point Likert scale. The scale ranged from 0-undecided, 1- strongly disagree, 2- disagree, 3- agree, to 4- strongly agree for the positive statement while the reverse was the case for the negative statement. The MES has four dimensions namely: cognitive engagement (eight items), emotional engagement (10 items), social engagement (seven items), and behavioral engagement (eight items). The reliability coefficients for the cognitive engagement factor, the behavioral engagement factor, the emotional engagement factor, and the social engagement

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

factor were 0.75, .082, 0.89, 0.74 respectively while the Cronbach alpha coefficient for the MES was .93 (Wang *et al*., 2016) and in this study, it was .90.

2.3.2. Mathematics Mindset Survey (MMS)

The MMS consisted of 40 items with distinguishable two factors fixed mindset (22 items) and growth mindset (18 items). It is anchored on a modified five-point Likert scale ranging from 0-undecided, 1- strongly disagree, 2- disagree, 3- agree, to 4- strongly agree for a positive statement while the reverse was the case for the negative statement. The reliability coefficients for the fixed mindset and growth mindset were .81 and 85 respectively while the Cronbach alpha coefficient for the MMS was .91.

2.4. Treatment Procedure

In the experimental group I, before the treatment, 14 heterogeneous clusters of five students were formed and in the experimental group II, 12 heterogeneous clusters of five students were created. The clusters in both experimental groups I and II had students with diverse learning styles and academic performance and were of mixed gender confirmation. Thereafter, the teachers were trained on how to deploy the PBL during pedagogical discourse after, which they were evaluated through micro-teaching exercises in the preparation of the PBL lesson. Each of the trained mathematics teachers led the teaching of the students in their corresponding schools using the PBL instructional strategy to confirm the trustworthiness of treatment and intactness of the PBL classes. Throughout the treatment, students operated in small clusters and dealt with ill-structured problems based on their experiences in problem-solving.

Problem solving heuristics are used and consist of (i) identifying the problem; (ii) making assumptions; (iii) formulating a model; (iv) using the model; and (v) evaluating the model. In both experimental groups, I and II the sitting arrangements of students were reconstituted in a semi-circular form that made it possible for teachers to walk across the groups and the students facing the chalkboard. As PBL is collaborative problem solving, each member of the cluster had some expected roles and responsibilities. Students were expected to partake meaningfully and dynamically in the cluster dialogue. Students had to express their ideas, and feelings and share their knowledge and experience, as each member had to be sensitive to the needs and feelings of other cluster members.

Aside from the cluster work, each member of the cluster had to carry out a self-determining study and evaluate his /her learning at both individual and cluster levels. Students were free to choose their learning issues and decide upon a suitable depth for study. Students also took explicit roles, which included the teacher, the learner, the reader, the reporter, and the presenter. For instance, the reader reads the pages containing the mathematics problems circulated by the teacher. This provided cumulative amounts of information about the mathematics problems.

The reporter wrote down the facts, ideas, assumptions, and learning difficulties recognized by the cluster. The cluster then discoursed the mathematics problem, created ideas, produced predictions, recognized learning difficulties, and examined what additional information was required to enhance comprehension of the mathematics problem. In the first contact period in the PBL classes, a diagnostic test on factorization was given in which students were to determine the correctness of the given quadratic equation: $x^2 + xy - 6y^2 = (x + 3y)(2x - 4y)$?.

Students were left to deliberate on the given task independently and in clusters following the identified problem-solving processes while the mathematics teacher in each PBL class

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

acted as a facilitator. One member from the clusters was chosen by the teacher in each PBL class to make presentations on the chalkboard while other members of the PBL clusters commented on the expositions and this generated discourse in the classroom. Thus, diverse feelings followed among members of the PBL clusters as some were in support that the equality holds for the equation, some were in contrast to this stand and obtained $(x - 3y)(2x + 4y)$ as the solution while others were unmoved.

In attaining agreement among the three conflicting groups, the teacher interpolated by calling the students' attention to expand the value on the right-hand side of the quadratic equation and see whether it would correspond to the value on the left-hand side. This made the two of the three contrasting clusters tilt back on their decisions and concurred that the equality did not hold stemming from the teacher's questions, a member of the cluster stated that the equality did not hold because the factors of the product of the first and last terms did not produce the middle term.

The entire class agreed with the final submission while another member of the cluster gave a brisk overview of the factorization. Similar procedures were adopted in each of the PBL classes in teaching topics related to rational fractions, simultaneous equations, and graphs for the seven weeks of the study. In each of the topics taught students in each of the PBL clusters were given ill-structured tasks as homework that required their staying in the libraries, and surfing the net in preparation for demonstration in the next contact period.

Each PBL meeting concluded with both self-assessment and a time in which clusters assessed their effort and made recommendations and clarifications to enhance their performance. Outside the four walls of the classroom, students carried out an autonomous study focusing on the learning issues determined in the cluster meeting. At the following meeting of the cluster, the presenter (chosen by lotto from each cluster) condensed the prior meeting's work by unfolding relevant problems solved thereby providing a connection between the two meetings.

Students debated their fresh knowledge and reviewed their preceding notions and propositions in line with their new knowledge. These procedures were sustained until the clusters were contented that sufficient basic mathematics was learned. Throughout the PBL meetings, the teacher acted as a facilitator who prearranged the clusters and engendered a relaxed classroom atmosphere.

The teacher made sure that students had total control of the dialogue. When direction was required, the teacher asked open-ended and very wide-ranging questions that provided many opportunities to students to concentrate on the goal of the study. With this, the teacher stimulated rational thinking in the students. At the close of the PBL enactment, students assessed each other concerning involvement, groundwork, social skills, and impact on cluster growth. In this manner, it was anticipated that students would be mindful of the degree to which they had participated in the PBL meetings as envisioned - both independently and as a cluster.

The mathematics teachers in the control schools unlike their counterparts at the two experimental schools were not trained on the use of the PBL strategy but the researchers paid impromptu visits to the two control schools during school hours and this gave them the chance to observe the teachers while teaching. Consequently, no efforts were made to discuss the classroom interaction patterns that triumphed between the teachers and the students in the classrooms.

The mathematics teachers in the control schools taught the students with the traditional lecture method following the already prepared instructional plan within the context of the contents selected for the study. The teachers covered topics related to factorization,

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

quadratic equations, rational fractions, simultaneous equations, and graphs. The instructional lesson plan in the control schools was different from the one enacted in the experimental schools in the area of presentation.

The presentation in the control schools followed the routine traditional activities in which the traditional mathematics instruction involved lessons with lecture and questioning methods to teach the concepts related to the study. The students in the control schools studied the approved mathematics textbooks on their own before the class hour. The teachers in the control schools structured the entire class as a unit and wrote notes on the chalkboard the definitions of concepts related to factorization, quadratic equations, rational fractions, simultaneous equations, and graphs.

The control school's mathematics teachers worked examples on the chalkboard involving factorization, quadratic equations, rational fractions, simultaneous equations, and graphs, and, after their explanations, students discussed the concepts and examples with teacher-directed questions. For the majority of the pedagogical time in the two control schools, students received tutoring and engaged in deliberations arising from the teachers' explanations and questions. Thus, teaching in the control schools was principally teacher-centered and learning restricted to the four walls of the classroom. The classroom instruction in the control classes was one period of 40 minutes for four days per week. The one period per day for four days was uniform across the schools in the education district used for the study.

2.5. Data Collection and Analysis

Permission to use the four schools for research purposes was obtained from the Lagos State Ministry of Education through the Education District II. After permission was approved, the researchers went ahead to inform the principals of the schools selected for the research, of the plan to carry out the study. The MMS and MES were used to collect primary data for the study. The pre-test MMS and MES were administered to one experimental group and one control group. The treatment, which took 9 weeks was given to the two experimental groups, while the control groups were taught using the lecture method. During the treatment, all the four groups were taught the same content.

Thereafter, the post-test MMS and MES were administered to all four groups. It should be noted that a reorganized version of the pre-test was used as a post-test to prevent the Hallo effect, which could result from over-familiarization with the pretest. The instruments were administered to the sample with the help of the mathematics teachers in the corresponding schools. The pre-test MMS and MES and post-test MMS and MES were then scored to obtain quantitative data for the study.

The independent samples t-test, analysis of variance (ANOVA), and analysis of covariance (ANCOVA) were deployed to test the null hypotheses. The ANOVA was deployed to analyze variances in the four means of the post-test MMS and MES scores. It was used to determine whether the differences were significant. ANCOVA was used to establish whether there were initial differences in the treatment and control groups as it is used to reduce experimental error by statistical rather than by experimental procedure.

3. RESULTS AND DISCUSSION

The Solomon four non-equivalent group design employed in the study allowed the possibility of having two groups sit for the pre-test. The experimental group I and control group I sat for the MMS pre-test. The results of the independent samples t-test pre-test scores for experimental group I and control group I showed that there was no statistically significant

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

difference t(128) = 0.05, p>0.05 as shown in **Table 2**. This shows that the two groups used in the study displayed analogous features.

Table 2. The t-test of the pre-test scores on the MMS for the PBL treatment group and TLM control group.

Variable	Number	Mean	Standard deviation	t value	df	p-value
MMS	70	73.21	5.97	0.05	128	0.96
	60	89.40	14.03			

3.1. Null Hypothesis One: PBL will Not Significantly Alter Students' Mindset about Mathematics

Exploration was done of the post-test MMS scores, to determine the effect of PBL on students' mathematics mindset. This was to test hypothesis H_{o1}. The post-test means scores obtained by the students revealed that the experimental groups had higher mean scores than the control groups (**Table 3**). However, the standard deviation of the experimental groups improved as compared to that of the control groups (**Table 3**). The one-way ANOVA results based on these means gave an F statistic of F(3, 256) = 533.53 and is statistically significant at the alpha level of 0.05 as shown in **Table 4**. To determine where the difference occurred, post hoc pair-wise comparisons were carried out and Scheffe's test was used.

The results showed that significant differences existed between the PBL experimental groups and TLM control groups. The mean scores of experimental groups I and II and those of control groups I and II showed no significant difference. The MMS means scores were adjusted for ANCOVA with Lagos Basic Education Certificate Examination (LBECE) scores as covariates. The LBECE examinations are administered at the end of junior secondary school year three also referred to as ninth grade, and in Lagos State, Nigeria, they are used for placement for students to join senior secondary schools. The scores were utilized as entry marks. The analysis of covariance in this study did reduce the effects of initial group difference statistically and so made compensating adjustments to the post-test means of the groups involved (Gall *et al*., 1996).

Table 3. MMS post-test mean scores of PBL treatment groups and TLM control groups.

Group	Number	Mean scores	SD
Experimental group I	70	112.79	5.97
Control group I	60	83.17	6.11
Experimental group II	60	113.62	6.16
Control group II	70	83.24	5.16
Total	260	98.19	260

Table 4. ANOVA Comparison of post-test MMS between PBL treatment groups and TLM control groups.

Group	Sum of squares	df	Means square	F	p-value
Between groups	58,372.59	3	19,457.53	533.53	0.00
Within groups	9,337.17	256	36.4		
Total	67,709.77		160		

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

The results obtained were 112.84 for experimental group I, 83.65 for control group I, 113.89 for experimental group II, and 98.25 for control group II. The ANCOVA results of the post-test MMS scores with LBECE scores as covariate show a statistically significant difference of F (3, 255) = 528.10, at an alpha level of 0.05 as shown in **Table 5**. This therefore means that: (1) The MMS pre-test did not impede the learning of the content by students; otherwise, the groups that took the pre-test would have obtained significantly different results from those that did not. (2) Students who were taught using PBL had a higher mathematics mindset than those who were taught through the traditional lecture method (TLM). Since the experimental groups obtained scores that were significantly higher than the control groups, therefore hypothesis H_{01} is rejected.

Table 4. Comparison of MMS post-test scores for ANCOVA between PBL experimental groups and TLM control groups.

Source	Sum of squares	df	Means square	F	p-value	partial eta squad.
Corrected model	58,374.13[a]	4	14,593.53	398.62	0.00	0.86
Intercept	69,162.11	1	69,162.11	1.889E3	0.00	0.88
LBECE	1.54	1	1.54	0.04	0.84	0.00
Treatment	58,002.24	3	19,334.08	528.10	0.00	0.86
Error	9,335.64	255	36.61			
Total	2,574,363.00	260				
Corrected total	67,709.77	259				

a. R squared=.862 (Adjusted R squared=.860)

The Solomon four non-equivalent group design employed in the study allowed the possibility of having two groups sit for the pre-test. The experimental group I and control group I sat for the MES pre-test. The results of the independent samples t-test pre-test scores for groups 1 and 2 showed that there was no statistically significant difference t(128) = 0.53, p>0.05 as shown in **Table 6**. This shows that the two groups used in the study displayed analogous features.

Table 6. The t-test of the pre-test scores on the MES for the PBL treatment group and TLM control group.

Variable	Number	Mean	Standard deviation	t-value	df	p-value
MES	70	58.10	6.59	0.63	128	0.53
	60	58.90	7.90			

3.2. Null Hypothesis Two: PBL Will Not Significantly Improve Students' Engagement in Learning Mathematics

Exploration was done of the post-test MES scores, to determine the effect of PBL on students' mathematics engagement. This was to test null hypothesis H_{02}. The post-test means scores obtained by the students revealed that the experimental groups had higher mean scores than the control groups (**Table 7**). Also, the standard deviation of the control groups improved as compared to that of the experimental groups (**Table 7**).

The one-way ANOVA results based on these means gave an F statistic of F(3, 256) = 382.32 and is statistically significant at an alpha level of 0.05 as shown in **Table 8**. To determine where the difference occurred, post hoc pair-wise comparisons were carried out and Scheffe's test was used. The results showed that significant differences existed between the PBL experimental groups and TLM control groups. The mean scores of experimental groups I and

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

II and those of control groups I and II showed no significant difference. The MES means scores were adjusted for ANCOVA with Lagos Basic Education Certificate Examination (LBECE) scores as covariates. The scores were utilized as entry marks. The analysis of covariance in this study did reduce the effects of initial group difference statistically and so did make compensating adjustments to the post-test means of the groups involved.

Table 7. ANOVA comparison of post-test MMS between PBL treatment groups and TLM control groups.

Group	Number	Mean scores	SD
Experimental group I	70	98.10	6.59
Control group I	60	68.90	7.90
Experimental group II	60	98.88	6.49
Control group II	70	68.59	7.29
Total	260	83.60	16.48

Table 8. Comparison of post-test MES between PBL treatment groups and TLM control groups.

Source	Sum of squares	df	Means square	F	p-value
Between groups	57,477.73	3	19,159.24	382.32	0.00
Within groups	12,828.87	256	50.11		
Total	70,306.60	259			

The results obtained were 98.25 for experimental group I, 68.96 for control group II, 98.92 for experimental group II, and 68.63 for control group II. The ANCOVA results of the post-test MMS scores with LBECE scores as covariate show a statistically significant difference of F(3, 255) = 416.55, at an alpha level of 0.05 as shown in **Table 9**.

This therefore means that: (1) The MES pre-test did not impede the learning of the content by students; otherwise, the groups that took the pre-test would have obtained significantly different results from those that did not. (2) Students who were taught using PBL had higher mathematics engagement than those who were taught through the traditional lecture method (TLM). Since the experimental groups obtained scores that were significantly higher than the control groups, therefore hypothesis H_{o2} is rejected.

Table 9. Comparison of MMS post-test scores for ANCOVA between PBL experimental groups and TLM control groups.

Source	Sum of squares	df	Means square	F	p-value	partial eta squad.
Corrected model	58,374.13[a]	4	14,593.53	398.62	0.00	0.86
Intercept	69,162.11	1	69,162.11	1.889E3	0.00	0.88
LBECE	1.54	1	1.54	0.04	0.84	0.00
Treatment	58,002.24	3	19,334.08	528.10	0.00	0.86
Error	9,335.64	255	36.61			
Total	2,574,363.00	260				
Corrected total	67,709.77	259				

a. R squared=.838 (Adjusted R squared=.835)

3.3. The Effect of PBL on Students' Mathematics Mindset

The results showed a significant main effect of the treatment on students' mindset in mathematics and that 86% of the variance in students' mathematics mindset could be

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

explained by the treatment. The results indicated that students' mathematics mindset was greatly improved when they were exposed to the teaching strategy of PBL when compared with the TLM. This finding supported the few studies (Fatade *et al*., 2014; Sahin, 2009), which associated improved non-cognitive outcomes with learner-centered teaching strategies.

This was further substantiated because the learner-centered teaching strategies alleviated misunderstandings about the nature of mathematics (Awofala *et al*., 2013), and in this study, the strategy of PBL had a positive impact on students' mathematics mindset when compared with the TLM. The TLM in this study seemed to show low improvement in students' mathematics mindset as it had not only been criticized for emphasizing teacher activity at the expense of student involvement (Ojaleye & Awofala, 2018) but that it had a negative effect on students' non-cognitive outcomes in mathematics (Fatade *et al*., 2014; Awofala *et al*., 2022).

The finding that students who were exposed to the PBL recorded significantly higher mathematics mindset than those exposed to the TLM corroborated the views of PBL proponents that the strategy was effective in enhancing students' self-regulated learning non-cognitive outcome (Sungur & Tekkaya, 2006; Wheijen, 2005). In the present study, the PBL students seemed to value the student-centered nature of PBL, including information seeking, high levels of challenge, group work, and personal relevance of the material.

3.4. The Effect of PBL on Students' Mathematics Engagement

The results of this study showed a significant main effect of the treatment on students' engagement in mathematics and that 83% of the variance in students' mathematics engagement could be explained by the treatment. The students could be engaged in learning mathematics as PBL involved group work in which every member of the group had a specific role to play. This is capable of boosting the PBL students' confidence in learning mathematics and their ability to stay focused on tasks as they think about different ways to solve a problem.

In this study, the PBL students built on other group members' ideas in which helping others who were struggling in mathematics was a norm. The ability to stay focused on the mathematics problem enabled the PBL students to engage fully in learning mathematics even in the face of difficulty. Students who learned under the PBL in this study generally liked the mathematics they were studying and were more confident of their capabilities as they used the opportunity to catch social skills that might be needed in their everyday lives.

The students who learned under the PBL strategy felt that mathematics was more important and useful to them and thus accepted greater personal responsibility for their learning as they were assigned roles than those who learned under the TLM without roles. PBL improves intrinsic motivation which can trigger engagement in learning and make students more competent in solving mathematics problems. However, the experimental groups' teachers believed that the PBL activities were time-consuming.

4. CONCLUSION

The conclusions reached from this study include:

(i) PBL strategy enhances students' mathematics mindset as compared to the TLM.
(ii) PBL strategy enhances students' mathematics engagement as compared to the TLM.

The results of this study show that the PBL strategy can alter not only students' mindsets but also improve their engagement in mathematics. Thus, PBL would enhance the learning of mathematics at senior secondary schools. This can in turn increase their achievement in mathematics. The onus is on the mathematics teachers to use the PBL strategy not only to alter students' mindset towards the growth zone but also to enhance their engagement in

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

mathematics learning. Curriculum planners and designers need to encourage the use of PBL to advance the efficiency of mathematics teachers.

In addition, teacher-training institutions in Nigeria and elsewhere should integrate the elements of PBL in the curriculum of pre-service and in-service teachers to empower them, as they become teachers of mathematics at the senior secondary schools. One limitation of this study is that it did not take into consideration the main effect of treatment on the individual dimension of mathematics mindset and mathematics engagement.

Therefore, it is difficult to isolate the effect of each treatment condition on each dimension of mathematics mindset and mathematics engagement. Mere investigating the relation between instructional strategies and total mathematics mindset and mathematics engagement as done in the present study might obscure some salient information, which may be useful in advancing appropriate intervention. This should be considered a fruitful area of further research, which may lend itself to the adoption of more powerful statistics of multivariate analysis of covariance (MANCOVA).

5. ACKNOWLEDGMENT

Many thanks to the teachers and students who participated in the study. More power to your elbow.

6. AUTHORS' NOTE

The authors declare that there is no conflict of interest regarding the publication of this article. The authors confirmed that the paper was free of plagiarism.

7. REFERENCES

Ajai, J. T. and Imoko, I. I. (2015). Gender differences in mathematics achievement and retention scores: A case of problem-based learning method. *International Journal of Research in Education and Science, 1*(1), 45- 50.

Akinoglu, O. and Tandogan, R.Ö. (2007). The effects of problem-based active learning in science education on students' academic achievement, attitude and concept learning. *Eurasia Journal of Mathematics, Science and Technology Education, 3*(1), 71-81.

Aronson, J., Fried, C. B., and Good, C. (2002). Reducing the effects of stereotype threat on African American college students by shaping theories of intelligence. *Journal of Applied Developmental Psychology, 38*, 113–125.

Awofala, A. O. A, Fatade, A. O. and Ola-Oluwa, S. A. (2012). Achievement in cooperative and individualistic goal-structured junior secondary school mathematics classrooms in Nigeria *International Journal of Mathematics Trends and Technology, 3*(1), 7-12.

Awofala, A. O. A. (2012). An analysis of the new 9-year basic education mathematics curriculum in Nigeria. *Acta Didactica Napocensia, 5*(1), 18 - 28

Awofala, A. O. A. (2016). Effect of personalisation of instruction on students' motivation to learn mathematics word problems in Nigeria. *Turkish Journal of Computer and Mathematics Education, 7*(3), 486-509.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Awofala, A. O. A. (2017). Effect of personalisation of instruction on students' anxiety in mathematical word problems in Nigeria, *Bulgarian Journal of Science and Education Policy, 11*(1), 83-120.

Awofala, A. O. A. (2021). A validation of the mathematical resilience scale for twelfth graders through confirmatory factor analysis and its relationship with achievement in mathematics in Nigeria. *SN Social Sciences, 1*(8), 1-17.

Awofala, A. O. A. Arigbabu, A. A. and Awofala, A. A. (2013). Effects of framing and team assisted individualised instructional strategies on senior secondary school students' attitudes toward mathematics. *Acta Didactica Napocensia, 6*(1), 1 – 22.

Awofala, A. O., Lawal, R. F., Arigbabu, A. A. and Fatade, A. O. (2022): Mathematics productive disposition as a correlate of senior secondary school students' achievement in mathematics in Nigeria. *International Journal of Mathematical Education in Science and Technology*, *53*(6), 1326-1342.

Awofala, A. O., Lawani, A. O., and Oraegbunam, C. O. (2020). A factor analytic structure of the conceptions of mathematics scale among pre-service mathematics teachers in south-west Nigeria. *JRAMathEdu (Journal of Research and Advances in Mathematics Education), 5*(1), 94-104.

Biggs, J. B. (1978). Individual and group differences in study processes. *British Journal of Education Psychology, 48*, 266–279.

Blackwell, L. S., Trzesniewski, K. H., and Dweck, C. S. (2007). Implicit theories of intelligence predict achievement across an adolescent transition: A longitudinal study and an intervention. *Child Development, 78*, 246–263.

Boaler, J., and Zoido, P. (2016). Why math education in the U.S. doesn't add up. *Science American Mind, 27*, 18–19.

Boaler, J., Dieckmann, J. A., Pérez-Núñez, G., Sun, K. L., and Williams, C. (2018). Changing students' minds and achievement in mathematics: The impact of a free online student course. *Frontiers in Education, 3*, 1-26.

Bude, L., Imbos, T., Wiel, M., Broers, N., and Berger, M. (2009). The effects of directive tutor guidance in problem-based learning of statistics on students' perceptions and achievement. *Higher Education*, *57*, 23-36.

Claro, S., Paunesku, D., and Dweck, C. S. (2016). Growth mindset tempers the effects of poverty on academic achievement. *Proceeding of National Academy Science U.S.A., 113*, 8664–8668.

Crawford, K., Gordon, S., Nicholas, J., and Prosser, M. (1998). University mathematics students' conceptions of mathematics. *Studies in Higher Education, 23*, 87 - 94.

Fatade, A. O., Arigbabu, A. A. Mogari, D., Awofala, A. O. A (2014). Investigating senior secondary school students' beliefs about further mathematics in a problem-based learning context. *Bulgarian Journal of Science and Education Policy, 8*(1), 1-42.

Fatade, A. O., Mogari, D., and Arigbabu, A. A. (2013). Effect of problem-based learning on senior Secondary school students' achievements in further mathematics. *Acta Didactica Napocensia, 6*(3), 27-43.

Finn, J. D. (1989). Withdrawing from school. *Review of Educational Research, 59*, 117-142.

Fredricks, J. A., Wang, M. T., Schall Linn, J., Hofkens, T. L., Sung, H. C., Parr, A. K., and Allerton, J. J. (2016). Using qualitative methods to develop a survey measure of math and science engagement. *Learning and Instruction, 43*, 5-15.

Good, C., Aronson, J., and Inzlicht, M. (2003). Improving adolescents' standardized test performance: an intervention to reduce the effects of stereotype threat. *Journal of Applied Development Psychology, 24*, 645–662.

Greene, B. A. (2015). Measuring cognitive engagement with self-report scales: Reflections over 20 years of research. *Educational Psychologist, 50*, 14-30.

Hmelo-Silver, E. (2004), Problem-based learning: What and how do students learn? *Educational Psychology Review, 16*(3), 235-266.

Hughes, J. N., Luo, W., Kwok, O., and Loyd, L. K. (2008). Teacher-student support, effortful engagement, and achievement: a three-year longitudinal study. *Journal of Educational Psychology, 1*, 1-14.

Kaharuddin, A. (2018). Effect of problem-based learning model on mathematical learning outcomes of 6th grade students of elementary school accredited B in Kendari city. *International Journal of Trends in Mathematics Education Research, 1*(2), 43-46.

Kong, Q. P., Wong, N. Y., and Lam, C. C. (2003). Student engagement in mathematics: development of instrument and validation of construct. *Mathematics Education Research Journal, 15*,4-21.

Kooken, J., Welsh, M. E., McCoach, D. B., Johnston-Wilder, S., and Lee, C. (2016). Development and validation of the mathematical resilience scale. *Measurement and Evaluation in Counseling and Development, 49*(3), 217-242.

Maguire, E. A., Gadian, D. G., Johnsrude, I. S., Good, C. D., Ashburner, J., Frackowiak, R. S., et al. (2000). Navigation-related structural change in the hippocampi of taxi drivers. *Proceeding of National Academy of Science U.S.A, 97*, 4398–4403.

Maltese, A. V., and Tai, R. H. (2010). Eyeballs in the fridge: sources of early interest in science. *International Journal of Science Education, 32*, 669-685.

Martin, A. J., Way, J., Bobis, J., and Anderson, J. (2015). Exploring the ups and downs of math engagement in the middle school years. *Journal of Early Adolescence, 35*, 199-244.

Maulidia, F., Johar, R., and Andariah, A. (2019). A case study of students' creativity in solving mathematical problems through problem-based learning. *Infinity Journal of Mathematics Education*, *8*(1), 1-10.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Mji, A., and Arigbabu, A. A. (2012). Relationship between and among preservice mathematics teachers' conceptions, efficacy beliefs and anxiety. *International Journal of Education Science, 4(3)*, 261 – 270.

Ojaleye, O. and Awofala, A. O. A. (2018). Blended learning and problem-based learning instructional strategies as determinants of senior secondary school students' achievement in algebra. *International Journal of Research in Education and Science, 4*(2), 486-501.

Olaoye, O. and Adu, E. O. (2015). Problem-based learning strategies and gender as determinant of grade 9 students' academic achievement in algebra. *International Journal of Educational Sciences, 8*(3), 485-492.

Sahin, M (2009). Exploring university students' expectations and beliefs about physics and physics learning in a problem-based learning context. *Eurasia Journal of Mathematics, Science and Technology Education, 5,* 321-333.

Savery, J. R. (2006). Overview of problem-based learning: Definitions and distinctions. *The Interdisciplinary Journal of Problem-Based Learning, 1*(1), 9-20.

Schmidt, H. G., and Moust, J. H. (1995). What makes a tutor effective? A structural-equations modeling approach to learning in problem-based curricula. *Academic Medicine, 70*(8), 708–714.

Siagian, M. V., Saragih, S., and Sinaga, B. (2019). Development of learning materials oriented on problem-based learning model to improve students' mathematical problem-solving ability and metacognition ability. *International Electronic Journal of Mathematics Education, 14*(2), 331-340.

Skinner, E. A. and Belmont, J. J. (1993). Motivation in the classroom: Reciprocal effects of teacher behavior and student engagement across the school year. *Journal of Educational Psychology*, *85*(4), 571-581.

Sungur, S. and Tekkaya, C. (2006). Effects of problem-based learning and traditional instruction on self-regulated learning. *The Journal of Educational Research, 99*(5), 307-320.

Van Berkel, H. J. M., and Dolmans, D. H. J. M. (2006). The influence of tutoring competencies on problems, group functioning and student achievement in problem-based learning. *Medical Education, 40*(8), 730–736.

Voelkl, K. E. (1997). Identification with school. *American Journal of Education, 105*, 204-319.

Wang, M. T., and Degol, J. (2014). Staying engaged: Knowledge and research needs in student engagement. *Child Development Perspectives, 8*, 137-143.

Wang, M. T., and Holcombe, R. (2010). Adolescents' perceptions of school environment, engagement, and academic achievement in middle school. *American Educational Research Journal, 47*, 633-642.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815

Wang, M-T., Fredricks, J. A., Ye, F., Hofkens, T. L., and Linn, J. S. (2016). The Math and Science Engagement Scales: Scale development, validation, and psychometric properties. *Learning and Instruction, 43*, 16-26.

Wheijen, C. (2005). Impact of constructivist teaching on student beliefs about teaching and learning in introductory physics. *Canadian Journal of Science, Mathematics and Technology Education, 5*(1), 95-109.

Zimmerman, B. J. (1990). Self-regulated learning and academic achievement: An overview. *Educational Psychologist, 21*, 3-17.

DOI: http://dx.doi.org/10.17509/xxxx.xxxx
p- ISSN 2775-6793 e- ISSN 2775-6815