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Effectiveness of STEM problem-based learning on the achievement of biology among secondary school students in Nigeria

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** The paper is from the thesis section*

ABSTRACT
Academic performance of students is global issue of great concern to educators. This study sought to ascertain the effect of STEM problem-based learning as an inquiry approach on secondary school student's performance in Biology at government-owned secondary schools in Kebbi State, Nigeria. The non-equivalent control group design was adopted. Two schools were selected in which purposive sampling was employed to select the participants. Each class contain 40 participants. The data was obtained using Diffusion and Osmosis Achievement Test (DOAT). The variables were evaluated using descriptive statistics and the Independent Samples t-test. Based on the results obtained the STEM Problem-Based Learning (STEM-PBL) have a significant and favorable impact on students' biology achievement and that students in the experimental group retained more Biology information compared to the control group. The study recommended among others that, Biology classes should be made more engaging to students and teachers need to be more creative and inventive when it comes to discovering, selecting, and implementing activity-based instructional strategies in the classroom.

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Introduction

Competition between nations has intensified as a result of global developments in technology, industry and engineering (Akgündüz et al., 2022). Speedy development by developed countries is due to emphasis they placed on how sciences was taught (Ma et al., 2019). The key for sustainable improvement is scientific literacy (Irmita & Atun, 2018; Kyle, 2020). However, secondary school learners tend to perform poorly in examination due to misconceptions. United State is now losing its competitive edge due to the poor performance of students in science subjects (Do & Cerrah, 2018; Jone, 2018). In Asia, Malaysian students failed to achieve the minimum international standards in Trends in International Mathematics and Science Study (TIMSS) and Programme for International

Student Assessment (PISA) (Chong, 2019). In Africa, academic achievement of Ghanaian students in biology has consistently remained poor (Annan et al., 2019). In Kenya, a steady decline in educational standards was observed among secondary school students (Mwaura et al., 2019).

Most secondary school students in Nigeria misunderstands some biological concepts. They consider them difficult and challenging (Etobro & Fabinu, 2017). Students have misconceptions and difficulties in understanding and explaining the concepts of diffusion and osmosis (Do & Cerrah, 2018; Oladipo & Cynthia, 2018; Zita & Winifred, 2021). In most schools in Nigeria, biology is taught in abstract fashion and in disjointed form resulting in comprehension deficiency.

In spite of all the instructional strategies employed by teachers, quite a number of students skipped and hardly attempt diffusion and osmosis related questions in West African Examination Council (WAEC), and if attempted are poorly answered (Yaki, et al., 2019). Biology achievement of students in WAEC in Nigeria was reported to be low in terms of credit level which qualifies students for admission into institutions of higher learning (Zita & Winifred, 2021). From 2016 to 2021, the percentage of secondary school students in Argungu Education Zone who received credit in biology was consistently lower than 50% (2016-2021 Credit % in Argungu Zonal Education Office).

Secondary school classrooms in Nigeria were dominated by teacher-centred approaches. Conventional methods of instruction, according to Gorowara & Lynch, (2019), Iji, et al., (2015) and Samsudin, et. al., (2020), were the dominant strategies in teaching and learning of biology. Teaching and learning from a conventional approach as observed in many secondary school classrooms have contributed to low skilled students and poor academic achievement in biology (Atsumbe, 2019; Clement et al., 2017).

The main way that school students learn about their abilities, talents and skills is through their academic abilities, which also serves as a guide for future development. Academic achievement is defined as an individual's degree of performance in the disciplines offered in school, as measured by test scores (Atsumbe, 2019; Mammadov et al., 2021). Suitable instructional techniques are required to identify ways to accomplish the desired instructional outcomes. Strategies that emphasized hands-on activities, problem-solving, critical thinking and collaborative learning should be employed (Garcia-higuera & Panamericana, 2019).

Today's educational system is moving toward activity-based and a more active role for students in learning science (Bahar, & Aksut, 2020). Teaching techniques that challenge students' thinking and clarify concepts should be emphasized to improve performance, increase scientific literacy and retention (Ahmed, & Abimbola, 2011; Garcia-higuera & Panamericana, 2019; Tharayil et al., 2018). Scientific literacy is needed to equip students with the ability to respond to real-world issues that exist in the society, think critically and creatively and involve in problem solving, and have in-depth knowledge and understanding to be applied to problem-solving (Dewi, et al., 2021). These could be achieved through STEM Education approaches like STEM problem-based learning.

STEM problem-based learning (STEM-PBL) is a student-centred learning process that uses problem-based learning procedures to implement the learning of diffusion and osmosis concepts in biology. The process is an inquiry approach and good alternative to improve students' science comprehension and is challenging for learners (Dervic et al., 2018; Erdogan et al., 2016). It has the potential to enhance and improve achievement. The approach contained hands-on activities, active student participation, collaboration to find solutions to the problems, communicating the results, and judging the findings, and the activities were always related to real-life scenarios (Dibiyantini et al., 2018; Welch et al., 2015). STEM-PBL in this study is defined as an inquiry approach applying the principles of problem-based learning (PBL) for students to learn diffusion and osmosis concepts.

Based on the literature reviewed in this research, the effects of a STEM-PBL for secondary school students in Kebbi State, Nigeria, are not yet clear (Agbidye, 2019; Ameen et al., 2022; Zudonu et al., 2020). Many of the studies found were centred on a particular topic, focusing on university level (Osuyi, 2021). References related to high school students are few in the STEM field and the STEM-PBL process in Kebbi State, Nigeria (Ameen, et al., 2022). The publications analyzed by the researchers were unable to address the present study's research variable, which are STEM-PBL and achievement in the diffusion and osmosis concepts.

STEM-PBL in this study was integrated with the 5Es (engage, explore, explain, elaborate, and evaluate) as the stages for learning diffusion and osmosis. Senior secondary school form four students in Kebbi state Nigeria served as the population of the study in which eighty participants were selected as sample from two schools in Argungu Education Zone of Kebbi state Nigeria. The study is hope to contribute to the existing literature through identification and resolution of students' misconceptions and other learning difficulties in the concepts of diffusion and osmosis. In this study, form four secondary school biology students were encouraged to solve diffusion and osmosis problems in a STEM problem-based inquiry learning environment.

The aim is to examine the effects of STEM-PBL as inquiry learning on form four secondary school students' achievement in biology on the concepts of diffusion and osmosis. For this reason, research questions and hypothesis were stated as below.

Research Questions

1. Is there any mean difference in the mean achievement of students taught diffusion and osmosis concepts using STEM PBL and Conventional Teaching Method?
2. How do the STEM PBL and Conventional Teaching Method influence student's retention?

Hypothesis

1. There is no significance difference in the mean achievement of students taught diffusion and osmosis concepts using STEM PBL and Conventional Teaching Method.
2. There is no significance difference in the mean achievement of post-test and delayed post-test of students taught diffusion and osmosis concepts using STEM PBL.

Literature Review

STEM Education

STEM (Science, Technology, Engineering and Mathematic) education is not just a field of study, but also comprise methods of teaching and learning which aim to solve real-world problems (Wahono et al., 2020). It is the educational system of the future, because critical thinking, teamwork and group work are vital for the future (English, 2016). According to previous research, learners learn best when they are encouraged to do hands-on activities to stimulate their learning curiosity to build their own knowledge about the world around them (Kibga et al., 2021; English, 2016). İn these approaches students are free to create their own knowledge under the guidance of a facilitator thereby improving their academic achievement (Aksela, 2019; Thibaut et al., 2018). STEM education-based approaches especially STEM-PBL, encourage hands-on activities leading to lifelong learning as well as motivate students to explore and discover new facts (Kibga et al., 2021).

STEM Education approaches have the potential to improve students' ability to integrate knowledge and skills such as communication and cooperation through various learning stages to improve problem-solving skills in open-ended problems (Baran et al., 2021). It is important for a nation with the intention to achieve its future progress goals to prepare curricula based on interdisciplinary STEM education (Cinar et al., 2022). Students in STEM programs look for answers to issues that they will face in the real world. The knowledge and abilities of one subject alone cannot be used to solve the problems that arise in real life since they are multidisciplinary in nature. Students must therefore employ the interdisciplinary approach, which by nature draws on the knowledge and abilities of other disciplines, to solve these difficulties. (Uğur et al., 2020).

STEM Problem-based Learning (STEM-PBL)

STEM-PBL uses problem-based learning procedures to implement STEM education so as to improve student's comprehension (Erdogan, et al., 2016). It has the ability for hands-on activities (Aidoo, et al., 2016), and improves students' knowledge retention (Dibyantini et al., 2018; Fitriani et al., 2020). As an interdisciplinary approach, STEM PBL enables learners to solve ill-structured, unclear and real-life problems (Dervic et al., 2018). Many academics and educators increasingly promote student engagement in STEM-PBL contexts for maximizing scores rather than using conventional methods (Brush & Saye, 2017; Dervic et al., 2018; Fitriani et al., 2020; Kasemsap, 2017; Sunyoung, 2016; Zudonu et al., 2020). Baran, et al., (2021), Bicer et al., (2015) and Kasuga et al., (2022); reported that Problem-based learning is capable of engaging in hands-on activities which enhance students to obtain high performance and develop scientific skills.

The STEM-PBL is an activity-based teaching technique that promotes student-centeredness and intellectual challenge. The approach includes enhancing learning activity and providing guides and comments to assist learning (Sakir & Kim, 2020). It improves academic success by fostering student creativity, peer engagement, communication skills and confidence in problem-solving. In contrast to conventional teaching methods that required students to be passive participants in their education, students in the STEM-PBL have the ability to actively engage in their learning (Funa & Prudente, 2021). According to them, conventional teaching methods often have a negative impact on the standard of science learning. Learning is facilitated by the STEM-PBL inherent structure, which enables smooth learning. Students are helped in the learning process by their active engagement, peer involvement, ability to communicate and judge their findings. According to the report of Blancia and Fetalvero (2021), STEM-PBL is an effective technique for promoting students' inquiry skills, which motivates them to explain scientifically discrepant events.

Compared to conventional methods of instruction, the STEM-PBL boost student's performance and retentive capacity (Osuyi, 2021), and improve students' potential for retention (Arifin et al., 2020; Osuyi, 2021). İt was found that when students are taught utilizing STEM-PBL, they retained information and perform better in their examinations (Ameen et al., 2022; Bicer et al., 2015; Laforce & Noble, 2017). STEM PBL is widely recognized as an effective learning strategy of teaching and learning in which students are presented with an ill-structured problem, be allowed to define the problem and brainstorm ideas based on prior knowledge, engage in independent study, share information and engage in peer teaching and work toward a solution, present their solution and review what they have learned and finally engage into self, peer and tutor review of the process (Dibyantini et al., 2018; Funa & Prudente, 2021; Snijders, et al., 2019). They are to be familiar with the problem presented, form groups, organizing the work, conduct research and negotiate to answer the problems.

Misconception in Diffusion and Osmosis

Secondary school biology curriculum in Nigeria consists of many topics that are basic to biology knowledge and interrelated with each other. For example, diffusion and osmosis are inseparable in relation to the role they play to living organisms. Diffusion is required for gas exchange between respiratory surfaces and surrounding environment and between body fluid and tissues. Osmosis on the other hand, is required to understand the processes of the water uptake from soil into root cells, the mechanism that lies behind the movement of water through the xylem tissues of plants, water balance in land and aquatic creatures, turgor pressure in plants, transport in living organisms etc. (Bhatla & Lal, 2018). However, many secondary school students have a deep-rooted misconception about how diffusion and osmosis work.

Studies focusing on understanding of diffusion and osmosis confirmed that students show a considerable number of misconceptions and difficulties that are resistant to change by traditional teaching methods (Abdullahi, et al., 2021; Ekon & Edem, 2018; Obochi, 2021). Ekon & Edem (2018) pointed many misconceptions about concentration and tonicity and the influence of life forces on diffusion and osmosis among biology students.

Dogru & Özsevgeç (2018), and Oladipo & Ihemedu (2018) conducted a study on the secondary school biology students on their perceived difficulty of isolated biology topics and reported that osmosis and water potential were regarded by students as being among the most difficult biological concepts to understand. Ahmad & Jamil (2020) maintained that conceptions of concentration and diffusion may be acquired by students through direct experience and believes. These existing conceptions can be used to provide a foundation for the scientific conceptions needed to understand the role of concentration in osmotic events. In terms of semi permeability of membranes, most students believed that there was either no movement of materials or the solute moved across the membrane (Oladipo & Ihemedu (2018). They further stated that only a small percentage of students understand that pressure was related to water movements and osmosis.

Methods

Research Design

A non-equivalent control group design was adopted from a quasi-experimental study. This was because it is not possible to randomized subjects to treatment or control group because the study involves two groups where the intervention is implemented in one group and compared with a second group without intervention, based on the post-test measure from both groups (Campbell & Stanley, 2015). This study employed the pre-test, post-test and delayed post-test design to find out the effect of independent variables on the dependent variables (Kenny & Kenny, 1975; Campbell & Stanley, 2015). This method is one of the most popular designs used in educational research (Campbell & Stanley, 2015).

Samples

In order to determine the study schools, convenience sampling was used. For this purpose, considering the similarities of the selected schools in terms of the geographical location, laboratory facilities, technological infrastructure and suitable class size for diffusion and osmosis activities, the research was carried out in the two schools in Argungu Education Zone of Kebbi state, Nigeria. These schools were Government Day Secondary School Bayawa (GDSSB) and Government Day Secondary School Tiggi (GDSST). The two selected schools also have the similar level of teachers in terms of qualifications and years of experience. The external exams (WAEC and NECON) that provide direct admission to higher education institutions both within and outside Nigeria, indicated low achievement results in biology among secondary school's students in Nigeria in which these schools are inclusive (Abdullahi et al. 2021; Argungu Education Zonal Office Report).

The groups were also selected using purposive sampling to assign participants into intact classes. Two intact classes comprising of 40 students in each class (experimental and control class) were composed. The research was carried out with 80 (see table 1) senior secondary school form four biology students (48 males and 32 females). Permanent Biology teachers of the two sampled schools with less than 15 years of teaching experiences and with the same qualifications and who were not the teachers of those students were used to deliver the intervention.

Instrument

One instrument is used in gathering data in the current study. This tool is Diffusion and Osmosis Achievement Test (DOAT) and discussed as follows:

Diffusion and Osmosis Achievement Test (DOAT)

The Diffusion and Osmosis Achievement Test (DOAT) was developed by the researchers; it is a researcher-made achievement test developed in collaboration with some biology teachers and validated by the four experts in science education. In the absence of the availability of the instruments for adoption or adaptation, the researcher has the option to develop a tool for his study (Ugwu & Mkpuma, 2019). The test covered the topics under the diffusion and osmosis concepts involved in the SS1 biology curriculum.

Twenty-five (25) multiple-choice questions were initially constructed for the participants which were later reduced to 20 after modifications by the experts. The multiple-choice questions are among the practices in academic assessment, good for learning, and the actual answer is visible, which could trigger a student’s memory and enable them to give the correct answer (Butler, 2018, Ciomek et al., 2017). The test contained four options (A–D). The instrument's reliability was calculated using Cronbach Alpha Coefficient methodology, yielding a value of 0.88, which is greater than the acceptable 0.70 (Abbas, Khanam & Ahmad, 2019). This tool was administered to both groups of students before the intervention, immediately after the intervention, and two weeks after the intervention.

Training of Research Assistants (RA)

Five days of training on the principles and guidelines on how to implement STEM-PBL was given to the eight (8) research assistants who were biology teachers of the selected schools. The training took place daily for four (4) hours. There were two training sessions every day. After the workshop training was successfully completed, a test was given to the trainees to see how well they understood the material. The research assistant with the best test score and improved performance during the simulated instruction was chosen. This instructor was tasked with administering the intervention to the study participants (i.e., Experimental group). The research assistant (RA) directs, oversees, evaluates, and organizes laboratory and classroom activities. They were instructed to serve as guide to the students and not go beyond the instructional packages (STEM PBL) given to them by the researchers. The research assistants in the control group, on the other hand, were instructed to use their usual methods of instruction. It should be noted however, that the research assistant in the control group does not participate in the five-day training workshop.

Implementation

Six STEM problem-based inquiry activities were carried out within the scope of the diffusion and osmosis concepts of biology. The intervention for both the experimental and control group was conducted after school hours (Monday and Thursday) with the permission of the two principals of the selected schools. Six-weeks were spent for the full implementation of the intervention in the first term in the year 2022. This was based on the suggestion of Vaughn et al., (2012) that intervention should at least be five weeks.

In allocating the time for each lesson, Vaughn et al., (2012) suggestion was followed. They stated that the length and frequency of the intervention should be 30-120 minutes per day. Each lesson was therefore conducted in 60 minutes. Each lesson lasted for one hour in the areas of exploring the diffusion process, rate of diffusion, movement of molecules across membrane, exploring osmosis process, plasmolysis and hemolysis. The lesson was implemented using 5E stages of learning (engage, explore, explain, elaborate and evaluate).

Findings

In this section, descriptive statistics was employed to answer research questions one and two, to find out the mean difference between the two groups (experimental and control) in their pre-test, post-test and delayed post-test. This was followed by testing the hypothesis at the fixed probability level of 0.05.

Solution to Research Questions

Research question one: *Is there any mean difference in the mean achievement of students taught diffusion and osmosis concepts using STEM PBL and Conventional Teaching Method?* The computed mean scores before and after the intervention were compared in table 1.

Table 1

Mean Scores of Students on DOAT for Pre-Test and Post-Test

		Pre-Test		Post-Test		
Group	N	Mean	Std. Dev.	Mean	Std. Dev.	Mean difference
Control	40	9.50	4.62	10.63	4.71	1.13
Experimental	40	10.25	4.96	16.90	3.47	6.65
Mean difference		0.75		6.27		

Note. N= number of participants; Std.. Dev. = Standard Deviation

The two groups had no major difference in their achievement before the intervention as shown in Table 1. The mean difference was 0.75. After the intervention in which the experimental group were taught with the STEM problem-based learning, the mean difference rose to 6.27. The mean score of students in the control group did not differ much between the pre-test and post-test. The mean difference was 1.13. The mean score of students in the experimental group increased from 10.25 to 16.9 with a mean difference of 6.65. Use of the STEM problem-based learning had a major positive effect on the achievement of students.

Research question two: *How do the STEM PBL and Conventional Teaching Methods influences student's retention?* The computed mean for the post and delayed post-test scores in the diffusion and osmosis achievement test (DOAT) by the two groups were compared in table 2.

Table 2

Mean Scores of Students on DOAT for Post-Test and Delay Test

		Post-Test		Delayed Test		Mean difference
Group	N	Mean	Std. Dev.	Mean	Std. Dev.	
Control	40	10.63	4.71	13.18	5.14	2.55
Experimental	40	16.90	3.47	16.80	3.07	0.10
Mean difference		6.27		3.62		

Note. N= number of participants; Std.. Dev. = Standard Deviation

The students in the control group had a lower mean retention score on the diffusion and osmosis achievement test compared with their counterpart the experimental group. The control group had a mean achievement of 10.63 compared with the experimental group with a mean score of 16.90. The mean difference was 6.27. At the delayed test (retention) test level the mean achievement of the control group rose to 13.18 with a standard deviation of 5.144 and increased mean difference of 2.55.

For the experimental group, mean achievement was 16.80 with a standard deviation of 3.065. The mean difference was 0.10. At the retention test level, the improvement in biology achievement test by students in the experimental group did not reduce much which showed that the application of STEM problem-based learning had positive effect on retention of achievement in diffusion and osmosis concepts of biology. This was as a result of their active participation in construction of their own knowledge.

Test of Hypotheses

Null hypothesis I: *There is no significance difference in the mean achievement of students taught diffusion and osmosis concepts using STEM PBL and Conventional Teaching Method before and after the intervention.*

Table 3 showed a summary of analysis of covariance procedure used for the test to ensure that post-test outcome was not influence by participation in the pre-test before the intervention.

Table 3

Analysis of Covariance on DOAT

Source	Sum of Squares	df	Mean Square	F	Sig.
Pre-test DOAT	3.795	1	3.795	.220	.640
Group	791.233	1	791.233	45.836	.000
Error	1329.180	77	17.262		
Corrected Total	2120.488	79			

Note. (F-critical = 3.84, $p < 0.05$)

The result of the test in Table 7 revealed that the two groups differed significantly in their mean scores in the biology achievement test after the intervention. The observed F-value was 45.836 obtained at df = 1, 77 with a p-value of 0.000 ($p < 0.05$). The result showed that participation in the pre-test achievement test did not significantly influence the outcome of the post-test. The observed F-value for the pre-test as the covariate factor was 0.200 with a p-value of 0.640 ($p > 0.05$). These observations provided enough evidence for rejecting the null hypothesis. The implication here is that use of the STEM PBL method had the advantage of improving mean performance of students in the selected biology concepts than could be obtained with the conventional teaching method.

Null hypothesis II: *There is no significance difference in the mean achievement of post-test and delayed post-test of students taught diffusion and osmosis concepts using STEM PBL.*

The result of the two samples t-test procedure used to determine significance of the variability between the post-test and delayed post test scores of the experimental group exposed to the use of STEM PBL method is summarized in Table 4.

Table 4

Two Sample T-Test on Post and Delayed Post-Test of DOAT for Students Expose to STEM PBL

Stage	N	Mean	Std. Dev.	Std. Error	t-value	df	p-value
Post-test	40	16.90	3.47	0.55	0.064	78	0.942
Delayed-test	40	16.80	3.065	0.485			

Note. (t-critical =2.00, $p < 0.05$)

Result in Table 4 revealed that mean post-test achievement of the students exposed to use of the STEM PBL method did not differ significantly from the mean score at the delayed post-test level. The observed t-value was 0.064 with a p-value of 0.942 ($p > 0.05$). These observations did not provide sufficient evidence for rejecting the null hypothesis. The null hypothesis that, there is no significant difference in the mean scores of post-tests and delayed post-test scores on the achievement in learning of diffusion and osmosis concepts by students in experimental group is therefore retained.

Discussion

The finding of this study revealed that use of STEM Problem-based learning significantly improved mean achievement of students in learning of diffusion and osmosis concepts of biology when compared with students who learned the concepts through conventional teaching method. The study found that performance of the students was significantly higher after the intervention than was obtained before the intervention. The observed difference was found to be significant. The finding here is in line with Kasuga et al., (2022); Baran, et al., (2021); Bicer et al., (2015) who reported that Problem-based learning is capable of engaging in hands-on activities which enhance students to obtain high performance and develop scientific skills.

As showed in table 6, the two groups (experimental and control) had no major difference in their achievement before the intervention. The mean difference was 0.75. According to Table 7 after the intervention, the results of the post-test on students' performance in Biology shows that students who received instruction using the STEM-PBL had higher mean scores (Mean =16.90) than students who received treatment using conventional teaching methods, with lower mean scores (Mean = 10.63). When the findings were analyzed through ANCOVA, a significant p-value of 0.000 ($p < 0.05$) was discovered. This was an indication that STEM-PBL has beneficial effects on students' Biology achievement at secondary school level. This finding is consistent with Fitriani, et al., (2020), and Sunyoung, et al., (2016) findings that students perform better academically when taught utilizing the STEM-PBL than those taught with conventional methods. The study's findings were actually supported by the report of Blancia and Fetalvero (2021), which stated that STEM-PBL is an effective technique for promoting students' inquiry skills, which motivates them to explain scientifically discrepant events.

The result supports the research by Fitriani, et al., (2020b), who looked at the impact of the PBL techniques on secondary school students' performance in biology. Their findings demonstrated that the PBL group outperformed the conventional teaching method group by a large margin. Additionally, the present study is in line with Blancia & Fetalvero, (2021), who reported that when biological concepts were taught via the PBL, students have positive understanding and performed better. When compared to conventional methods of instruction, the study found that students in the STEM-PBL class had a better conceptual knowledge of the concepts of diffusion and osmosis.

The results of a post-test support Fitriani et al., (2020b) claim that PBL have a good impact on students' knowledge and skills acquisition and Aidoo, Boateng, Kissi & Ofori, (2016) who maintained that STEM-PBL is a powerful method for enhancing learning. The Engage, Explore, Explain, Elaborate, and Evaluate, learning phases are the five learning phases used in this study. Following the procedures outlined by Banihashem, et al., (2022), instructional phases enable the creation of knowledge as envisioned by the constructivist theory of learning, which acts as a learning aid for students' retention of knowledge. Arifin, et al., (2021) also asserted that, as compared to conventional teaching methods, PBL improve students' potential for retention. It is important to mention, that "explore," "explain," and "elaborate" is showed to have the most influence on students' conduct. This was because, students have the chance to build their knowledge and felt free to make mistakes without feeling guilty.

Mean post-test achievement of the students exposed to use of the STEM-PBL method did not differ significantly from the mean score at the delayed post-test level. The observed t-value was 0.064 with a p-value of 0.942 ($p > 0.05$). This was an indication that, students taught with STEM-PBL can retained information learned and can produce it any time needed. The study therefore is in support of Osuyi (2021) who stated that compared to conventional methods of instruction, the STEM-PBL boost student's performance and retentive capacity. The present study is also in line with the findings of Ameen, et al., (2022) who claimed that utilizing STEM-PBL, in classroom instructions helps students to retain information and perform better in their examinations. Conventional methods of instruction have been found by this study to have negative effect in learning biology. This supported the findings of Samsudin et al., (2020), Gorowara & Lynch, (2019) that effective learning is minimal via traditional styles of instruction.

Similar results from the post-test (Mean = 16.90) and delayed post-test showed that students who were taught biology using the STEM-PBL method retained more information (Mean = 16.80). This could be due to active participation and hands on activities. The finding here is in line with Bicer et al., (2015) who reported that STEM Problem-based learning is capable of engaging in hands-on activities which enhance students to recall and obtain high performance. The null hypothesis, which claimed that there is no significance difference in the mean achievement of post-test and delayed post-test of students taught diffusion and osmosis concepts using STEM PBL has been retained. The difference between the two test scores was statistically insignificant when the findings were subjected to two sample t-test analysis ($p > 0.05$). Thus, the STEM PBL enhances student retention in Biology in government-owned secondary schools by having a beneficial effect.

The majority of students were found to comprehend the concepts of diffusion and osmosis incorrectly during the engage stage. But, during the exploration phase which mostly consisted of practical experiments and decision-making, students were able to grasp the concepts of diffusion and osmosis and to clarify their misconceptions that had developed throughout the engagement stage. This study is in conformity with the findings of Sakir & Kim, (2020), that PBL is the strategy which encourages practical activities, increases learning activities and allowed decision-making as well as offering suggestions and feedback to aid in learning. Accordingly, social constructivist theory aligned with STEM-PBL, which is founded on the idea that students actively participate in their learning by cooperating and sharing their results with one another while the instructor serves as a facilitator (Han, 2013; Lou et al., 2011). Because knowledge is created through interactions with the environment, this strategy (STEM-PB) is in line with social constructivism.

The ability to integrate relevant knowledge with earlier notions has allowed students to comprehend that solid molecules may diffuse through liquid and that gases (oxygen and carbon dioxide) can diffuse through air readily for the use of living things. The results of Oladipo and Ogundiwin, (2018), who discovered that students exhibit a sense of identification with the gaseous, solid, and liquid molecules diffusing to living cells in the body, are consistent with this discovery. For students to be able to accommodate by talking about and evaluating facts, the engage phase is essential for posing thought-provoking questions. The instructor helped the students learn the diffusion and osmosis concepts while encouraging them to share their ideas. Both assimilation and accommodation occur throughout the elaboration phase as the students arrange or connect the newly generated notion to earlier concepts. In order to help students, develop their higher-level thinking skills, teachers, in accordance with Dibyantini et al., (2018), should include both activities that call for precise, factual answers and those that have no right or wrong answers but demand that students think abstractly and create their own concepts using data-based reasoning.

Conclusion and Implications

The primary motivation for educators to seek out more effective pedagogical strategies is to improve student achievement. Based on the results of using the STEM-PBL technique to assess students' biology achievement, it can be concluded that the approach greatly outperforms the conventional teacher-centred method in terms of student achievement. The application of STEM PBL would be an effective learning technique that may be utilized to help students overcome conceptualization or misconceptions issues. This would undoubtedly address the long-standing issue of low success caused by student incapacity to recollect facts during examinations.

The current research has a wide range of implications for students, teachers, curriculum planners, states and federal ministry of education and educators. The results indicated that providing equity in classroom ensure equality of outcome across students irrespective of their learning difference. There is evidence that teaching a content course using instructional material prepared based on STEM problem-based learning can support students to learn actively and improve students' learning, as a result, increases students' achievement. Therefore, the study has provided a better understanding of the constructivism school of thought on instruction, specifically the two theories, (i.e., Piaget's cognitive constructivist learning theory and Vygotsky's social constructivist theory) in providing lighter to the teaching and learning process.

Teachers need to consider and determine student's possible misconceptions before teaching delivery so as to promote concrete and meaningful learning and to avoid the building up more misconceptions. In addition, teachers need to be mindful of the difficulties faced by students when learning the concepts. Teachers should be aware that students need only guidance by providing them with all the necessary materials and procedures to construct their own knowledge. Teachers should therefore use appropriate materials in teaching, guide students by providing procedures in the conduct of any scientific experimentation. Moreover, considering the scarcity of the conventional equipment and materials in the school, use the familiar materials found in the environment through improvisation. The following suggestions are given based on the findings of this study:

Secondary school Biology teachers need to be more creative and inventive when it comes to discovering, selecting, and implementing activity-based instructional techniques in the classroom. Teachers would need to be taught by discipline-based instructional strategists to be able to achieve these things.

Researchers in science education should focus more on figuring out how to improve biology teaching and learning for secondary school students. This will be accomplished by creating various teaching models and modules for each secondary school's biology topics.

Biology students should be given the opportunity to perform learning tasks through hands-on activities that allow them to construct their own knowledge based on their prior conceptions. Constructivist learning strategies should be incorporated into Biology curriculum.

To improve student academic achievement, Biology curriculum planners should prioritize student-centred learning/teaching. To do this, the number of topics that secondary school Biology students should learn must be lowered.

STEM Problem-based Learning (STEM-PBL) should be embraced for usage in Biology instructional delivery in order for students to eliminate misconception in biological concepts, retain learned biological principles and improve their chances of admission to institutions of high learningPlease use Palatino Linotype as the font type, 10 points as the font size; single line spacing, zero spacing before and after paragraphs; justify the text, and do not use indentations throughout the article.

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