THE EFFECTIVENESS OF STEM PROBLEM-BASED LEARNING MODULE ON SELF-EFFICACY, INTEREST AND ACHIEVEMENT IN BIOLOGY AMONG SENIOR SECONDARY SCHOOL STUDENTS IN NIGERIA

USMAN GADO BIRNIN TUDU

UNIVERSITI SAINS MALAYSIA

2023

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by

USMAN GADO BIRNIN TUDU

Thesis submitted in fulfilment of the requirements
for the degree of
Doctor of Philosophy

September 2023

ACKNOWLEDGEMENT

All gratitude is due to Almighty Allah, the Master of the Day of Judgment, who kept me alive so that I could successfully complete my PhD program. May Allah grant our prophet, Muhammad, the last and greatest messenger, peace and blessings. My sincere appreciation goes out to my primary supervisor, Dr. Mohd Norawi bin Ali, for making time despite his busy schedule to guide, critique, and provide objective and critical observations and ideas that helped this effort succeed. His supervision efforts never stopped, and his fatherly treatment throughout this study in the form of assistance, counsel, encouragement, and mentorship is exceptional. You have, in fact, changed my academic career. I'm really grateful to you. There aren't enough words to express my gratitude for your unwavering support during my program; you are one of the kindest people I've ever encountered. May Allah's affection be with you and your entire family. Amin. This study would not have been successful without the help, inspiration, and advice of my co-supervisor, Prof. Mohammad Zohir Ahmad. I'm really grateful for your generosity.

Additionally, I would like to express my gratitude to my examiners, Associate Prof. Rabiatul-Adawiah Ahmad Rashid and Dr. Nur Jahan Binti Ahmad, for their encouragement, constructive criticism, and insightful suggestions about my prospectus, proposal and pre-viva examination. I'd like to express my gratitude to the entire School of Educational Studies' staff for their assistance in making this study feasible. I want to thank all the scientific educators who contributed their ideas and opinions to the STEM problem-based leaning module's development. The Kebbi State Secondary Education Board deserves special praise for approving my request to do research on schools under their watch. I would like to express my gratitude to the

experts, Professor Kamar, Professor Rabi Muhammed, Professor Mamman Audu, Dr. Abubakar Abbakar, and Dr. Aminu Aliyu, for their knowledge in ensuring that the instruments were in line with the main goals of this study through a variety of suggestions and recommendations on the content and face validity.

I want to express my gratitude to my dear wives, Fatima Muhammad Mashaya, and Khadija Ibrahim D/Gari for their sacrifices, endurance, and unwavering support throughout my PhD journey. You are truly soul mates. In spite of the fact that it has taken me years away from my darling children, Munzir, Aisha, Rahmatullah, Asma'u, Ummi, Abdurrahman, Ummu Salmat, Abdullahi, Alhassan, Buhari, Abubakar (Abba), Maryam, and Ummu Kulthum, I am grateful for their love, prayers, and understanding during my studies. My deepest gratitude goes to my brothers, particularly, Alhaji Shehu B/Tudu for their educational, and financial supports. I also, want extend my thanks to my uncles, sisters, and the rest of my extended family, which is far too large to name, for their prayers and support during this process. Sadly, this is my memorial to my late, beloved father, who sponsored my education right from primary to high school, for his counsel and assistance before he passed away. May Allah, in His great mercy, grant him paradise and pardon his transgressions. In the same vein, I would like to express my sincere gratitude to my mother for her motherly counsel, prayers, support, and concern. I will never forget with your prayers and supports. Without you, life has never been the same. Finally, I'd like to express my gratitude to the Nigerian government for supporting my PhD program.

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LIST OF ABBREVIATIONS

5E	Engage, Explore, Explain, Elaborate, and Evaluate
ADDIE	Analyze, Design, Develop, Implement, Evaluate
ANCOVA	Analysis of Covariance
DOAT	Diffusion and Osmosis Achievement Test
FGN	Federal Government Nigeria
FRN	Federal Republic of Nigeria
ILB	Interest in Learning Biology
ILBQ	Interest in Learning Biology Questionnaire
NECON	National Examination Council of Nigeria
NPE	National Policy on Education
NSTF	National Science and Technology Fair
PBL	Problem-Based Learning
PBLM	Problem-Based Learning Module
PISA	Program for International Students Assessment
SLB	Interest in Learning Biology
SLBQ	Self-efficacy in Learning Biology Questionnaire
SMET	Science, Mathematics, Engineering, Technology
SSCE	Senior School Certificate Examination
STEM	Science, Technology, Engineering, Mathematics
TIMSS	Trends in International Mathematics and Science Study
UBE	Universal Basic Education
WAEC	West Africa Examination Council

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KEBERKESANAN MODUL PEMBELAJARAN BERASASKAN MASALAH STEM TERHADAP EFIKASI KENDIRI, MINAT DAN PENCAPAIAN BIOLOGI DALAM KALANGAN PELAJAR SEKOLAH MENANGAH DI NIGERIA

ABSTRAK

Kajian ini melibatkan dua fasa iaitu (i) untuk membangunkan Modul Pembelajaran Berasaskan Masalah- STEM (STEM-PBL) menggunakan Model ADDIE dan 3C3R untuk murid sekolah menengah Tingkatan 4 bagi tajuk difusi dan osmosis. Fasa kedua (ii) menguji keberkesanan modul (STEM-PBL) terhadap peningkatan efikasi kendiri, minat, dan pencapaian murid dalam topik tersebut. Kajian ini menggunakan reka bentuk kumpulan kawalan bukan setara kuasi eksperimen. Sampel kajian terdiri daripa 80 murid Tingkatan Empat (48 lelaki dan 32 perempuan) daripada dua sekolah menengah harian kerajaan di Kebbi, Nigeria. Kumpulan eksperimen terdiri daripada 40 murid, sementara kumpulan kawalan terdiri daripada 40 murid. Data kajian terdiri daripada gabungan data kuantitatif dengan sokongan data kualitatif. Pengumpulan data diperolehi daripada enam instrumen; (i) Efikasi Kendiri dalam Soal Selidik Biologi Pembelajaran (SLBQ), (ii) Soal Selidik Minat Belajar Biologi (ILBQ), (iii) Ujian Pencapaian Difusi dan Osmosis (DOAT), (iv) Soal Selidik Tinjauan Guru (TSQ), (v) Protokol Temuduga Murid (SIP), dan (vi) Protokol Temuduga Guru (TIP). Data kuantitatif diperolehi daripada ujian pra, ujian pasca, dan ujian pasca tertunda, sementara data kualitatif diperolehi daripada analisis dokumen sukatan pelajaran, buku teks, dan rancangan pengajara serta temu bual murid dan guru. Keputusan ujian ANCOVA menunjukkan perbezaan yang signifikan efikasi kendiri, minat, dan pencapaian murid dalam tajuk defusi dan osmosis yang memihak kepada

kumpulan eksperimen (STEM-PBL) berbanding kumpulan kawalan (CTM). Pada masa yang sama, walaupun tidak terdapat perbezaan min yang ketara pengekalan efikasi kendiri, minat dan pencapaian antara kumpulan eksperimen dan kumpulan kawalan, tetapi min skor efikasi kendiri, minat dan pencapaian bagi kumpulan eksperimen lebih tinggi berbanding kumpulan kawalan. Ini menunjukkan bahawa STEM-PBL adalah lebih berkesan daripada CTM dalam mempelajari konsep difusi dan osmosis. Tema yang muncul daripada temu bual murid dan guru menunjukkan bahawa modul ini berkesan untuk mempelajari konsep difusi dan osmosis dalam subjek biologi. Guru disarankan menggunakan modul STEM-PBL yang memberikan pengalaman autentik bagi membangun efikasi kendiri, minat serta pencapaian murid.

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ABSTRACT

This study involves two phases, namely, (i) developing a STEM problem-based learning module (STEM-PBLM) using the ADDIE and 3C3R models for Form 4 secondary school students learning diffusion and osmosis concepts. The second phase (ii) tests the effectiveness and suitability of the module (STEM-PBLM) in increasing the self-efficacy, interest, and achievement of students. The study used a quasi-experimental, non-equivalent control group design. The sample of the study consisted of 80 students (48 boys and 32 girls) from two public schools in Kebbi, Nigeria. Both the experimental and control groups were composed of 40 students. The research data consists of a combination of quantitative and qualitative data. Six instruments were used in data collection: (i) the Self-efficacy in Learning Biology Questionnaire (SLBQ); (ii) the Interest in Learning Biology Questionnaire (ILBQ); (iii) the Diffusion and Osmosis Achievement Test (DOAT); (iv) the Teacher Survey Questionnaire (TSQ); (v) the Student Interview Protocol (SIP); and (vi) the Teacher Interview Protocol (TIP). Quantitative data was obtained from the pre-test, post-test, and delayed post-test. On the other hand, qualitative data was obtained from document analysis of teachers' schemes of work and lesson plans, analysis of biology textbooks, and interviews with students and teachers. The result of the ANCOVA test showed a significant difference in self-efficacy, interest, and achievement in favor of the experimental group exposed to STEM-PBLM compared to the control group exposed

to CTM. Although there was no significant difference in the pre-test measures of self-efficacy, interest, and achievement between the experimental and control groups, the mean scores of the experimental groups in the post-test and delayed post-test were found to be higher than those of the control group. This shows that STEM-PBLM is more effective in learning the concepts of diffusion and osmosis. The themes that emerged from the students' and teachers' interviews show that this module is effective and suitable for learning the concepts of diffusion and osmosis in a biology subject. It is recommended for the teachers to use the STEM-PBL module to provide authentic experiences to develop students' self-efficacy, interest, and achievement.

CHAPTER 1

INTRODUCTION

1.1 Introduction

The 21st-century "knowledge age" has brought globalization and scientific revolutions worldwide. Because of global complexities, it is necessary to examine science teaching and learning at all stages of the educational system in both emerging and industrialized nations (Kelley & Knowles, 2016). Scientific and technological advancements improve learning processes by utilizing a variety of resources and technologies (Ghavifekr & Rosdy, 2015). However, it also imposed a number of requirements on students in order to help them adequately prepare for their future carrier (Tufail & Malik, 2016). Instead of gathering only theoretical knowledge, students are now required to develop self-efficacy (Ugwuanyi et al., 2020) in performing scientific activities and increase interest to understand how to use the knowledge to accomplish tasks (Jerrim et al., 2020; Osman et al., 2013). They continued by saying that having both professional and life skills is essential for surviving in the twenty-first century.

Therefore, it is important to help senior secondary school students to have high self-efficacy and interest to develop knowledge of 21st-century abilities. This was due to the fact that senior secondary school level is the end of formal schooling, during which learners are totally controlled by the government and after which they select their career (Olonade et al., 2022). Most students engaged in their desired work after graduation from the senior secondary school level. Moreover, during this time, teenagers' personalities are developing and their character is coming into being, so they are very easy to control and mold into any shape (Fatoba, 2015; Tufail & Malik, 2016).

Students were required to do scientific research in the modern era of science education in order to put their knowledge to use for skill development and to make scientific and socio-scientific judgments. Science education must play a role in developing students' personalities and interests in scientific knowledge, as well as educating them about environmental and other global challenges and assisting them in developing moral attitudes (Hurd, 1998; Sorgo & Spernjak, 2012; Khalil et al., 2014). This is in addition to developing scientific attitudes and mastering cognitive skills. By so doing, science education's students may be able to contribute their own quota to the technical and scientific advancement of the country.

A country's science education is a global determinant of its scientific and technical growth (Tufail & Malik, 2016). It should be highlighted that paying significant attention to and investing heavily in science education has greatly enhanced America and Japan's outstanding progress (Epstein, 2011; Kiyahora, 2017). Nigeria is equally aware of the giant contribution of science education particularly, biology, to the social and economic advancement of a society (Akpokiniovo & Odebala, 2015). As such, the National Policy on Education recommends the adoption of a learner-centered approach to teaching and learning at secondary school level (Federal Republic of Nigeria, 2013).

Senior secondary school students in Nigeria, are required to take biology as one of their core science subjects. Knowledge of biology is the key to sustainable development (Ahmad, 2008). Understanding the ideas, theories, and laws relating to nature and the environment is facilitated by studying living creatures (Ahmad et al., 2018; Kim & Diong, 2012; Umar, 2011; Ahmad, 2008). One of the goals of teaching biology at the secondary school level is to enable students to become environmentally conscious, to possess the necessary biology knowledge for effective living in a

scientific and technological world, and to accommodate technological innovation (Annan et al., 2019).

However, in Nigeria, apart from conventional approaches used in teaching, biology is overloaded and contain irrelevant material (David-Egbenusi, 2019; Anjum, 2008). For many of the academic disciplines that have made significant contributions to the nation's technological advancement, biology knowledge is a prerequisite. Yet the performance is not impressive. In general, teaching in Nigeria, still retains the old conservative method in which teachers acted as repertoire of knowledge and students the dormant recipient (Atsumbe, 2019). This conventional teacher-centered learning style often favors passive reception of knowledge (Precious, & Feyisetan, 2020). On the other hand, interactive lesson encourages active learning; hence teaching should no longer center around transfer of content from teacher to student (Alake & Olojo, 2020). In most schools in Nigeria, biology is taught in an abstract and disjointed fashion with no resources, resulting in misconceptions, comprehension deficiencies, and learning difficulties (Adzape, 2015; Atsumbe, 2019). This was because, instructional materials are irrelevant, and the methods employed in teaching biology are not suitable and are teacher-centered (Oladipo & Ihemedu, 2018; Etobro & Fabino, 2017; Adzape, 2015).

This affected the learning of biology in Nigeria and led to misconceptions. Students that encounter misconceptions can be induced by a variety of causes, including students themselves, textbooks, teachers, and the use of teaching methods (Ibrahim, 2012). Students were found in the literature to have high misconceptions in misplacing the definition of osmosis to diffusion and diffusion to osmosis (Azqiya & Rahayu, 2022) they went on to say that, majority of the students cannot distinguish the process of plasmolysis and that of hemolysis nor are they able to differentiate the

mechanisms of passive and active transport. In addition to this, Ekon and Edem (2018) stated many misconceptions among biology students about concentration and tonicity, the influence of life forces on diffusion and osmosis, the process of diffusion, and the process of osmosis. This however, resulted in learning difficulties among secondary school students in Nigeria (Okoli & Mbonu, 2020; Etobro & Fabino, 2017). Students under traditional teaching find it difficult to engage with material and develop a deep understanding of the concepts (Okoli & Mbonu, 2020)

Many students experienced difficulties in understanding the diffusion and osmosis concepts of biology. It was reported that students considered some biological concepts difficult and performed poorly in examinations, particularly questions related to diffusion and osmosis concepts (Shuaibu & Ishak, 2020; Oladipo & Ihemedu, 2018), cells, and genetics (Ishaku, 2017; Gungor & Ozkan, 2017). It was reported that, in the biology WAEC questions, many students failed the tests (Oladipo & Ihemedu, 2018). According to Shuaibu and Ishak, (2020), there are several reasons that can cause difficulties among students learning of biology among which include: complexity of concepts, lack of experience, lack of interest, limited exposure to practical work, teacher-centered instructions, language barrier and a host of others. The researcher's personal experience in marking WAEC examination scripts also confirmed that quite a number of students skipped and hardly attempted diffusion and osmosis-related questions, and if attempted, they were poorly answered. To overcome these difficulties and misconceptions, teachers are advocated to use various strategies such as using real-world examples, providing hands-on experiences, open-ended, and encouraging collaborative learning which are all characteristics of STEM education approaches (Atsumbe, 2019).

STEM education is a type of learning in which academic concepts are combined with real-world lessons in which scientific knowledge, technology, engineering, and mathematics are applied in a context that connects schools, community, work, and the global enterprise, allowing students to develop STEM literacy and the ability to compete in the new economy (Bruice-Davis et al., 2014; Gerlach, 2012). It is also known as an "interdisciplinary approach to learning," in which students recognize the connection between course issues and real-world problems and are able to solve the problems using STEM knowledge (Hung Tseng et al., 2013). STEM education can also be defined as a curriculum that combines knowledge from four STEM fields to teach students how to use an interdisciplinary approach to tackle real-world problems in these four areas (Brophy et al., 2008).

Problem-based learning (PBL) is an example of STEM education approaches that focuses on solving real-world problems. In PBL, students are presented with a problem that requires them to use their existing knowledge and skills to develop a solution, work in a collaborative group, gather information, develop hypothesis, and test their solutions (Dibyantini et al., 2018). PBL is an active learning approach that emphasizes student-centered learning, encourages students to responsibility of their own learning, identify their learning needs, set goals, and develop strategies to achieve them (Savery, 2015). He also, went further to say that it promotes the development of critical thinking, problem solving, and communication skills, which are essential for success in the 21st century. In PBL the teacher acts as facilitator, guiding students through the learning process and providing support as needed, also provides feedback to students on their progress and help them to reflect back on their learning and identify areas of improvement (Bicer et al., 2015). The principles and guidelines of PBL, using the 5Es learning stages are applied in developing the present STEM-Problem-based

learning in teaching the concepts of diffusion and osmosis (Fathurrohman, 2015). He added that that the sequence of the PBL approach is related to the teacher's behaviors in the teaching and learning process and can be combined with other constructivist learning approaches.

STEM problem-based learning can be used to implement STEM teaching and learning in the classroom (Yaki et al., 2019; Promentilla et al., 2017). The PBL approach principles was chosen because, the approach is able to expose students from the conventional to a new experience, which can improve their self-efficacy, interest, and achievement (Bounderup-Dohn, 2011). It is a student-centered approach in which a teacher acts as a facilitator (Yaki et al., 2019). They added that it enables learners to solve ill-structured, unclear, and real-life problems. The use of PBL approach procedures in learning makes students apply knowledge to real-world problems (Promentilla et al., 2017; Araz & Sungur, 2007).

However, there are few studies adopting constructivist approaches on how to address student's learning difficulties, misconceptions, low self-efficacy, interest, and achievement with regard to diffusion and osmosis concepts (Oladipo & Ihemedu, 2018; Akomolafe et al., 2013; Bal-Taştan et al., 2018). The literatures reviewed by the researcher at both the national and local level in Nigeria, were unable to embed 5E with problem-based learning (PBL) in learning biology (Agbidye, Achor, & Ogbeba, 2019). Although there are few studies conducted in Nigeria and other countries to improve these problems at the secondary school level (Akomolafe et al., 2013; Bal-Taştan et al., 2018; Uroko, 2010; Khalil et al., 2014; Osman, Hiong, & Vebrianto, 2013; Sorgo & Spernjak, 2012), none of these previous studies are able to assess and analyze the documents of biology with a view to improving the low self-efficacy level,

decline in interest, and poor achievement in biology among senior secondary school students (Akomolafe et al., 2013).

1.2 Background for the study

STEM education seeks to develop a scientific mind and innovative, responsible people who are capable of critical thought and discovery that will make living in the environment and society easier. Rapid development has brought many global environmental crises, which require individuals who are good at problem solving, decision-making, and critical thinking to overcome the situation (Tang et al., 2020). Based on that, Nigeria's curriculum specified the goals and objectives for teaching and learning science in schools at all levels, including: cultivating students' curiosity about science and the natural world, learning information and conceptual understanding, and developing students' problem-solving abilities, acquire the ability to think critically and creatively to solve issues, to evaluate arguments and make judgments in a scientific manner, to design and carry out scientific research, and to accurately convey scientific ideas, reasoning, and real-world experiences (National Policy on Education, 2013).

However, there are a lot of problems in Nigerian education today in that the recently graduated students from secondary schools are not ready for those skills. They are more about memorization of ideas to pass the examinations (Atsumbe, 2019). Their level of self-efficacy is low in such a way that they could not be able to carry out scientific investigations (Jerrim et al., 2020; Ugwuanyi et al., 2020). They were unable to reflect on the steps to be taken in solving problems, nor were they able to retain the knowledge and skills obtained (Jerrim et al., 2020). As such, they found science learning uninteresting and difficult, which made their performance poor (Akpoghol,

2016; Ahmad et al., 2018). Retention is an important aspect for students. In this study, the retention level of students was examined comparing the posttest and delayed posttest. The retention among students depend on various factors, i.e., instructional strategies, attention, self-efficacy, satisfaction, testing, rewards, and practice (Souza et al., 2020)). So, to have long-term retention of self-efficacy, interest and achievement, the students need to pay complete attention while learning under approaches that emphasizes active participation.

Low self-efficacy, decline interest and poor performance among secondary school's students in STEM disciplines are global issues great concern (Shahali, 2017; Menon & Sadler, 2018; Usher et al., 2019). For example, the United States is losing its competitive edge due to the low self-efficacy, declining interest, and poor performance (Jone, 2018). In Asia, Malaysian students failed to achieve the minimum international standards in the Trends in International Mathematics and Science Study (TIMSS) and the Program for International Student Assessment (PISA) (Jamali, 2018). In Africa, the academic achievement of Ghanaian students in biology has consistently been poor (Annan et al., 2019). In Kenya, Nairobi County is witnessing a steady decline in educational standards (Mwaura et al., 2019).

High self-efficacy at the secondary school level in Nigeria is reported to be available to very few students (Oladipo et al., 2019). Self-efficacy is defined as one's belief in one's own ability to complete a specific task, no matter the difficulties (Bandura, 1977). As scientific applications keep changing, a high percentage of students need to have lifelong skills of self-efficacy to develop interest and ensure positive achievement. Low self-efficacy beliefs have been reported to reduce interest and achievement (Pleiss et al., 2012). Self-efficacy beliefs can have diverse effects on

students' learning interests and achievement (Bandura, 1993; Onaunuga & Saka, 2018).

Interest in biology is reported to be declining from junior secondary school students to senior secondary school students (Dewitt & Archer, 2015; Van Aalderen et al., 2019; Yoa, 2019; Guzey et al., 2016). Many researchers have observed and reported that secondary school students in Nigeria are losing interest in learning biology (Guzey et al., 2016; Akpoghol, 2016; Agbohoroma & Ovovwi, 2015).They went further to report that the majority of students seek admission into high-level institutions for courses unrelated to STEM. This is clear evidence of a lack of interest in science subjects. Early interest and positive attitudes toward learning are related to achievement and career aspirations. Previous researchers have pointed out that several teaching-related and non-teaching-related factors are involved in both the formation and decline of science interest: interest differentiation across adolescence, science related stereotypes, and parental influence are among the factors that are not directly related to teaching (Harackiewicz et al., 2012; Hulleman, et al., 2017). The most important factors that cause formation or decline in interest are more related to teaching strategies or intervention and change (Hulleman et al., 2017).

It was reported that Nigerian students perform poorly in sciences academically. The quality of the educational performance of students in Nigeria is even more worrisome. In terms of educational quality, Nigeria is ranked 124th out of 137 nations (World Economic Forum, 2017). Nigerian students received a score of zero in the 2018 reports of the Program for International Student Assessment (PISA), which provides cross-country comparisons of the performance of 15-year-old school students in mathematics, science, and reading in member and non-member nations. This is because they were not included in the ranking (Atsumbe, 2019). Performance in

science subjects, especially biology, among Nigerian students in WAEC and NECON over the years has not been impressive (Yaki et al., 2019). Poor achievement, as reported by many scholars, is attributed to the use of conventional teaching approaches (Abdullahi et al., 2021; Adazape, 2015; Oladipo et al., 2018).

It has been discovered that integrated STEM education approaches are effective in learning science irrespective of student's learning ability (Guzey et al., 2017; Robinson, 2017; Aidoo et al., 2016; Yaki et al., 2019; Pomentilla et al., 2017; Karpudewan & Chong, 2017; Ajagun, 2017; Yoa, 2019). The initiatives seek to eliminate the four fields' historical barriers (Atsumbe, 2019). Integrated STEM approaches have the potential to improve students' self-efficacy, interest, and performance in science and help motivate them to choose STEM fields as their careers (Iji et al., 2015). They maintained that these approaches, especially PBL, could be implemented to improve students' skills in science.

To develop the PBL module, documents analysis were first conducted to serve as the basis for its development. The documents analyzed include teacher's scheme of works, lesson plans, biology textbooks, and student notebooks. ADDIE and 3C3R instructional design model's principles were employed for the present module development. The ADDIE instructional design model was used in the process's development, while 3C3R was utilized to develop the content of the module. These models are widely used in educational sectors and are in line with constructivist learning cycles (Khasyyatillah & Osman, 2022). The developed module was validated by 15 experienced biology teachers with less than 15 years of teaching experience. Five phases of learning: engage, explore, explain, elaborate and explain were included in the module. Eight lessons on the concepts of diffusion and osmosis were prepared

To conduct the intervention, two methods were used: the STEM problem-based learning module (STEM-PBLM) and the conventional teaching methods (CTM). Two schools from Argungu Education Zone of Kebbi State were selected using convenience sampling. Government day secondary school Bayawa served as experimental school with one intact class of 40 students. While the government day secondary school Tiggi is considered as control school with 40 students. The groups were purposefully created to compare the effectiveness of the two independent variables (STEM-PBLM and CTM) on students' self-efficacy, interest, and achievement in biology.

Senior secondary schools in Argungu Education Zone, served as the population of this study. The sample consisted of 80 participants, comprising 48 males and 32 females, distributed among the experimental group (EG) and control group (CG). Explanatory mixed method design was employed to collect the data using six instruments. STEM-PBL Module was found to be effective in enhancing self-efficacy, interest, and achievement in biology among secondary school students, which will lead to the promotion of education in Nigeria.

1.3 Problem Statement

More than ever before, educators need to employ teaching and learning approaches that inspire and prepare students to embrace science and potentially pursue it in their colleges and career choices. This was because science impacts countless decisions we make each day. There was an intensive need for the best way students in the 21st century should learn science (Saavedra & Opfer, 2012). Today's world faces a challenge in terms of student learning quality. Despite significant efforts in curriculum development, Nigeria continues to face the same problem, with minimal

results recorded in terms of student achievement success at all levels of education (Ayodele, 2016). The challenges of learning success were attributed to students' low self-efficacy and interest in learning science (Ugwuanyi et al., 2020; Oladipo et al., 2019). Hence the rationale behind the development of the present module to offer solutions to these classroom challenges.

Self-efficacy has been identified as one of the most powerful determinants of interest and academic achievement (Bandura, 1997; Ugwuanyi et al., 2020). It is one's own ability to complete a specific task. One's beliefs, therefore, dictate the actions one will take to solve a problem. It has been demonstrated that students' self-efficacy influences their choice of science subjects, the amount of cognitive effort they put into these subjects to solve real-world problems, and their overall success (Nugent et al., 2015). They went on to state that students are more inclined to select occupations in which they are confident in their talents rather than careers in which they are unsure of their performance. However, low self-efficacy among students in Nigeria was reported as one of the major challenges to their comprehension of scientific concepts (Abdullahi et al., 2021; Oladipo & Ihemedu, 2018). High self-efficacy among students in Nigeria is reported to be available to only a very few students (Ugwuanyi et al., 2020; Ugwu et al., 2013; Oladipo et al., 2019). This means that the majority have a low level of self-efficacy, which results in a reduction in their interest in learning.

The significance of positive interest in the learning of science cannot be overemphasized (Mohd et al., 2019; Nugent, 2015; Kelly, 1988). Interest is very critical to learning. It is a powerful predictor of academic success as well as subject and course selection (Olsen et al., 2011). However, students in Nigeria get disinterested in and demotivated to learn biology (Audu, 2018; Rabgay, 2018; Akinwumi & Falemu, 2020). There are many researchers who have suggested the

conduct of research into the field of interest on how it could be determined, how it may be improved and evolved, how things might be interested, and how individuals might arouse interest in themselves, others, and things (Ainley et al., 2005; Hidi & Renninger, 2006). This is because students' academic achievement is determined by their level of interest.

Academic achievement of students in Nigeria in biology is reported to be very poor (Oladipo & Ihemedu, 2018; Akinwumi & Falemu, 2020; Abdullahi et al., 2020). The low level of student's performance is reported in terms of credit level at the West Africa Examination Council (WAEC) (Shuaibu & Ishak, 2020; Abdullahi et al., 2020). This could be evident from the examiner's reports of the Argungu Zonal Education Office, Kebbi State, Nigeria, with low percentages in biology over the years: in 2015, only 38.32% of students obtained credit level, and 37.39% of students possess credit level in 2016. In 2017, only 35.99% had been realized, compared to 39.08% in 2018. The results of 2019 were even worse compared to previous years, with only 32.23% of students reaching credit level. A look at the Argungu Education Zone's WAEC results would be a clear reason for conducting this study at this time.

Moreover, it was reported that students performed poorly in biology examinations, particularly questions related to diffusion and osmosis concepts (Shuaibu & Ishak, 2020; Oladipo & Ihemedu, 2018). Poor understanding of certain concepts in biology, such as cells and genetics, was also revealed (Ishaku, 2017; Gungor & Ozkan, 2017). It was reported that, in the biology WAEC questions, many students failed the tests (Oladipo & Ihemedu, 2018). The researcher's personal experience in marking WAEC examination scripts also confirmed that quite a number of students skipped and hardly attempted diffusion and osmosis-related questions, and if attempted, they were poorly answered.

Previous research has concluded that among the reasons why students fail science courses in schools is the way they learn the subject (Sellers et al., 2007; Adzape, 2015; Atsumbe, 2019; Shuaibu & Ishak, 2020). In most schools in Nigeria, biology is taught in disjointed fashion with no resources, resulting in comprehension deficiencies and learning difficulties (Atsumbe, 2019). Most classroom lessons are dominated by conventional teaching approaches, which are teacher-centered methods (Ugo & Akpogohol, 2016; Adzape, 2015). Teacher-centered instructional methods make students passive with less interaction, and a lack of active participation leads to low self-efficacy and interest (Ketelhut, 2007) and consequently poor performance (Gambari et al., 2013). As a result of the use of conventional approaches, students were un able to retained the knowledge gained. Retention refers to a person's ability to transfer new information into their long-term memory which allows learners to recall and put knowledge to use in the future (Halpern & Hakel, 2003)

The order in which the material is presented affects the likelihood of retention. Students were unable to retained the information because of ineffective encoding of materials, decay of information, interference, competition of newly learned material, and retrieval failure (Roediger et al., 2010). Information is retained through active learning, repetition and recall (Halpern & Hakel, 2003). Memory and the process of learning are also, connected (Roediger et al., 2010). Memory is the site of storage and enables the retrieval and encoding of information, which is essential for the process of learning (Cowan, 2019). He went on to say that, learning is dependent on memory processes because, previously stored knowledge functions as a framework in which newly learned information can be linked. According to Sarac, and Ok, 2010), students in the conventional teaching methods are mostly poor in retention. He further maintained that they are characterized by forgetting answer the moment the teacher

picks them, cannot follow simple instruction, and always seems absentminded. Students were reported to have poor retention of self-efficacy, interest and achievement due to poor learning condition, lack of active learning, teaching out of the context of real-world, failure in the first attempt and lack of background knowledge (Cottone & Yoon, 2020).

To ensure high self-efficacy, interest, achievement and high retention level among biology students, novel STEM approaches that encourages students to participate fully, construct their knowledge, and apply it in real-world situations are needed (Gulen, 2018; Guzey et al., 2017; Karamin, 2017). Among the innovative STEM strategies is problem-based learning (PBL), where the teacher acts as a guide (Promentilla et al., 2017). They added that it enables students to solve unclear and real-life problems. Use of PBL's procedures in learning helps students apply knowledge to real-world problems (Promentilla et al., 2017; Araz & Sungur, 2007). PBL's procedures are recommended to be implemented in the classroom setting (Sheppard et al., 2017; Promentilla et al., 2017).

PBL was chosen for intervention because it was found to be effective in promoting deep learning, enhancing student motivation, self-efficacy, interest and improving student's performance (Yaki et al., 2019). In addition, PBL, is used in a variety of educational stings, including medical and health sciences, engineering education, and teacher education (Erdogan et al., 2017). PBL can also be implemented in a variety of formats, from short-term projects to log-term interdisciplinary courses (Wondie et al., 2022). As such, in this study, PBL's procedures were employed in the development of the current module named the STEM Problem-based Learning Module (STEM-PBLM).

STEM problem-based learning (STEM-PBL) is a student-centered learning process that uses problem-based learning procedures integrated with the 5Es (engage, explore, explain, elaborate, and evaluate) to implement the learning of diffusion and osmosis concepts in biology. The process is the good alternative to improve students' science comprehension and is challenging for learners (Erdogan et al., 2016). It has the potential to enhance and improve self-efficacy, interest, and 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; Wells, 2013).

Using the STEM-PBL Module as the innovative approach for intervention with the experimental group has improved many learning challenges. Low self-efficacy, interest, achievement and retention level of form 4 secondary school's biology students are expected at the end of the intervention to be improved. Continuous use of this module would promote the quality of education in Nigeria. Based on the literature reviewed in this research, the effects of a STEM-PBL for secondary school students in the Argungu Educational Zone of Kebbi State, Nigeria, are not yet clear (Wilder, 2015). Many of the studies found were centered on a particular topic, focusing on university level and learning achievement (Tugwell, 2020). References related to high school students are few in the STEM field and the STEM-PBL process in Kebbi State, Nigeria.

1.4 Research objectives

This research study intends to achieve the following objectives:

1. To develop a STEM problem-based learning module for senior secondary school form four students in learning diffusion and osmosis concepts.
2. To compare the effect of the STEM problem-based learning module (STEM-PBLM) and conventional teaching method (CTM) on the self-efficacy of form four students in learning diffusion and osmosis concepts.
3. To determine the retention level of self-efficacy between the posttest and delayed posttest of students exposed to STEM-PBLM.
4. To compare the effect of STEM-PBLM, and CTM on the interest of form four students in diffusion and osmosis concepts.
5. To examine the retention level of interest between the posttest and delayed posttest of students exposed to STEM-PBLM.
6. To compare the effects of STEM-PBLM, and CTM on the achievement of Form 4 students in learning diffusion and osmosis concepts.
7. To examine the retention level of achievement between the posttest and delayed posttest of students exposed to STEM-PBLM.
8. To explore how a STEM problem-based learning module is effective and suitable for enhancing students' learning of diffusion and osmosis concepts.

1.5 Research Questions

To achieve and fulfil the stated objectives, the following research questions were outlined:

1. How is the STEM problem-based learning module on the diffusion and osmosis concepts developed?
2. Is there any mean difference in the pre-test and post-test scores of Self-efficacies in Learning Biology Questionnaire (SLBQ) between students exposed to STEM-PBLM, and CTM?
3. Is there any mean difference between the effects of STEM-PBLM and CTM on students' retention of self-efficacy in diffusion and osmosis concepts?
4. Is there any mean difference in the pre-test and post-test scores of Interests in Learning Biology Questionnaire (ILBQ) between students exposed to STEM-PBLM, and CTM?
5. Is there any mean difference between the effects of STEM-PBLM, and CTM on students' retention of interest in diffusion and osmosis concepts?
6. Is there any mean difference in the pre-test and post-test scores of Diffusions and Osmosis Achievement Test (DOAT) between students exposed to STEM-PBLM, and CTM?
7. Is there any significant difference between the effects of STEM-PBLM and CTM on the retention of students' achievements in the concepts of diffusion and osmosis?

8 To what extent is the STEM problem-based learning module effective and suitable for enhancing students' learning of diffusion and osmosis concepts?

1.6 Research Hypotheses

To answer research questions the following research hypotheses were tested:

1. There is no significant mean difference in the SLBQ scores between students exposed to STEM-PBLM, and CTM at the pre-test and post-test stages.
2. There is no significant mean difference in the SLBQ scores of students exposed to STEM-PBLM at the post-test and delayed post-test stages.
3. There is no significant mean difference in the ILBQ scores between students exposed to STEM-PBLM, and CTM at the pre-test and post-test stages.
4. There is no significant mean difference in the ILBQ scores of students exposed to STEM-PBLM at the post-test and delayed post-test stages.
5. There is no significant mean difference in the DOAT scores between students exposed to STEM-PBLM, and CTM at the pre-test and post-test stages.
6. There is no significant mean difference in the DOAT scores of students exposed to STEM-PBLM at the post-test and delayed post-test stages.

1.7 Limitation of the Study

The present study was limited to form four students in public senior secondary schools in Argungu education zone of Kebbi state only. The exclusion of private senior secondary school students and other educational zones in the state or throughout Nigeria limits the generalization of the current study's findings. The limitations of the current study are:

1. The study was carried out in Bayawa and Tiggi Day Secondary Schools with eighty (80) respondents. The experience and characteristics of these respondents may not be the same as those of other respondents found in other educational zones in the state or Nigeria. It is therefore inaccurate to generalize the findings.
2. The study was also limited to form four biology students and the diffusion and osmosis concepts only. The restriction to the topics of diffusion and osmosis concepts would not be enough to generalize the whole body of knowledge.
3. The study was restricted to the effect of STEM-PBLM on Form 4 students' self-efficacy, interest, and achievement in biology only. If, therefore, a different method with different students or similar students with a different method were used, the result would be different.
4. Moreover, the type of instruments used in this study is another restriction. If different instruments were used, the result would be different.
5. Due to the time factor, the study was an after-school program. This was possible because of the permission granted by the Secondary School Management Board. The intervention was an after-school program

because time constraints are a challenging factor in the implementation of a student-centered approach in the classroom environment (Dunne et al., 2007). They further stated that students need to spend a lot of time doing things their own way so as to understand the concepts of instruction.

1.8 Significance of the Study

The current study shows researchers, educators, and teachers how to develop a learning module that aids in the identification and resolution of students' misconceptions and other learning difficulties in the concepts of diffusion and osmosis. The outcomes of this study provide evidence that exposing secondary students to STEM problem-based learning modules has a positive impact on their level of self-efficacy, interest, and achievement. The study also provides an example of how secondary school students can engage in problem-based learning processes. The findings of this study demonstrated that STEM-PBLM is a hands-on and innovative approach that improves students' learning. This was because it covered different strategies ranging from inquiry to hands-on problem-solving to independent and collaborative learning.

The findings of this study were intended to benefit a large number of people, groups, professional organizations, the community, and the government. Biology teachers, students, curriculum designers, etc. will derive some benefits from the results of this study. As stated earlier, one of the problems in biology teaching was the teacher’s inability to select suitable techniques of instruction. Modular teaching was confirmed to be the most effective method to ensure concrete learning. This study is specifically useful for the following:

1. Curriculum planners: The findings of this research might provide biology curriculum developers and planners with insight into the kind of teaching approach that is effective for teaching biology concepts to senior secondary students in Form 4. This could be by providing valuable information about how students learn best. It helps to develop new methods for teaching and allows educators to explore different topics and ideas in more details.
2. Education Policymakers: This study might assist in educating the curriculum developers and planners regarding the suitable student-centered strategy for biology study at the senior secondary school level.
3. Researchers: The study may help other researchers in the field of education further investigate other teaching areas that the scope of this study did not cover.
4. Biology Teachers: Through the findings of the present study, biology teachers can structure their lessons in a way that will ensure that students will understand and retain the subjects that need to be covered in biology. The instructors, on the other hand, can adopt this module in teaching diffusion and osmosis concepts.
5. Biology Students: The present study is important to students since it may allow them to identify what they need to know so as to excel in Biology. In addition, the study might improve students' learning of biology.
6. Existing Literature: The study may contribute to and add value to the few existing works in this area of study in the following ways:

(a) STEM-PBLM familiarizes students with thinking creatively and critically;

(b) is proactive in conducting exploration related to investigation;

(c) strengthens their self-efficacy, interest, and achievement;

(d) the roles of the instructor as facilitator, advisor, and intermediary provide a good contribution to obtaining optimal results in accordance with the imagination, creativity, and innovation of students.

Finally, this study is important and unique to other studies for some reasons. The majority of the literature found was centered on a particular topic, with many of them focusing on high education studies and learning achievement (Tugwell, 2020). References focusing on secondary school students are few in the STEM field and the STEM-PBL process in Kebbi State, Nigeria (Abubakar & Arshad, 2015). None of the publications analyzed by the researcher addressed all of the present study's research topics, which are STEM-PBL, self-efficacy, interest, and achievement in the diffusion and osmosis concepts. Based on the literature reviewed by the researcher, the effects of STEM-PBL for secondary school students in Kebbi State, Nigeria, have not yet been implemented (Wilder, 2015). He further stated that researchers are also unable to assess and analyze the documents of biology with reference to STEM skills. Moreover, none of them was found to embed the 5Es as the learning phases with the STEM problem-based learning to learn diffusion and osmosis concepts (Agbidye, Achor, & Ogbeba, 2019). More researches in these areas are therefore required. As such, the researcher set out and developed the current module to close these gaps.

1.9 Operational Definitions

Definitions of terms may differ from one source to another. The terms used in this study are appropriately selected to achieve the requirements of this study. The definitions, therefore, will be given based on how the term is used in this study. This study aimed at researching the effect of STEM-PBLM on self-efficacy, interest, and achievement in biology among Form 4 secondary school students. Operational definitions of terms were prepared so as to ensure the clarity of the variables involved in the research.

1.9.1 STEM

These are acronyms referring to Science, Technology, Engineering, and Mathematics.

1.9.2 STEM Education

STEM education aims to remove the traditional barriers erected between the four disciplines in STEM and uses an integrated approach to teaching and learning (Atsumbe, 2019). It is an interdisciplinary instructional strategy that integrates science, technology, engineering, and mathematics to solve ill-structured problems by likening it to real-life professional processes (Tsai et al., 2018). In this study, "STEM education" is considered as a transdisciplinary learning approach in which concepts from two or more STEM domains are blended in a way that makes them applicable to real-world problems.