The STEM Problem-based Inquiry Learning for Diffusion and Osmosis Concepts

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ABSTRACT

Without proper and efficient learning methodologies, educational achievement cannot be of high quality. Modular teaching and learning have reportedly been shown to boost students' academic performance. The purpose of this paper was to develop STEM Problem-based inquiry module for learning diffusion and osmosis concepts for form four biology students at secondary school level in Nigeria. This study is significant for the curriculum planners, education policy-makers, and biology teachers on how to develop learning module. Several studies have continued to report students' poor performance in biology due to ineffective teaching strategy employed by teachers. The paper also highlights some instructional design models and selects the design guidelines of the ADDIE instructional model. The researchers utilised purposive sampling to select the subjects. The Fuzzy Delphi Method (FDM) was used to determine the experts who would validate this module. Experienced biology teachers (n = 15) are provided with a checklist questionnaire for validation purposes. The validation of the module yielded the S-CVI of 0.86. The developed module revealed that it is suitable and appropriate for biology students' learning of diffusion and osmosis concepts. Additionally, the findings of this study suggest that the ADDIE instructional design model is the best choice for creating modular teaching approaches at secondary educational setting.

Keywords: *Modular Teaching, Diffusion and Osmosis, Instructional Design Models (IDM).*

INTRODUCTION

Globally, science plays a significant role in national development. Because they prioritised the sciences, developed nations have experienced rapid progress (Messerli, Murniningtyas, Eloundou-Enyegue, Foli, Furman, Glassman, & van Persele, 2019; Zhou & Leidesdorff, 2006). These topics form the cornerstone of national development. Scientific literacy is essential for long-term progress. One of the keys to development is biology, which aids in understanding the needs of the natural and environmental world for societal advancement (Yaki et al., 2019).

The secondary biology curriculum in Nigeria is structured into multiple courses that are connected to one another and comprise key biological concepts. Diffusion and osmosis are concepts that, despite challenges with teaching them, are crucial to understanding fundamental biological concepts (Cimer, 2012). It was strongly advised that students gain knowledge of how materials are transported across cell membranes. Diffusion and osmosis principles are fundamental to understanding many physiological processes in plants and animals (Oladipo & Ihemedu, 2018; Reinke et al., 2020), so it's important to stop the emergence of new misconceptions and eliminate those that already exist in order to increase students' understanding and accomplishments (Dilber & Duzgun, 2008; Oladipo & Ihemedu, 2018). For instance, diffusion is a simple technique for short-distance transport in cells and cellular systems. To understand processes like water uptake from soil into root cells, the mechanism underlying the movement of water through xylem tissues of plants, the balance of water in land and aquatic organisms, turgor pressure in plants, transport in living organisms, and the exchange of gases between respiratory surfaces and the environment as well as between body fluid and tissues, it's important to accurately address the concepts of osmosis (Bhatla & Lal, 2018).

When it came to scientific education, Nigeria was not an exception. The ability of the students to develop an awareness of the environment and to have meaningful and relevant biology information necessary for successful living in a scientific and technological world are just a few of the aims of teaching biology at the secondary school level in Nigeria (NPE, 2009). Biology knowledge is a requirement for many academic disciplines that have made significant contributions to the country's technological advancement. Yet students typically perform poorly on it.

However, it is said that a widespread problem is the low academic accomplishment in the sciences. Due to students' low performance in scientific classes, the United States, for instance, is losing its competitive edge (Jones, 2018). Ghanaian students' academic performance in biology has continuously lagged below that of other African peers (Annan, Adarkwah, Abaka-Yawson, Sarpong, & Santiago, 2019). Nairobi County, Kenya, is seeing a consistent deterioration in educational levels (Mwaura, Kimani, & Manyasi, 2019).

Even though Nigeria places a strong focus on science courses, both the quality and quantity of educational performance are incredibly low. Even more concerning is the standard of educational performance in Nigeria. This was due to Nigeria's low position among 137 nations in terms of the quality of education (World Economic Forum, 2017). According to the 2018 PISA results, which compare the performance of 15-year-old school students in member and non-member countries in the subjects of mathematics, science, and reading, Nigerian students received a score of zero because they were not included in the ranking (Atsumbe, 2019). Over the years, Nigerian students' WAEC biology performance has not been particularly spectacular.

Without proper and efficient learning approaches, educational achievement cannot be of high quality. Conventional teaching techniques predominate in the majority of Nigerian classroom lessons. Teacher-centred educational techniques make students passive with less interaction (Gambari, James, & Olumorin, 2013). Poor performance is the outcome of the student's lack of active involvement in the class. Low performance in the sciences, especially biology, was a result of the conventional learning methods used in many classrooms (Atsumbe, 2019). In order to comprehend the future of STEM education as an enterprise, how can we improve the problems for science learning? To ensure that students learn to assess and favourably respond to the challenges of real-world problems, a focus should be shifted to STEM modular teaching and learning (Guido, 2014). For this purpose, the research objectives and research questions are stated as:

Research Objectives

1. To create STEM problem-based inquiry learning module for form four secondary school students.
2. To examine the views of biology teachers on the suitability of the STEM problem-based inquiry learning module for form four secondary school students.

Research Questions

1. How is the STEM problem-based inquiry learning module is developed?
2. What are the views of biology teachers on the suitability of the STEM problem-based inquiry learning module for form four secondary school students?

LITERATURE REVIEW

Modular Teaching

Constructivists contend that learning is the end result of a social process including many modes of perception, interaction, and problem-solving (Krajcik, Blumenfeld, Marx, & Soloway, 1994). Students can examine the depth of their critical and creative thinking by actively engaging in STEM activities while utilising the module (Guido, 2014). Learning biology involves the use of constructivists approaches that motivate learners to participate in the production of the knowledge and connect it to real-life scenarios. Finding a strategy that would encourage students to actively participate in the course, help them build their own knowledge, and use it to address real-world problems.

Modular teaching and learning have reportedly been shown to boost students' academic performance. Researchers recommended using the modular teaching and learning approach at various study levels (Ali, Ghazi, Khan, Hussain, & Fatima, 2010). According to research, instructions created as modules are suitable for students' learning processes (Ali et al., 2010; Alias & Siraj, 2012). The best teaching methods for adjusting learners' knowledge are those that are level-appropriate and modular. A module is described as a standalone, self-contained portion of a planned sequence of educational activities that aids students in achieving clear, explicit objectives (Guido, 2014). The creation of the present module would encourage biology teachers to use it in the classroom to ensure favourable learning outcomes.

Concepts of Diffusion and Osmosis

An analysis of the literature was done to identify common misunderstandings and learning challenges among biology students in senior secondary one (SS1). Students misunderstand and find it difficult to learn the concepts in biology (Oladipo & Ihemedu, 2018). Diffusion and osmosis student's performance was deemed to be below average (Ishaku, 2017; Gungor & Ozkan, 2017). Numerous misconceptions about diffusion and osmosis were discovered in studies of students' comprehension at various grade levels, many of which were resistant to being cleared up by conventional teaching methods (Ekon & Edem, 2018; Abdullahi, Asniza, & Muzirah, 2021).

The research done by Abdullahi et al., (2021), discovered that senior school students had trouble comprehending the concept of osmosis. Furthermore, according to Ekon and Edem (2018), learners have a lot of misinterpretations about concentration and tonicity, the influence of life forces on diffusion and osmosis, and the difficulties with learning that arise from diffusion and osmosis processes. According to Dogru and Zsevgeç (2018) and Oladipo & Ihemedu (2018), among the most difficult biological concepts for secondary school biology students to understand are osmosis and water potential. Ahmad and Jamil looked into what students thought osmosis was (2020). They suggested that children might pick up concepts of concentration and diffusion through personal experience and beliefs. The majority of students in their study thought that there was either no movement of materials or the solute migrated across the membrane.

The interaction of pressure and water motions in osmosis was only partially understood by the students (Oladipo & Ihemedu, 2018). Potential reasons why secondary school students have trouble conceptually grasping concepts and steps relating to cell-water relationships have been found (Oladipo & Ogundiwin, 2018). They conducted their research using three true-or-false questionnaires with paper and pencil, three content analyses of widely used textbooks, and individual interviews based on two experiments. The findings indicate that students in high school have serious misconceptions about basic concepts like solutions, solubility, the particulate nature of matter, and molecular movement. These misconceptions could be a contributing factor in students' inability to comprehend osmosis and osmotic relationships. Additionally, without fully comprehending the concepts, students use the textbook definitions of osmosis and diffusion. In light of these issues, the ideas were picked to be incorporated into the STEM problem-based inquiry learning module that teachers could use to teach and learn about diffusion and osmosis concepts.

Instructional Design Models (IDM)

Instructional system designs were considered when creating the present module. Although there are many ISDM, some of them, like the Delphi approach, are product-oriented (Akbulut, 2007). The Sidek model, ASSURE model, Dick and Carey model, and Morrison and Kemp model are program-oriented, while others are classroom-oriented, with the ADDIE model being the most often used model in educational settings. The ADDIE model was chosen because it has been widely documented in the literature over the past ten years to be suitable, effective, and acceptable for use in learning (Sweller, 2016). According to reports, teaching and learning activities created using the ADDIE approach are suitable and efficient (Glogger-Frey, Fleischer, Grunny, Kappich, & Renkl, 2015). The following instructional design models were discussed below:

The Dick and Carey Model (DC)

This is a model for instructional design that takes into account the teacher, the students, the materials, the instructional activities, the delivery system, and the environment for learning and performance (Sweller, 2016). The basic instructional design pattern used by the model is ADDIE's analysis, design, development, implementation, and evaluation of teaching. This process consists of ten steps: identifying needs to establish objectives; conducting instructional analysis; analyzing learners and contexts; writing performance objectives; developing assessment instruments; creating an instructional strategy; choosing instructional materials; developing and implementing formative instruction evaluation; revising instruction; and, finally, conducting summative evaluation. The process is rigid and difficult for situations involving real-world instructional design (Akbulut, 2007).

The DC model uses a methodology that is more behaviorist. More specifically, it assumes a reliable connection between stimulus and reaction, or, to put it another way, between the subject matter being learned and the teaching tools. The Dick and Carey model on the other hand is at disadvantage to be used in this study because of its complexity and length. It involves a lot of steps and tasks that can be time-consuming and overwhelming especially for novice or inexperienced instructional designers (Akbulut, 2007).

Morrison, Ross, and Kemp Model (MRK)

Kemp’s model is a nonlinear design model that emphasizes flexibility and adaptability. This method focuses on the classroom and considers all outside factors (Akbulut, 2007). The MRK model proposes a nine-step, design process that is interrelated. The MRK model is different from other models in that it views teaching from the viewpoint of the learners; effectively implements; presents the ID process as a continuous cycle; and lastly, places more focus on managing the instructional design process. The weakness to this model is that teachers might feel overwhelmed when using the Ross and Kemp model especially if they have time constraints and wants to focus on the teaching of the content solely (Akbulut, 2007).

Assure Instructional Design Model

Assure model is a procedural guide for planning and delivering instructions that integrates technology and media into the teaching process. It also refers to a systematic approach of writing lesson plans that helps teachers in organizing instructional procedures (Smaldino, 1996). The model, which is one of the ISD models, provides detailed instructions for creating lessons that effectively use media and technology to improve students' learning (Smaldino, 1996). He also believed that the National Education Technology Standards for Teachers and local and national curriculum standards could be met by using the ASSURE model when creating lessons. In addition, the ASSURE model uses a typical research-based lesson design approach that is probably suitable for any school's lesson plan pattern (Smaldin, 1996). He added that Assure model take into account all the details of the instruction but it is time consuming with narrow scope where focus is on unit, lesson or module and too simple. Among the weaknesses to this model is that it does not incorporate all the details of complex natural phenomenon and is oversimplified, leading to misunderstanding about the subject.

ADDIE Instructional Design Model

ADDIE is a learning model used by instructional designers and training developers to create effective learning experiences (Sweller, 2016). The researchers used the ADDIE instructional model to guide the construction of the STEM 5E inquiry-based learning module for learning the concepts of diffusion and osmosis. ADDIE was chosen because of its popularity and widespread use among instructional designers (Sweller, 2016). In addition, the model comprises five stages that serve as a benchmark for the creation of effective learning and performance scaffolding tools (Glogger-Frey, et al., 2015; Renkl, 2014; Sweller, 2016). Additionally, numerous module developers employed the ADDIE model in developing their learning module (Ghani & Daud, 2018; Ali, Ibrahim, Abdullah, Surif, Abdul Talib, & Saim, 2015).

ADDIE is still one of the most widely used and regularly updated models for instructional design (Ghani & Daud, 2018). It is described as being learner-centered, goal-oriented, and emphasizing performance in the real world (Glogger-Frey et al., 2015). "ADDIE," an acronym for analyze, design, develop, implement, and evaluate, is frequently used to refer to a systematic approach to instructional creation. Because of this, ADDIE's components are not strictly ordered in a linear fashion.

RESEARCH METHODOLOGY

Research Design

Explanatory sequential design was adopted. Documents analysis were conducted in this study. Along with these, ADDIE model was adapted to develop the present module for it serves as the foundation for all other design models (Ali, Ibrahim, Abdullah, Surif, Abdul Talib, & Saim, 2015). A learning module can be created based on theories, models work of literature or expert consensus and also by adopting or adapting other models (Milano & Ullius, 1998). The development of the present module is designed in the following ways:

- Analyze (Content Analysis and Needs Analysis)
- Design (design of the module)
- Develop (the module)

Sampling

The Fuzzy Delphi Method (FDM) was used to determine the experts who would validate this module. FDM is a method that can prevent hiring a non-expert because it requires fewer respondents (Anderson, 1975). As a result, fifteen (n = 15) experienced biology teachers participated in this study. According to Jones and Twiss (1978), the use of the fuzzy Delphi technique requires 10 to 50 specialists. This is further supported by Adler and Ziglio (1996), who asserted that 10 to 15 experts are sufficient if there is a high degree of agreement and consistency among the experts.

Teachers from five senior secondary schools in Argungu Emirate of Kebbi state, Nigeria, were chosen using a purposeful sampling technique. The qualifications and job experiences are the basis for the selection criteria for the sample. At least ten years of professional experience and a minimum of a BSc in Education (Biology) are requirements for becoming an expert in this field. Teachers (n = 15) with expertise in biology are given a 20-item questionnaire to complete in order to assess the applicability of the created module.

Table 1 Sample Participants Based on Schools

School	Qualification	Total
A	BSc. Ed	3
B	BSc. Ed	3
C	BSc. Ed	3
D	BSc. Ed	3
E	BSc. Ed	3
Total		15

Data collection

The qualitative part of the study was collected through documents analysis; analysis of the learners, analysis of biology concepts through literature review, analysis of form four biology textbook, biology teacher's scheme of work and lesson plans. The quantitative part is by using teacher's survey questionnaire.

Data Analysis

Participants' comments were examined and analysed using the scale content validation index (S-CVI). As proposed by Davis (1992), four Likert scores (1 = not relevant, 2 = less relevant, 3 = quite relevant, and 4 = highly relevant) were used.

LIMITATION

Despite the evidence indicating that the current module is appropriate and applicable for learning diffusion and osmosis in the classroom, it is still limited in its effectiveness to improve students' academic performance and develop their scientific thinking. It is advised that the current module be used in the classroom in order to gauge its effectiveness. When a developed module is used and produces the anticipated outcomes in terms of raising academic achievement, it is deemed effective (Abi Hamid, Aribowo, & Desmira, 2017).

DEVELOPMENT SEQUENCE OF THE STEM PROBLEM-BASED INQUIRY MODULE

Following the ADDIE methodology, the present STEM problem-based inquiry learning module was created. The resultant instructional materials using the model meet not only the challenges of poor performance in science but also those of learner-centeredness, activity-orientation, and problem-solving. It is said that the ADDIE model has been successfully utilized to develop curricula across a number of fields (Sweller, 2016). Although there are many classroom-oriented models, the ADDIE model is the most widely used model in schools and other educational settings (Branch, 2009), which is why it has been adapted and used. The present module has three stages of development. These are the analysis, design, and development stages. The researcher explained below the sequence of the module in detail.

Analysis Phase

This phase's main goal and focus are the students who are the module's intended audience (Sweller, 2016; Youssef-Shalala, et al., 2014). At this point, the researcher analyses the following documents:

Analysis of Learners and Context

Students in Nigeria's Form 4 represent several tribes and dialects; most of them are Hausa but can speak English. The student's characteristics, such as age, sex, socioeconomic status, entry habits, and individual differences, among other things, were analyzed. The majority of the students are from lower socioeconomic backgrounds. To identify any individual differences in students' grades, the report cards, final exam papers, test papers, assignments, and classwork were scrutinized. Students who reside out the school environment frequently obtain lesser marks and positions. The daily trip from their fairly areas to the school may be the cause of this. For some students, learning may become less comfortable as a result. It was found that several gaps exist as a result of important ideas such plasmolysis and haemolysis not being effectively covered, and some of them not even being treated.

Analysis of Biology Textbook

After examining the "Cell and its Environment" chapter of the biology textbooks for senior secondary school, a significant gap was discovered. Analysis of the material in the textbook found that there were not enough details on the contents. Students become bored by the textbook's heavy use of words to illustrate concepts. It can be extremely difficult to learn complicated concepts that require extra help, especially for children with low IQs. Since there were no activities or questions that required students to use their problem-solving abilities, the curriculum did not promote students' critical thinking or creativity.

A large portion of the chapter's information was organized and presented logically. It took a while for each description to be given throughout the concept's exposition. During the explanation of the text, some errors, misunderstandings, and false information were discovered. It's possible to comprehend the words used. The majority of the illustrations, drawings, figures, and photographs in the chapter, however, lacked clarity. Additionally, the chapter made no suggestions for a class or group activity that would support the growth of a range of verbal communication abilities. The curriculum did not emphasize any opportunities for students to collaborate with others to achieve a learning objective. The questions are fairly hard and may be resolved by reading the provided information.

Scheme of Works and Lesson Plans

When assessing scheme of work and the lesson plans, compliance with the syllabus was carefully examined. What learners are learning and what is in lesson plans and strategies for teachers frequently diverge. The course objectives and the assessment have no connections. The evaluation criteria in the lesson plans and scheme of works did not appropriately represent the subject matter that would be or had already been taught. The objectives of the lesson were not sufficiently emphasized by some teachers in their lesson plans and schemes of work. The lesson plans also don't have any real-world application. There was no provision in the lesson plans or the scheme of work for letting students build their own understanding through hands-on activities while being guided by a facilitator.

Furthermore, the lesson plans and program don't go into great length with experiments and other activities that teach students about the osmosis and diffusion processes. Additionally, none of the lesson plans or schemes of work contained any STEM-related abilities, such as innovation, creativity, critical thinking, communication, teamwork, leadership duties, etc. Additionally, some of the topics taught in class are not listed on the syllabus, and some are skipped since they are not included in the course syllabus or the plan of study. The topics are not rationally arranged within the works' structure. It's possible that the items on the syllabus aren't always listed in the correct order for instruction. While some topics don't require prior knowledge, teachers are expected to be aware that others do. As a result, the instructor needs to be aware of the issue and organize the content logically, moving from simple to complex and from well-known to esoteric topics. Many of these teachers made a mistake by not considering the substance of the related topics when planning the subject.

Another issue found during the investigation of the scheme of work was the lack of some of the programs to adjust for anticipated and unplanned disruptions in the classroom. Just a few of the disruptions include revision week, exam week, a public holiday, sports day, and pre-arranged school breaks like mid-term break. Several subjects required revision before the exams were administered. Last but not least, most lesson plans used by teachers do not include a summary of the complete course material, sequential listening activities for learning, a relationship between the content and the supporting materials, or a basis for long-term planning, instruction, or evaluation of the topics.

Design Phase

Tiruneh, et al., (2018), claim that all the aims and objectives to be achieved, the approaches for assessing' performance on the aims, the kinds of assignments and tests to be chosen, the content to be selected, the learning environment to be selected, and the planning and provision of the required resources, must all be identified at this point. These are explained as follows:

Establishing Objectives and Goals

In this module, the goals and objectives are explained in plain language. When stating the aims of this study for each module, the researcher took into consideration each component of learning objectives. In addition, words and phrases that cover all three learning domains were employed. Every goal outlined in each module unit is related to the STEM competencies that students are expected to develop.

The following are the course's objectives:

1. To determine if the learning direction is pertinent and consistent with the stated goals.
2. To convert the objectives into more goals.
3. To encourage your students to evaluate their progress each lesson.
4. To improve students' capacity to recognize and use their STEM skills.

Therefore, the following is required of the students:

1. Perform tasks involving the manipulation of materials to illustrate the processes of diffusion and osmosis.
2. sketching and illuminating osmosis in plant and animal cells as well as diffusion in gases and liquids.
3. Collaborate and get ready to share your research on the osmosis and diffusion processes.
4. be able to use what they learnt in class to solve difficulties in the real world.

Establishing Content

Students in secondary schools were found to find it particularly difficult to understand concepts related to diffusion and osmosis, as was already mentioned. As a result, the STEM problem-based inquiry learning module was created. The learning stages of the current module the "engage" stage, during which students will be drawn into a problem that incorporates concepts of diffusion and osmosis. The "explore stage," as the second stage, exposes students to a variety of experimentation activities on the ideas of diffusion and osmosis. The third stage, dubbed the "explain stage," requires students to present an explanation of their findings. The next stage was the "elaborate stage," where students engaged in extra activities to deepen their understanding of the subjects. The final stage, "evaluation" encourages students to evaluate their own learning. Additionally, lessons on diffusion and osmosis include hands-on activities.

Selection of Assessment Methods

The researcher created and constructed one instrument, the teacher's questionnaire. The questionnaire for teachers was made expressly to get their opinions on how suitable the module was. It should be emphasized that fifteen (15) biology teachers validated a questionnaire with 20 items. Scale content validity index (S-CVI), a statistical analysis of the responses, was 0.86, higher than the required level of dependability of.70.

Resource and Learning Environment Selection

The laboratory at the school ought to be used for instruction. So, it is necessary to employ laboratory equipment. The educational resources offered by the school should be used, but some of the supplies required for instruction and learning should come from the teacher, and the school library should have copies of the suggested textbooks. For the purpose of learning, the following tools should be available: microscopes, slides, test tubes, beakers, syringes, cellular models, water-soaked dialysis tubes, measuring tools, yam or potato tubers, bottles of perfume, ink, salt or sugar solutions of various concentrations, decalcified eggs, fresh filament of spirogyra, strings, fresh blood, litmus solution, dilute hydrochloric acid, and litmus solution.

Development Phase

This phase entails developing and approving the project's methodology (Kelley & Knowles, 2016; Ghani et al. 2019). They further maintained that a module should be developed from the data obtained from the analysis and design phases. Thus, the researcher's decision to develop the present module was based on the data acquired from the two earlier phases.

Module Validation Analysis

Finding out whether a module is legitimate is a crucial step in determining whether it is appropriate for implementation. Some module developers frequently forget to complete this phase. Any module's capacity to measure what it was designed to measure is a sign of its validity. A module might be considered valid if the degree of its applicability determined by experts is greater (Madihie & Noah, 2013).

The validation was conducted using a questionnaire with 20 items that was presented to fifteen (15) seasoned biology teachers. These specialists in science education were chosen because they each have a wealth of experience and expertise in the field. In addition, they all used the STEM constructivist learning cycle in scientific instruction.

Each of the chosen experts received a letter inviting them to take on the role of module validation evaluators. Following their confirmation, a set of the module's draught and the form for validating the scores were delivered to them. Twenty items on a Likert scale of Not Relevant, Less Relevant, Quite Relevant, and Highly Relevant make up the survey. The validators were tasked with determining whether the module met the requirements for content, objectives, language, and evaluation methods. This was done in order to achieve internal consistency.

The researcher also interacts personally with each validator to engage in intellectual discourse that will yield more information, deeper understanding, and sincere responses. Before all fifteen experienced teachers' responses were collected, the process took more than a month. It took the researcher two weeks to modify the module in accordance with the recommendations made by the experts after receiving input from all of them. After doing an analysis, the computation was made using the percentage (%). The percentage value was converted to point form, where 100% is shown as 1.00 and 0% is shown as 0.00 (Madihie & Noah, 2013). They continued by arguing that the accepted content validity should be 70% and above. The validity of the module was evaluated using the Content Validation Index (CVI) (Sidek & Jamaluddin, 2005; Polit & Beck, 2006).

FINDINGS

The responses of the teachers with regards to the content, objectives, language and assessment techniques of the current module were analysed as showed in table 2.

Table 2 Rating 20-Items on the Module Scale by 15 Experts

Items (A-D)	Exp1	Exp2	Exp3	Exp4	Exp5	Exp6	Exp7	Exp8	Exp9	Exp10	Exp11	Exp12	Exp13	Exp14	Exp15	NA	CVI
A. Content																	
1	✓	×	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	**13**	**.87**
2	✓	✓	×	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	**12**	**.80**
3	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	**13**	**.87**
4	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**14**	**.93**
5	✓	✓	×	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	**12**	**.80**
B. Objectives																	
6	✓	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**13**	**.87**
7	✓	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	**13**	**.87**
8	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	×	✓	×	✓	**13**	**.87**
9	✓	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	✓	**13**	**.87**
10	✓	×	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	**13**	**.87**
C. Language																	
11	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	×	**12**	**.80**
12	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	**13**	**.87**
13	✓	✓	✓	✓	✓	×	✓	×	✓	✓	✓	✓	✓	×	✓	**13**	**.87**
14	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	**14**	**.93**
15	✓	✓	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	×	✓	✓	**13**	**.87**
D. Assessment																	
16	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	×	✓	✓	✓	×	**12**	**.80**
17	×	✓	×	✓	✓	✓	✓	✓	✓	×	×	✓	✓	✓	✓	**11**	**.73**
18	✓	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	×	✓	✓	**12**	**.80**
19	✓	×	✓	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	✓	**13**	**.87**
20	✓	✓	✓	×	✓	✓	×	✓	✓	✓	✓	✓	✓	✓	✓	**13**	**.87**
M=I-CVI=	**.95**	**.80**	**.80**	**.80**	**.80**	**.80**	**.80**	**.80**	**.85**	**.80**	**.90**	**.90**	**.85**	**.90**	**.90**	**S-CVI= .86**	

Exp= Expert, N/A= Number Accepted, I-CVI= Individual Content Validity Index, S-CVI= Scale Content Validity Index

The acceptable indexes for the Individual Content Validation Index (I-CVI) and Scale Content Validation Index (S-CVI) are 0.78 and 0.80, respectively (Polit and Beck, 2006). As showed in table 1, all of the I-CVI of this module are higher than 0.78 except item 17. While the study's S-CVI, which was 0.86, is within the acceptable index.

Table 3 Composite mean of Fifteen (15) Experts

Expert	Content	Objective	Language	Evaluation	Mean
1	3.75	3.75	3.75	3.00	0.95
2	3.00	3.00	3.75	3.00	0.85
3	3.00	3.75	3.00	3.00	0.85
4	3.00	3.00	3.75	3.00	0.85
5	3.75	3.00	3.00	3.00	0.85
6	3.00	3.00	3.00	3.00	0.80
7	3.75	3.00	3.00	3.00	0.85
8	3.00	3.00	3.00	3.00	0.80
9	3.00	3.00	3.00	3.75	0.85
10	3.00	3.00	3.00	3.75	0.85
11	3.00	3.75	3.75	3.00	0.90
12	3.75	3.00	3.00	3.75	0.90
13	3.00	3.75	3.00	3.75	0.90
14	3.75	3.00	3.00	3.75	0.85
15	3.75	3.75	3.00	3.00	0.90
Mean	**3.30**	**3.25**	**3.20**	**3.25**	**0.86**

The teachers' acceptance is shown in Table 3. The module's composite mean of all the variables is satisfactory. The content's composite means of 3.28 shows that all the teachers were in agreement that the module was applicable to the intended students, suitable for them. Additionally, it shows that all of the themes are in keeping with the intended audience's curriculum. This indicates that the resources, activities, and methods used to carry them out are all on the learners' level. The composites mean of the teachers, which is 3.23, the objectives are also up to standard, well stated, achievable, and within the content.

The teacher's composite means of 3.19 for the vocabulary used in the module indicated the language's acceptability. That is to say, the language is unambiguous, straightforward, and clear. Additionally, the evaluation methods were dispersed among the three learning domains and were capable of gauging the desired learning outcomes. This is supported by the composite mean of teachers, which is 3.23. The composite mean of all the factors (content, objectives, language, and evaluation) is 0.86, which is higher than the acceptable validity index. The composite means of all the variables demonstrated that secondary school students may learn the concepts of diffusion and osmosis from the current module.

DISCUSSION

This research aimed at developing STEM problem-based inquiry learning module for diffusion and osmosis concepts as such, ADDIE was adapted to develop the present module. The present study shows researchers, educators, and teachers how to develop a learning module on biology concepts especially diffusion and osmosis. Evidences were provided that; the present module is suitable and appropriate and may be used to teach and learn biological concepts like diffusion and osmosis to secondary school students. This study therefore, is supported by Ali et al., (2010), which said that a module that demonstrates and explains how learning should occur in a certain classroom context could be developed using a variety of theories and learning cycles. In addition, this study is specifically significant for the curriculum planners, education policy-makers, researchers, biology teachers and biology students

Based on the findings, it has been determined that the STEM problem-based inquiry learning module is appropriate for Biology students to acquire concepts of diffusion and osmosis. Glogger-Frey et al. (2015) provided support for the study by stating that learning activities created using the ADDIE instructional design paradigm are successful and appropriate. The study is also consistent with other studies that demonstrated that using the STEM problem-based Learning to teach and learn was appropriate, effective, and applicable to different grade levels (Barman, 1992; Purser & Renner, 1983; Saunders & Shepardson, 1987). Additionally, the study supports claims that say instructions prepared as a module are found to be suitable for students' learning processes (Ali et al., 2010; Alias & Siraj, 2012). The documents analysed in this study shows that there are a lot of gaps which needs to be bridged. These gaps that are highlighted can be closed using the current module (Barman, 1992).

CONCLUSION

The suitability of the STEM problem-based inquiry learning module was revealed by the study, in which the teachers show their high level of agreement regarding the content, objectives, language and assessment technique of the module. ADDIE and problem-based inquiry leaning are confirmed by teachers to be the most suitable and effective in developing any learning and teaching module for learning biological concepts particularly diffusion and osmosis concepts.

AUTHOR STATEMENTS

All the three authors have contributed greatly to the publication of this article. Mohd Norawi Ali and Muhammad Zohir Ahmad contribute with data analysis while Usman Gado Birnin Tudu perform document analysis and literature review.

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