

**DESIGN AND DEVELOPMENT OF INTEGRATED STEM TEACHING MODULE FOR
PRE-SERVICE TEACHERS IN NIGERIA**

By

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Abstract

Integrated Science, Technology, Engineering, and Mathematics (iSTEM) is a new strategy that provides innovative and higher-order thinking skills which are the needed impetus of the 21st century. Many stakeholders in education believe that the iSTEM strategy is an effective pedagogy to empower STEM competence among learners. The iSTEM teaching module was designed to transform the current curriculum in Nigeria from teaching in separate STEM disciplines to integrated STEM-based strategy. Therefore, the purpose of this study was to design and develop the iSTEM teaching module for teaching iSTEM strategy in Nigerian secondary schools. The iSTEM teaching strategy focused on the five levels of integration that included: Single, Combine, Multiple, Engineering design projects, and fully integrated STEM disciplines. The iSTEM teaching module was developed using the 5 phases of instructional design model namely: Analysis, Design, Development, Implementation and Evaluation (ADDIE) of the iSTEM teaching module. A total of three experts in iSTEM education validated the iSTEM teaching module. The results show that the iSTEM teaching module has good validity and acceptable reliability capable of being used as an instruction for training the pre-service teachers in implementing iSTEM strategy with content validity index (CVI) and inter-rater reliability of 0.94 and 0.83 respectively.

Keywords: Integrated STEM, iSTEM Strategy, ADDIE Model, Teaching Module.

Introduction

Integrated Science, Technology, Engineering, and Mathematics (iSTEM) is a recent strategy that emphasizes transdisciplinary among Science, Technology, Engineering, and Mathematics (STEM) by eliminating the boundaries between the disciplines and teaching the subjects as a single entity (Nadelson & Seifert, 2017). The reality in Nigeria is that each of the STEM disciplines is taught as a separate field of study (Okpala, 2012). The situation is that most of the learners are not exposed to the iSTEM strategy and are only receiving teaching in the separate and single field of STEM (Galadima *et al.*, 2019b). The consequences associated with iSTEM instruction is that, if iSTEM strategy is not introduced in Nigeria, it would affect the learners' productivity. AS such, for stakeholders to move from teaching separate STEM

disciplines in Nigeria, the iSTEM teaching module would serve as a guideline for pre-service teachers in teaching iSTEM-based pedagogy.

In addition, the need for iSTEM is to meet the present and future global economic, social and technological challenges, such as sufficient and sustainable energy, healthcare and technologically development (English, 2016). Similarly, literature described the need of iSTEM for resolving societal needs for new technological and scientific advances; economic needs for national security; and personal needs to become a fulfilled productive and knowledgeable citizen (Mahmud & Arifin, 2021; Zollman, 2012).

In this regard, the use of iSTEM strategy would provide opportunities with a more relevant, more meaningful learning experience and less fragmented knowledge (Furner & Kumar, 2007). In relation to solving real-world problems, single discipline prevent the learners from building the needed competencies and connection between and among the four fields of STEM as literature contends (Kalolo, 2016). Reiteratively, real-world problems are not fragmented and isolated in single disciplines as they are taught in the school's curriculum in Nigeria. Thus, to solve the problems of teaching in a single discipline, pre-service teachers need skills that make sense of learning content cut across the disciplines (Thibaut *et al.*, 2018) sought to prepare the learners for the global demands of the 21st century. The 21st century demand needs for workers to know mathematical skills and science, creativity, expertise in information and communication technology, and the capability to solve complex real-world problems (Jayarajah *et al.*, 2014). The iSTEM approach helps to determine whether Nigeria will be able to solve challenges in teaching individual STEM disciplines without connection between and among the disciplines. In bridging this gap, this study designed and developed a teaching module to teach the iSTEM course by connecting the content area of the STEM as one entity in their future classroom instructions.

In this study, pre-service teachers are students of education at the University levels and Colleges of education who are training to become certified mathematics teachers within a formal teacher education program (National Research Council, 2010). The pre-service teachers are much more likely to implement integrated teaching strategies within and during their teaching method course in the colleges and universities. Consequently, as the pre-service teachers are the future leaders in the field of education, they were in the position to carry the responsibilities of new initiatives encouraging the use of best practices in the teaching of iSTEM education. Specifically, pre-service teachers are new in the field and must be prepared for STEM integrations because they are the future leaders in the field who will play a vital role in steering the route of STEM education in Nigeria. This study provides meaningful learning opportunities for pre-service teachers in encouraging integration and collaboration within the classroom. Due to little existence of empirical research on iSTEM education in Nigeria, this study serves as an excellent starting point for researchers who wish to drive the future of pre-service teachers to design and develop iSTEM teaching module in Nigerian secondary schools.

Purpose of the Study

This study focused on the design and development of iSTEM teaching module as a systematic structure that will guide stakeholders to design a teaching module that will transform the current curriculum of teacher education programme in Nigeria from receiving teaching in separate STEM disciplines to integrated STEM-based practices.

Theoretical Foundation

The design and development of the iSTEM teaching module was based on the theory originated from Bruner's social constructivist theory. The constructivist theory is important in designing this module in which the learners through social interaction with others actively construct new ideas based on their prior knowledge and experience. In these perspectives, the teacher acts as a facilitator and also emphasizes on collaborative learning, student-centred pedagogy, engineering design challenges, and hands-on experience for better development of learners' ability in solving their real-life problems (De Loof *et al.*, 2022; Huang, 2002). In this study, constructivist learning theory is important and closely fitted in designing module for teaching iSTEM-based pedagogy for pre-service teachers in Nigeria.

Methodology

Design and Development of the iSTEM Teaching Module

The iSTEM teaching module was designed and developed based on the 5 phases of ADDIE instructional model that included: Analysis for the need of iSTEM teaching module; Design of iSTEM learning objectives; Development; Implementation; and Evaluation of the iSTEM teaching module. The ADDIE model helped the researcher to organize the development process properly. The following provides an explanation of the process based on the phases of the ADDIE instructional model.

Analysis for Need of iSTEM Teaching Module

This phase analyzed the need for teaching iSTEM and also comprehend why a learning gap existed. The preliminary investigation was conducted (Galadima *et al.*, 2019a) through experts on the need for developing the iSTEM teaching module. The experts mentioned that they had little knowledge and feel underprepared to connect STEM disciplines. In this regard, the participants revealed that they have no idea about combining two or more disciplines, and they are still teaching individual discipline. Basically, all the experts expressed the need for a teaching module for teaching iSTEM by making the teaching and learning more connected (Galadima *et al.*, 2019c). Besides, the participants mentioned that the current teaching practice in Nigeria is based on single discipline instruction. The outcomes of the preliminary study provided a strong justification for the researcher of this study to design and develop iSTEM teaching module as a guideline for preparing the learners in teaching site.

Design of iSTEM Teaching Module

The iSTEM teaching module was designed and covered the learning outcomes ranging from the concepts of STEM, nature and goal of STEM education. The structure of the iSTEM teaching module were designed and organise on weekly basis based on the combine ideas of the various level of integration in teaching the iSTEM course and for promoting relevant learning experience in solving a real-world problem. The features of the module for teaching iSTEM involves the strategies and engineering design process with hands-on and minds-on activities applied for solving the real-world problems. Additionally, the learning outcomes of the module had to be described under the knowledge of pedagogy, knowledge of content for teaching iSTEM in understanding the five levels of integration (Galadima *et al.*, 2019b) .

Development of iSTEM Teaching Module

This development phase of the iSTEM teaching module encompasses the characteristics of iSTEM; learning outcomes; resources, materials and tools needed for better understanding the technology and engineering design challenges. The learning outcomes contains features such as collaboration, working in a group, brainstorming of ideas and increases creative thinking. The learners appropriately construct their learning environment and organise their learning to enable them improve the teaching of the iSTEM under the guidance of facilitators. Whereas, the materials and tools required for iSTEM teaching module comprises construction paper, ruler, glue, straws, Styrofoam, computer, projector, spaghetti, marshmallow, masking tape, string, scissors, harmers, and measuring devices. Table 1 provides an excerpt from the iSTEM Teaching Module.

Table 1

Teaching Module

Course: iSTEM Modules	Duration : 3 Hours
Topic: Construction of Tower	Group Size: 5
Assumed Prior Knowledge: participants are familiar with the upstairs and skyscrapers	
Learning outcomes	
By the end of this module, participants will be able to:	Materials:
<ul style="list-style-type: none">• Outline the factors to be considered in teaching iSTEM• Incorporate the knowledge of content in teaching the multiple disciplines• Apply the knowledge of multiple STEM in solving real-life problems	Chart Learning outcomes Videoclip Build the tallest tower challenge Handout Copy of PowerPoint as a handout Resources Whiteboard makers, facilitator lesson plan, computer and projector, pieces of spaghetti, fresh

- Build a tallest free-standing tower using marshmallow, masking tape, string, spaghetti that can support a Marshmallow in just 25 minutes
- Increases team-work, collaboration, and creative thinking
- Learn how the Engineers collaborate to design, test, and improve on their ideas

Step outline:

Step 1 Introduction	20minute
Step 2 Consideration for teaching integrated STEM	35minutes
Step 3 Content knowledge for teaching iSTEM	25minutes
Step 4 Multiple disciplines as an iSTEM strategy	20minutes
STEM Activity 1 Making a tower using spaghetti	20minutes
STEM Activity 2 Free-standing Tower challenges	25minutes
Evaluation	35minutes

Background for Facilitator

The main focus of this module is to prepare the participants become familiar with an iSTEM teaching approach. This module will ensure that participants are able to outline the factors to be considered in teaching iSTEM; to connect the multiple disciplines in the teaching of iSTEM in solving the real-life problems; and to guide the participants to build the tallest free-standing tower using spaghetti with limited period of 20 minutes that can support a marshmallow.

In addition to the above module extract, the iSTEM activities and challenges in the iSTEM teaching module provide opportunities for the learners to have the exposure that requires them to become scientists, technicians, engineers, and mathematician to solve real-world problems. The need is to increase learners' interest in the field of iSTEM education through collaborative learning and team-work during the activities.

The Validity of the Module

In getting the validity of the module, the researcher submitted the module for comments and suggestion to three experts in iSTEM education. Based on their feedback some corrections

in the wording and structure of the instruments was made and the content validity index (CVI) of 0.94 was calculated (see Table 2). This can be calculated by computing the average of raters' agreement on item by denoting 3 as a quite relevant item or 4 as highly relevant (Polit *et al.*, 2007; Zamanzadeh *et al.*, 2015). Table 2 shows the ratings on a 6-items scale by three experts

Table 2

Ratings on 6-items Scale by Three Raters, 3 or 4 on the 4-points scale

	Item	Rating			Experts in	
		Expert 1	Expert 2	Expert 3	Agreement	CVI
1	Sufficiency of the iSTEM teaching module in realise the purpose of the research.	4	4	4	3	1.00
2	Appropriateness of objectives in measuring the iSTEM contents	4	4	4	3	1.00
3	Suitability of the content for the iSTEM teaching module	3	3	3	3	1.00
4	Clarity of the connections between and among the iSTEM levels of integration	3	3	4	2	0.67
5	The appropriateness of the iSTEM teaching module.	4	4	4	3	1.00

6	The interactive nature of Learners/ Facilitators activities	4	4	4	3	1.00
Average CVI						0.94

Reliability of the Module

The reliability of 0.83 was obtained (see Table 3) using inter-rater agreement investigating six items based on the rating of three experts. The experts agreed on 5 out of 6 ratings (i.e 5/6= 0.833). Thus, Inter-rater agreement was used to determine the degree in which the raters assigned the same value for each item being rated. The percentage agreement obtained between the three raters was recorded 83% which indicated an excellent level of agreement among the raters. Table 3 shows the percentage agreement between the three experts.

Table 3

Percentage Agreement between Three Experts

	Item	Rating			Agreement
		Expert 1	Expert 2	Expert 3	
1	Sufficiency of the iSTEM teaching module in realise the purpose of the research.	4	4	4	1
2	Appropriateness of objectives in measuring the iSTEM contents	4	4	4	1
3	Suitability of the content for the iSTEM teaching module	3	3	3	1
4	Clarity of the connections between and among the iSTEM levels of integration	3	3	4	0
5	The appropriateness of the iSTEM teaching module.	4	4	4	1
6	The interactive nature of Learners/ Facilitators activities	4	4	4	4
Number of Ratings in Agreement					5
Percentage of Agreement					83%

Implementation of the iSTEM Teaching Module

These phases embodied the implementation of the iSTEM teaching module in the classroom situation in which the researcher acted as a facilitator that guided and assisted the learners in their learning environment. The facilitator organised and assisted the learners in working in a small group of six participants. Some among the activities organised are guiding the learners to design a mind map and by providing the materials necessary for making hands-on activities and helped the participants in making collaboration accordingly.

Evaluation of the iSTEM Teaching Module

It can be seen from the data gathered from expert's validation that the iSTEM teaching module has interactive nature for activities; that the iSTEM teaching module is very appropriate and sufficient to measure the understanding of the learners; clarity of the connection between and among the iSTEM level of integration; appropriateness and suitability of the objectives in measuring the iSTEM content. The evaluation also provided evidence that the ADDIE model developed an effective and valid interactive iSTEM teaching module and it is still viable.

Conclusion

This module was designed to transform the current curriculum in Nigeria from teaching in separate STEM disciplines to integrated STEM-based strategy. Also, the module may help the teachers to connect the STEM disciplines into one cohesive teaching and learning pedagogy for solving real-world problems. Also, the experts' consensus during validation shows this iSTEM teaching module has good content validity. Therefore, it is hoped that in future, higher institutions in Nigeria could adopt this teaching module strategy in preparing the teachers in teaching iSTEM-based strategy.

Recommendations

Based on the findings of this study, it is recommended that the pre-service teachers should be given a training on designing the iSTEM teaching module in all level of Nigerian secondary schools for improving their performance in iSTEM-based strategy. Also, the curriculum developers should accept this module as an innovation per excellence in teaching iSTEM in Nigerian secondary schools.

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