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The Effect of STEM-based 5E Module (in the topic of Waves) in Enhancing Scientific Literacy Among Ninth-grade Students in Doha, Qatar

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Abstract

Scientific literacy has received more attention as the main objective of science education, as it fosters critical thinking, the creation of scientific evidence, and problem-solving skills. The purpose of this research is to examine if science instruction using a STEM-5E module on the topic of waves enhances students' scientific literacy in Doha, Qatar. A quasi-experimental technique known as "the non-equivalent (pretest and posttest) control-group design" was applied in this study. 120 students were in the sample; 58 students from two of the 9th grade classes served as the control group, and 62 students from two classes served as the experimental group. Two instruments were used: the scientific literacy test created by the researcher using the "PISA 2018 Scientific Literacy Framework “to evaluate the 9th graders' acquisition of scientific literacy competencies in the topic of waves, and the STEM-5E module (on the topic of waves) developed by the researcher. A one-way ANCOVA analysis was conducted to see whether there was a significant difference in scientific literacy, and a one-way MANCOVA analysis was conducted to determine whether there was a significant difference in the competencies of scientific literacy; "Explain Phenomena Scientifically," "Evaluate and Design Scientific Enquiry," and "Interpret Data and Evidence Scientifically.". that using the STEM-5E module had statistically significant effects on students' results of scientific literacy and its competencies. This indicates that the STEM-5E module improves scientific literacy as well as all three competencies.

Keywords: STEM, 5E Model, Scientific Literacy,

Introduction

According to the argument that acquiring scientific literacy would give students the knowledge and skills required to become literate in science as well as responsible citizens enabled in critical thinking, designing scientific evidence, and problem- solving abilities, there has been an increasing focus on scientific literacy as the overarching goal of science education (Bybee, 1997; National Academies of Sciences, Engineering, 2016; Rennie et al., 2017).

Researchers claim that if physics concepts (such as waves) are taught in STEM education sessions, pupils will understand scientific concepts in a well-planned setting. Students can learn about physics in contexts they are acquainted with in STEM education programs, which can foster cross-disciplinary linkages and the growth of strong competences (Tupsai et al., 2019).

The 5E's model is one of the most significant models in science learning that is based on scientific enquiry. The Biological Science Curriculum Study (BSCS) team developed the 5Es teaching paradigm, which is based on a constructive learning method, in the late 1980s (Bybee et al., 2006).

Despite the State of Qatar's efforts to enhance teaching practices and move to student-centered learning methodologies, the continued use of traditional methods of teaching and assessment has been criticized (Treagust et al., 2020). The educational methodologies used in Qatar to teach science are not of high quality, consistency, or correctness (Said et al., 2018). Qatar's performance in international assessments also suggests that Qatar's teaching techniques need to be revised (Qureshi et al., 2016). This suggests that the existing teaching technique is insufficient to assist students increase their scientific literacy. So, in order to build scientific literacy, science instruction in Qatar needs new teaching strategies.

STEM Education

STEM education has its origins in the 1990s in the United States of America, when studies suggested that contemporary approaches to teaching science and math should be investigated and students should be motivated to pursue these disciplines (R. W. Bybee, 2013; Sanders, 2009). The National Science Foundation (NSF) laid the groundwork for the STEM education strategy. The approach was afterwards followed by numerous nations, including England, Korea, Australia, Singapore, and others (Bybee, 2013b; Freeman, 2013; Idris et al., 2013; Phaprom et al., 2019; Sanders, 2009).

Based on constructivism theory, integrated STEM education is regarded as a recent development from the constructivist movement's effort to integrate general curriculum (Murphy et al., 2020; Richardson, 2016). Real-world problems and aspects of daily life are emphasized in STEM education, which calls for distinctive learning methodologies centered on scientific inquiry and high-quality curriculum (Bybee, 2013b; Kelley & Knowles, 2016; Kennedy & Odell, 2014; NRC, 2011a; Sanders, 2009).

Numerous educators emphasized the value of STEM education in developing highly skilled scientists, engineers, and technicians as well as in boosting student interest in STEM areas and preparing pupils for life in the twenty-first century. (Bishop, 2015; NRC, 2009; NRC, 2014). Additionally, several studies have demonstrated the effectiveness of STEM in assisting students in accomplishing cognitive and skill goals, boosting students' accomplishment, and enhancing their understanding of the topic of science, technology, and engineering (Becker & Park, 2011; Boyster, 2018; Bybee, 2013b; NRC, 2014).

The personal quality of life of every individual as well as the competitiveness of the country in the global economy depend on literacy in STEM fields (Freeman et al., 2019; NRC, 2011b; UN general assembly, 2015). In order to achieve the 17 Sustainable

Development Goals (SDGs) and 169 goals, reinforcement STEM education was suggested in the UNESCO Incheon Declaration for Education 2030 (UNESCO, 2015).

5E Instructional Model

In order to develop a deeper understanding of scientific and technological knowledge, attitudes, and skills, the BSCS (Biological Science Curriculum Study) has been widely used as one educational model. The BSCS 5E educational model supported constructivist pedagogy and considered inquiry-based learning model. This educational model consists of five phases that include engagement, exploration, explanation, elaboration, and evaluation. Each stage serves a distinct purpose (Bybee et al., 2006; Ihejiamaizu et al., 2018; Texley & Ruud, 2018).

The 5E instructional model emphasized the use of constructivist methods and a model of inquiry-based learning to get a deeper comprehension of scientific and technical concepts, attitudes, and abilities. This model is organized into five phases: Each phase performs a certain function (Bybee et al., 2006; Ihejiamaizu et al., 2018; Texley & Ruud, 2018).

The five phases of the 5E model are intended to support 5E conceptual transformation, provide consistency to various instructional tactics, provide connections between various instructional activities, and support scientific instructors in their decisions about student interactions. It provides a well-planned set of classes that put the learning process in the hands of the pupils. All students are encouraged to do research, develop a fundamental understanding of scientific ideas, and use that knowledge to solve technical or scientific problems (Bybee et al., 2006).

5E instructional model is widely used in science learning (Bybee et al., 2006; Morgan et al., 2013). Because the 5E model improves cognitive process skills, achievements, attitudes, , higher-order thinking, problem solving, and incentives (Bybee, 2009). In addition, It is clearly helpful to use it in STEM classes (Bybee, 2019). because 5E instructional model is inquiry- based learning focus in real world issues (Rodriguez et al., 2019) and useful for 21st century skills learning (Bybee, 2009; Chitman-Brooker & Kopp, 2013; Rodriguez et al., 2019).

In science education, the 5E strategy, which promotes the development of scientific literacy, is widely used. Teachers may ensure that students are expanding their understanding of the issue, expressing their ideas well, and increasing their knowledge of it by using the 5E strategy. The 5E method emphasizes the need of having students evaluate their understanding of and application of scientific principles. This evaluation procedure is essential for the growth of scientific literacy because it requires students to analyze the accuracy of their data and reflect on what they have learned (NSTA, 2018).

STEM-based 5E model module (STEM-5E)

In STEM education, one of the preferred learning models among teachers is the 5E (Dass, 2015). Bybee (2015) claims that the model is excellent for teaching 21st-century skills and STEM subjects. additionally, The STEM approach and the 5Es' phases encourage learning across disciplines (Sugiarti et al., 2018).

When 5E learning and STEM are combined, students may benefit from an all-encompassing, integrated learning experience. By combining the 5E and STEM approaches, teachers may create a comprehensive learning experience that encompasses the finest features of both. 5E activities may pique students' attention and curiosity as they solve problems from the real world and support the growth of scientific reasoning skills. Through the utilization of inquiry-based learning, students are taught to think critically and apply their knowledge to new situations. Through the fusion of 5E and STEM, students' transdisciplinary skills for the modern workplace are also fostered (Bybee, 2019; Kaniawati et al., 2017).

A STEM-based 5E model module employs the 5E educational model to help students understand science in a STEM-based classroom. Given that STEM disciplines are covered in the 5E educational model stages, it is considered as a STEM-based module. There should be some STEM fields in each step of the 5E Educational model. While some of the stages of the 5E teaching model stated that it included certain disciplines more than others. When students are driven to create and construct using technology that corresponds with the scientific and mathematical knowledge they have just received, engineering is included in the elaboration phase (Ong et al., 2020).

The STEM-5E module included: The five-phases 5E model, STEM integration, which involves integrating mathematics, technology, and engineering in the instruction of the subject of waves in the context of actual events and applications, STEM Challenge, and Unit Project.

Scientific Literacy

Many educators have argued that the purpose of science instruction should be to increase scientific literacy (Bybee, 1997; Holbrook, 2010; Holbrook & Rannikmae, 2007; X. Liu, 2013; Millar & Osborne, 1998; Osborne, 2007) and help students develop the civic responsibility skills they need (Costa et al., 2021; Holbrook & Rannikmae, 2007, 2009; Roth & Lee, 2004).

According to the PISA 2018 scientific literacy framework, scientific literacy is “The ability to engage with science-related issues, and with the ideas of science, as a reflective citizen. A scientifically literate person is willing to engage in reasoned discourse about science and technology, which requires the competencies to explain phenomena scientifically, evaluate and design scientific enquiry, and interpret data and evidence scientifically” (OECD, 2019b, p15).

The Organization for Economic Co-operation and Development's (OECD) Program for International Student Assessment (PISA), which started at the end of the late 1990s and was developed in the first and second decades of the 21st century(OECD, 2017; Schleicher, 2019), helped establish the idea of scientific literacy by providing a definition and a framework for scientific literacy which involves many interrelated aspects of science " (Bybee et al., 2009; Darci & Harland, 2011; Harlen, 2001; OECD, 2019b). The scientific literacy perspective of the PISA focuses a high emphasis on teaching future citizens (Bybee et al., 2009).

Theoretical Framework

This research relies on the constructivism (Dewey, 1938) and social constructivism (Vygotsky, 1978) theories, as well as situated cognition theory (Brown et al., 1989) theories, which serve as the theoretical framework for the STEM-5E module. Constructivism, social constructivism, and situated cognition theory promote inquiry-based learning and could have an impact on scientific literacy. Each of these theoretical concepts is linked to the STEM-5E module. Because of all of its aspects, constructivism, social constructivism, and situated cognition theory are consistent with the STEM-5E module to enhance students' scientific literacy in the topic of waves.

PISA scientific literacy framework is the model on which scientific literacy will be assessed in this study. PISA framework assesses students' ability for recognizing and solving scientific issues, offering scientific explanations for events, and applying scientific evidence when in situations involving science and technology PISA framework is consistent with the theories on which this researchis based; the constructivist and social constructivist approaches, such as socioscientific-based instruction and the PISA method of science evaluation, seem to be very closely aligned (Kahn & Zeidler, 2014; Sadler & Zeidler, 2009).

The PISA scientific literacy framework will be used to measure scientific literacy in this study. PISA measures students' capacity to recognize and solve scientific problems, provide scientific explanations for occurrences, and apply scientific evidence in settings requiring science and technology. The constructivist and social constructivist techniques, such as socioscientific-based education and the PISA method of science evaluation, appear to be very well matched with the ideas on which this research is founded (Kahn & Zeidler, 2014; Sadler & Zeidler, 2009).

Research Method

The present research aims investigate the effects of learning science that use a STEM-5E module on the topic of waves on improving the scientific literacy of ninth-grade students in Doha, Qatar.

The following are the study's objectives:

To evaluate the efficacy of STEM-5E module science learning in improving the scientific literacy of ninth-grade students in Doha, Qatar.

To assess the efficiency of STEM-5E module science learning in improving the "Explain Phenomena Scientifically" competency of ninth-grade students in Doha, Qatar.

To assess the efficiency of STEM-5E module science learning in improving the "Evaluate and design scientific enquiry" competency of ninth-grade students in Doha, Qatar.

To assess the efficiency of STEM-5E-based science instruction in improving the "Interpret data and evidence scientifically" competency of ninth-grade students in Doha, Qatar.

This research's question has been divided into four questions:

RQ1: Does using the STEM-5E Module learning science improve ninth-grade students' scientific literacy in Doha, Qatar?

This question is subdivided into the following parts:

RQ1.1: Does using the STEM-5E Module learning science improve students' ability to "Explain Phenomena Scientifically" in Doha, Qatar?

RQ1.2: Does using the STEM-5E Module learning science improve students' ability to "Evaluate and design scientific enquiry" in Doha, Qatar?

RQ1.3: Does using the STEM-5E Module learning science improve students' ability to "Interpret data and evidence scientifically" among ninth-grade students in Doha, Qatar?

In this research, a quasi-experimental research approach called "the non-equivalent (Pretest and Posttest) control-group design" was used, which comprises of distributing individuals into multiple groups without employing randomization. Randomization is neither viable nor practicable in this research since it's dealing with entire classes and not students individually, There is no possibility to select random individuals and arrange them in classrooms (Campell & Stanley, 1963).

The sample included four classes from two schools, two from the first represented the control group, and two from the second represented the control group. The experimental group's classrooms contain 62 students. The control group's classrooms contain 58 students.

Two instruments will be used in this research:
1- The scientific literacy test (pre-test and post-test) was designed by researcher to assess 9th graders' acquiring of scientific literacy competencies in the topics of waves using the "PISA 2018 Scientific Literacy framework". The test consists of 6 questions with multiple answers and 9 essay questions relating to the content's educational goals. These questions address scientific literacy's three competencies: "explaining phenomena scientifically", "interpreting data and evidence scientifically", and "evaluating and designing scientific enquiry".

2- The instructional material, was a module relying upon the STEM-5E model (on the topic of waves). This developed module's lessons were designed utilizing the 5E model, with integrated STEM education integrating science topics with technology, engineering, and mathematics.

The designed STEM-based 5E model module (STEM-5E) comprises of the following elements:
1-As an inquiry model, the 5E model with it's five phases is employed.

2- Integration of STEM Using the Roehrig et al. (2021) framework for STEM integration, technology, engineering, and mathematics are integrated into learning the topic of waves in the context of real-life situations.

3- STEM Challenge: In each lesson, students will be challenged to apply what they have studied in engineering design.

4- Unit Project: Students are tasked with developing a project that incorporates the majority of the unit's main themes and benefits from the integration of Science, Technology, Engineering, and Mathematics. The project is the final assessment of the module learning.

The "ADDIE Instructional Design Model" was utilized as a framework for building and developing the STEM-5E instructional module in the waves area. The ADDIE Instructional Design Model is divided into five stages: "analysis, design, development, implementation, and evaluation" (Kurt, 2018). The module's material was validated by five experts.

Research Results

A one-way ANCOVA analysis was performed to evaluate if there was evidence of a significant difference among the post-scientific literacy test results when the students' pre-test of scientific literacy results were adjusted for by treatment groups. Table 1 shows the One-way ANCOVA findings for the Scientific Literacy Test.

Table 1

Results of the One-way ANCOVA for Scientific Literacy Test.

Source	Type Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Covariate (Pre- Scientific Literacy Test)	566.17	1	566.17	37.46	0.00	
Treatment Group	1101.79	1	1101.79	72.91	0.00	0.38
Error	1768.18	117	15.11			
Corrected Total	4050.37	119				

Note. $p<.05$*, Dependent variable: post-Scientific Literacy Test

According to Table1, the findings of one-way ANCOVA analysis revealed that, after adjusting for pre-scientific literacy test scores, there was a significant difference in post-scientific literacy test scores based on teaching technique group ($F_{(1, 119)} = 72.91$, p-value = .00. That is, p-value (.00) < (.05) with $\eta^2 = 0.38$), therefore, the findings indicated that there was a significant main influence of teaching techniques (STEM-5E, CTM) on the results of the posttest of Doha ninth-grade students' science literacy in the topic of waves. The partial eta square score of 0.38 implies that the STEM-5E module might account for 38% of the variation in the Post-Scientific Literacy Test.

Meanwhile, Table 2 summarizes the estimations of post-scientific literacy test Means for instruction groups following covariate (Pre-Scientific Literacy Test) correction.

Table 2.

Estimated Marginal Means of Scientific Literacy Test.

Group	Mean	Std. Error	95% Confidence Interval	
			Lower Bound	**Upper Bound**
Experimental	20.17	0.50	19.17	21.17
Control	13.86	0.52	12.82	14.89

As shown in Table 2, the estimations of mean value for Experimental group results in the scientific literacy post-test following covariate (Scientific Literacy Pre-Test) adjustment were 20.17 with (SE=0.5) and 13.86 with (SE=0.52) for the Control group. This suggests that the experimental group's mean post-scientific literacy test results were greater than the Control group.

A one-way MANCOVA analysis was carried out to see if there was a significant difference in the skills of scientific literacy post-test scores when the students' pre-test scores were adjusted for by treatment groups. Table 3 shows the findings of the One-way MANCOVA for Scientific Literacy Test.

Table 3
Results of the One-way MANCOVA for Competencies of Post-Scientific Literacy Test.

Source	Statistic test	Value	F	Hypothesis df	Error df	Sig.	Partial Eta Squared
Treatment Group	Wilks` lambda	0.57	28.71	3	115	0.00	0.43

As shown in Table 3, there was actually a statistically significant difference between the research groups on the combined dependent variables (Post-Scientific Literacy Test Competencies) after correcting for the pre-scientific literacy test, with a considerable impact size. $F(3, 115) = 28.71$, $p < 0.001$, Wilks' $\Lambda = 0.57$, partial $\eta 2 = 0.43$.

This implies the experimental as well as control groups' linear composite competencies on the scientific literacy post-test differ. The partial eta square score of 0.43 shows that the STEM-5E module might account for 43% of the variation in the composite of all three Competencies.

As a result, follow-up Univariate analysis tests of between-subject effects for competence of Scientific Literacy Test were performed to determine whether skills had statistically significant differences. The findings are shown in Table 4:

Table 4
Tests of Between-Subjects Effects for Competency of Scientific Literacy Test.

Source	Dependent variable	Type Sum of Squares	Df	Mean Square	F	Sig.	Partial Eta Squared
Pre-Scientific Literacy Test (Covariate)	Post-"Explain Phenomena Scientifically"	185.98	1	185.98	23.52	0.00	
	Post-"Evaluate & Design Scientific Enquiry"	27.28	1	27.28	13.72	0.00	
	Post-"Interpret Data and Evidence Scientifically"	24.35	1	24.35	5.93	0.02	
Treatment Group	Post-"Explain Phenomena Scientifically"	402.85	1	402.85	50.94	0.00	0.30
	Post-"Evaluate & Design Scientific Enquiry"	82.40	1	82.40	41.44	0.00	0.26
	Post-"Interpret Data and Evidence Scientifically"	16.36	1	16.36	3.99	0.048	0.03
Error	Post-"Explain Phenomena Scientifically"	925.28	117	7.91			
	Post-"Evaluate & Design Scientific Enquiry"	232.65	117	1.99			
	Post-"Interpret Data and Evidence Scientifically"	235.81	115	2.05			
Corrected Total	Post-"Explain Phenomena Scientifically"	536.33	119				
	Post-"Evaluate & Design Scientific Enquiry"	1727.87	119				
	Post-"Interpret Data and Evidence Scientifically"	379.99	119				

As shown in Table 4, there were statistically significant differences between research groups in the three Post-Scientific Literacy Test Competencies after adjusting for Pre-Scientific Literacy Test, for Post-" Explain Phenomena Scientifically" $F_{(1, 119)}$ =50.94, p-value =.00. That is, p-value (.00) < (.05), partial $\eta 2$ = 0.30, for Post-" Evaluate & Design Scientific Enquiry" $F_{(1, 119)}$ =41.44, p-value = .00. That is, p-value (.00) < (.05) partial $\eta 2$ = 0.26 and for Post-" Interpret Data and Evidence Scientifically" $F_{(1, 119)}$ =3.99, p-value =.048. That is, p-value (.048) < (.05), partial $\eta 2$ = 0.03.

Table 5 summarizes the estimated Competencies of the scientific literacy post-test means for teaching groups following covariate (Scientific Literacy Pre-Test) adjustments.

Table 5
Estimated Marginal Means for Competency of Scientific Literacy Test.

Dependent Variable	Group	Mean	Std. Error	95% Confidence Interval	
				Lower Bound	Upper Bound
“Explain Phenomena Scientifically”	Experimental	8.88	0.36	8.16	9.77
	Control	5.06	0.38	4.31	5.71
“Evaluate & Design Scientific Enquiry”	Experimental	4.59	0.18	4.23	5.01
	Control	2.87	0.19	2.49	3.19
“Interpret Data and Evidence Scientifically”	Experimental	6.70	0.26	6.18	7.40
	Control	5.93	0.27	5.39	6.29

After adjusting for covariate (Pre-Scientific Literacy Test), it can be seen in Table 5 that the estimates of the mean values of "Explain Phenomena Scientifically," "Evaluate & Design Scientific Enquiry," and "Interpret Data and Evidence Scientifically" among 9th grade students in Doha, Qatar, were higher for the Experimental group compared to the Control group.

Discussion

The results showed statistically significant differences between the means of the students who studied the topic of waves using the STEM-5E module and those who studied it using the CTM module on the scientific literacy exam, favoring the students who examined the waves unit using the STEM-5E module. This implies that students who used the STEM-5E module to study the wave topic performed greater on the post-test compared to those who used the CTM. Additionally, the findings revealed that there were statistically significant effects of teaching methods (STEM-5E, CTM) on the posttest results of Doha, Qatar 9th grade students' "Explain Phenomena Scientifically", "Evaluate and Design Scientific Enquiry" and "Interpret Data and Evidence Scientifically" competencies in the waves topic.

As a constructivist-based module, STEM-5E improved students' scientific literacy. Students take an active role in developing their understanding of scientific knowledge as constructivism theories support students to make significant contributions to knowledge growth, peer collaboration, and participation in real-life scenarios, practical experiences, scientific inquiry, problem-solving, experiments, data analysis, and interpretation. Students' scientific literacy is increased as a as a constructivist-based module, STEM-5E improved students' scientific literacy. Students take an active role in developing their understanding of scientific knowledge as constructivism theories support students to make significant contributions to knowledge growth, peer collaboration, and participation in real-life scenarios, practical experiences, scientific inquiry, problem-solving, experiments, data analysis, and interpretation (Brown et al., 1989; Orak & Al-Khresheh, 2021; Powell & Kalina, 2009).. Students' scientific literacy is increased as a result of this active participation and their ability to absorb scientific concepts more deeply and meaningfully (NRC, 2000).

The STEM-5E module enhances scientific literacy by thorough providing students with an interdisciplinary learning experience whenever STEM education is incorporated into the unit on waves using Roehrig et al.'s (2021) framework for STEM integration which emphasis on real-world problems, engineering design, integrating context and content, STEM practices, 21st-century skills, and STEM career awareness.

Conclusion And Recomendations

This study examined the development, evaluation, and effects on students' scientific literacy of the STEM-5E Module on waves topic. Teachers employed the STEM-5E module to instruct students about waves. The experimental group that utilized the STEM-5E module showed a statistically significant increase in scientific literacy, according to the study's findings. The study's findings also showed that all three of the scientific literacy sub-competencies—"Explain Phenomena Scientifically," "Evaluate & Design Scientific Enquiry," and "Interpret Data and Evidence Scientifically"—saw statistically significant improvements in the experimental group employing the STEM-5E module.

It is necessary to change a teacher's typical position to that of a coordinator, leader, and advisor in order to implement the STEM-5E module. Teachers play a big part in encouraging students' curiosity, critical thinking, cooperation, and in-depth understanding of STEM topics. When using the STEM-5E curriculum, teachers need to embrace roles, tactics, and approaches that will adequately enhance the learning experience. Teachers ought to guide students through each step of the inquiry process as facilitators. They assist kids in thinking critically, posing inquiries, and drawing their conclusions. Teachers frequently apply STEM concepts to real-world problems and applications in order to contextualize their lessons.

Students participate actively in their education in the STEM-5E module by engaging in practical assignments, research projects, and problem-solving activities that improve their understanding of STEM concepts. Students develop an inherent curiosity and questioning habit as they research real-world topics, which inspires wonder and a desire to learn more. Students' critical thinking skills are developed as they analyze the information, weigh the facts, and draw conclusions from their understanding of the material in this module. Students engage in conversations, group projects, and cooperative problem-solving activities with their classmates to strengthen their communication and teamwork abilities. Through practical problem-solving tasks, students enhance their problem-solving skills by discovering how to apply STEM ideas to real-world challenges.

The adoption of the STEM-5E module requires a shift in classroom practices toward inquiry-driven and student-centered learning. By embracing these implications, educators may create a vibrant and dynamic learning environment that promotes deep understanding, critical thinking, collaboration, and preparedness for 21st-century challenges. The STEM-5E module uses an inquiry-based approach to education that encourages students to think critically, find answers, and investigate. It creates an environment in the educational setting that encourages inquiry and appreciates student-led research projects.

Future research can make use of a few recommendations from this study. Examining the STEM-5E module's effects at several educational levels—primary, secondary, and university—is one of them. The effect of using STEM-5E on additional dependent variables, including motivation, achievement, attitudes, career interest, etc., must be investigated. In addition, long-term research on the effects of using STEM-5E should be conducted.

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