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Real-World in Science Learning : An Science, Technology, Society (STS)-Based Science E-Module to Enhance Critical Thinking Skills

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Abstract: This study aims to develop a valid, practical, and effective STS-based science e-module to enhance critical thinking skills in supporting the science learning process. This research used Research and Development with a ADDIE model. The subject of this research were seventh grade students at MTsN 1 Jember. The data collection is done using primary and secondary data. Primary data include validity score, practicality score, and effectiveness score. Secondary data include interviews, observation, and documentation. The data analysis technique used in this research were validity test, practicality test, and effectiveness test. The results of the validity analysis show a category of very valid with a percentage of 89.4% based on validation sheets covering content and construct validation. The practicality analysis obtained from the implementation during the science learning process achieved a convenient category with a percentage of 92%. With an N-Gain score of 0.66 and a medium category, the e-module's effectiveness in assessing the development of critical thinking skills was determined by the results of the pre-test and post-test. Additionally, the effectiveness analysis data from student response questionnaires show a very positive category with a percentage of 83%. Thus, an STS-based science E-Module effectively enhances critical thinking skills and suitable for junior high school learning by connecting science concepts with real-world phenomena.

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Introduction

Natural Science (IPA) is a subject that discusses various events that occur in nature by understanding the cause-and-effect relationship of the underlying scientific process. Experts study and further develop multiple events in nature (Setyawan & Kristanti, 2021). Science learning requires students to learn various scientific concepts and conduct numerous experiments to build knowledge based on observation and empirical evidence (Siahaan et al., 2020; Dwipoyanti et al., 2024) This process helps students enhance critical thinking skills, apply scientific knowledge to solve real-world issues, and make science education essential in preparing them for future challenges.

Critical thinking skills are a crucial aspect of science learning. Critical thinking skills can be defined as a process of thinking by individuals that involves cognitive processes in an evaluative and analytical manner (Alsaleh, 2020; Putra et al., 2023) . Essential thinking skills require individuals to have reasons and goals for solving a problem, and making decisions also helps students describe and analyze problems systematically (Marudut et al., 2020;Wahono et al., 2022). So that students can face challenges, understand complex issues, and provide practical solutions based on facts, making them more active and productive in community life. The six indicators measured in critical thinking skills include interpretation, analysis, inference, evaluation, explanation, and self-regulation (Facione, 2015).

The Trends in International Mathematics and Science Study (TIMSS) as an international assessment reveals that critical thinking abilities remain low. In TIMSS 2011, Indonesia ranked 38th out of 42 countries. In addition, the following year, TIMSS 2015, Indonesia ranked 44th out of 49 countries (Hamzah & Dahlan, 2023). This weakness is mainly due to the monotonous learning process that cannot engage and motivate students effectively. To address this challenge, advances in technology and information have brought significant changes in various sectors, including education (Haleem et al., 2022). These technological innovations present opportunities to improve learning experiences, primarily through technology-based devices such as electronic modules.

Learning materials must now integrate technology and information to stay relevant. E-module is a digital version of a printed module that can be accessed through various electronic devices (Nuha et al., 2024). As a learning resource, e-modules are considered capable of helping students better understand concepts and improve learning outcomes by creating a different learning experience. E-modules are systematically arranged and designed with a specific applicable curriculum (Delita & Berutu, 2022). As digital learning materials, e-modules are designed to support the educational process using technology. E-Modules offer flexibility, allowing students to learn anytime and anywhere and content updates to ensure continued relevance (Erdi et al., 2022; Rofikoh et al., 2024).

The Science-Technology-Society (STS) approach in science education places a strong emphasis on applying scientific ideas to real-world problems (Rustiani & Supriyanto, 2020). The goal of incorporating the STS approach into scientific instruction is to help students comprehend how science and technology relate to one another, how science advances technology in society, and how technology affects society and the environment. (Putra, 2013). The stages of Science, Technology, Society (STS) learning are divided into five phases: introduction or apperception, concept development, application of concepts in everyday life, concept reinforcement, and evaluation or assessment (Poedjiadi, 2010). The STS approach is also expected to increase motivation in the learning process by integrating science concepts with an understanding of how technology and science contribute to various aspects of society so that students have many points of view to develop their concepts so that they can improve their critical thinking skills (Sundari & Oktaviani, 2024).

Some previous studies have provided several alternative solutions that can improve students' critical thinking skills towards scientific concepts in science learning. Based on research from (Sari et al., 2022) E-Modules can effectively improve students’ critical thinking skills however, the content of e-modules only focuses on delivering material and does not have interactive elements integrated with real-world applications. Research from (Jayadiningrat et al., 2022) howed that the Science, Technology, Society (STS) approach can be used as an effective learning method to contextualize science learning however, research on STS integration into digital learning media is still limited. This research develops STS-based science e-modules that explicitly integrate real-world contexts into science learning, enabling students to apply scientific concepts to everyday life phenomena (Sofiah et al., 2020). With a digital and interactive approach, this e-module connects theory with practice, makes science learning more interesting and relevant and is designed to improve students' critical thinking skills through exploration, analysis and real context-based problem solving.

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Research Method

This research used a Research and Development (R&D) method with a ADDIE model which consists of five phases as research procedures, including analysis, design, development, implementation, and evaluation (Branch, 2010). This development model analyzes learning needs, student characteristics, and competencies. The e-module was designed with science topics, namely temperature, heat, and expansion, to improve critical thinking skills. Its development includes review by experts to ensure its quality and accuracy. After that, the STS-based science e-modules were implemented in science classes and evaluated based on feedback from students and teachers to refine their quality and suitability for further learning. These five phases of the ADDIE model are shown in Figure 1.

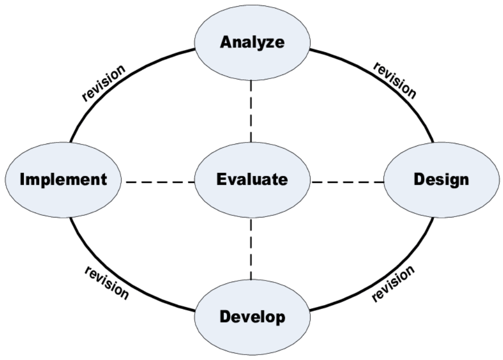

Figure 1. Five stages of the ADDIE (Branch, 2010)

The population consists of seventh-grade students from MTs Negeri 1 Jember, with 33 students from class VII F taken as samples in this research. Data collection techniques involved both primary and secondary data. Primary data included the validity, practicality, and effectiveness scores of the e-module that applied to science learning. Three experts evaluated the validity score, the practicality score was obtained through observation sheets during the science learning process, and the effectiveness score was obtained from pre-test results, post-test results, and student response questionnaires. Secondary data include interviews, observations, and documentation. The data analysis method applied in this study is as follows:

a) Validity Data

The data analysis method for the e-module validity was obtained from the validity assessment sheets assessed by three experts and calculated using the following formula:

$$V - ah = \frac{Total\ score\ achieved}{Total\ score\ expected}\ x\ 100\%$$

The results are adjusted to a specific scale grouped into four categories, namely, a very valid category for percentage values in the 81.25 < P ≤ 100 range. Valid category for percentage values in the range of 62.50 < P ≤ 81.25. Less valid category for percentage values in the range of 43.75 < P ≤ 62.50. Non-valid category for percentage values in the range of 25.00 < P ≤ 43.75 (Akbar, 2017).

b) Practicality Data

The data analysis method for the practicality of the e-module was obtained from observation sheets calculated with the practicality formula as follows:

$$Vp = \frac{Total\ assessment\ score\ collected}{Total\ score}\ x\ 100\%$$

The results of practicality data obtained are adjusted to a specific scale. The efficient category for percentage values is in the 81.25 < P ≤ 100 range. Practical category for percentage values in the range of 62.50 < P ≤ 81.25. Less practical category for percentage values in the range of 43.75 < P ≤ 62.50. Non-practical category for percentage values in the range of 25.00 < P ≤ 43.75 (Riduwan, 2013).

c) Effectiveness Data

Data on the effectiveness of e-modules were obtained from test results and student response questionnaires. The test was conducted using pre-test questions before the learning process and post-test afterward. By computing the difference between the posttest and pretest scores and dividing it by the difference between the maximum score and the pretest score, the N-Gain formula is used to assess how effective a learning process is. The N-Gain value obtained is adjusted to the N-Gain value category, which is divided into three categories. High category for N-Gain values ≥ 0.70, medium category for values 0.30 ≤ N-Gain < 0.70, and N-Gain values < 0.30 are categorized as low category (Hake, 1998). Students fill out a response questionnaire as feedback after conducting the science learning process, and to get the analysis, the sheet is calculated using the formula as follows:

$$P = \frac{Score\ of\ items\ obtained}{Total\ Score}\ x\ 100\%$$

The results obtained are adjusted to a specific scale which is grouped into four categories. The very positive category for percentage values in the 81.25 < P ≤ 100 range. Positive category for percentage values in the range of 62.50 < P ≤ 81.25. Less favorable category for percentage values in the range of 43.75 < P ≤ 62.50. Non-positive category for percentage values in the range of 25.00 < P ≤ 43.75 (Arikunto, 2006).

Results and Discussion

Analyze Stage

The Analyze stage in this research was conducted by observing classroom learning and interviewing teachers teaching science subjects at MTsN 1 Jember. Curriculum analysis shows that the school uses the Merdeka Curriculum, which allows teachers to apply flexible and contextual learning approaches. Science learning in this school is under phase D learning outcomes. Analysis of students indicated that students often feel bored and passive during science learning, as seen from their low participation and enthusiasm in class. This problem is partly caused by using conventional teaching materials that are less interactive and unable to attract attention effectively. This problem aligns with the statement of Jannah & Atmojo (2022) that the science learning process often emphasizes scientific concepts so that students memorize more than explore. As a result, students are less involved in expressing opinions and lack curiosity during learning. Students cannot answer questions requiring reasoning and connecting scientific theories with everyday problems. The development of science e-modules is needed to increase student engagement and critical thinking skills because the results of observations and interviews show low student engagement and undeveloped critical thinking skills.

Design Stage

The design stage focused on planning and developing STS-based science e-modules on temperature, heat, and expansion. This process also includes the preparation of learning tools to guide learning activities. Tools such as the flow of learning objectives and teaching modules were carefully designed to align with the desired learning objectives and outcomes. The E-Module includes several components, such as material explanations, sample problems, real-life applications, practice problems, and answer keys, thus providing a comprehensive and structured learning resource. The e-module design process starts from finding several

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science book references that are in accordance with the material and designing the layout using Microsoft Word. The science e-module is then converted in PDF format to be converted into a flipbook using Flip PDF Corporate software to be uploaded online and can be accessed via a link or QR Code. These components ensure that e-modules fulfill the main characteristics: self-instruction, self-contained, stand-alone, adaptive, and user-friendly (Daryanto, 2013). Thus, the e-module developed in this study becomes an effective and practical tool for science learning.

Develop Stage

The development stage focuses on refining the science e-module made at the design stage into a learning tool integrated with the Science-Technology-Society (STS) approach. In this process, the validity test is conducted by three validators to assess whether or not the e-module is feasible and determine that the module meets the criteria for effective learning. The e-module was developed by integrating the STS approach, which links science concepts with technology and its impact on society. Features related to the STS approach in this E-Module include the application of technology concepts, a brief explanation of the technology, and its operational principles based on scientific concepts. In addition, this module also includes real phenomena often encountered in society, thus helping students connect the science concepts they learn with the real world. The features of the STS approach in the e-module are shown in Figure 2.

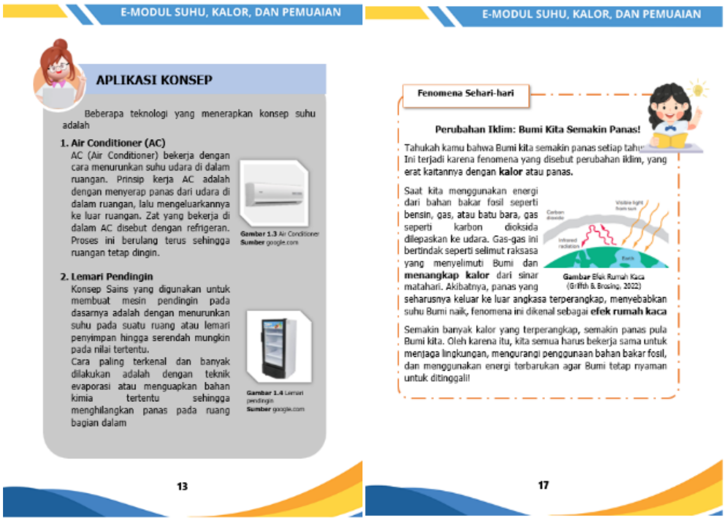

Figure 2. The features of STS-Based Science E-Module

The validity test aims to test the feasibility of the science e-module before it is implemented in learning. Three validators carried out the validity test, including lecturers of the Science Education Study Program at the University of Jember and teachers of natural science subjects at MTsN 1 Jember. The aspects validated by the validators include content, appearance, language, and graphics. These aspects play an important role in determining the feasibility of the Science E-Module to be used in learning.The results and analysis of the validity data of the STS-based science e-module are shown in Table 1.

Table 1. Validity Data of STS-Based Science E-Modul

Assessment Aspect	Interval Score (%)			Percentage (%)	Category
	1	2	3		
Content	0.90	0.85	0.85	87	Very valid
Appearance	0.94	0.88	0.94	92	Very valid
Language	0.88	0.75	1.00	88	Very valid

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Graphic	0.92	0.83	1.00	92	Very valid
Average	**0.91**	**0.83**	**0.95**	**89.4**	**Very valid**

The validity data analyzed from each aspect of the e-module in Table 1 from the three experts showed an average validation value percentage of 89.4%, included in the very valid category. This very valid result reflects that the STS-based science e-module can be confirmed as suitable for use in science learning because it has been proven to meet all the requirements of e-module development (Akbar, 2017). This statement aligns with the opinion of Nisrina et al. (2022) that the validity results show that the products developed have met the standards in terms of content and constructs, which include content, visual aspects, language, and presentation. The feasibility of the products is an important aspect to ensure the quality of the products and provide learning benefits.

Implement Stage

The implementation phase is the trial phase of using the STS-based science e-module in learning after it is declared valid and feasible. The implementation stage aims to test the effectiveness in improving students' critical thinking skills in learning using science e-modules. At this stage, observations and data collection are also carried out, such as the results of pre-tests, post-tests, and student response questionnaires to identify strengths and weaknesses of the science e-module. Product trials were conducted at MTsN 1 Jember with a research sample of 33 students in class VII-F for temperature, heat, and expansion material. Learning using E-Modules is done face-to-face with an allocation of 6 meetings or 12 lesson hours.

Learning activities begin with teachers introduce the topic in class through interesting phenomena or real-world problems to provide context and arouse curiosity. Next, students conduct observation activities outside the classroom, exploring the surrounding environment to collect relevant data. Students actively document their findings at the data collection stage, including measurements, photographs, or field notes. The data that has been collected is analyzed collaboratively with teacher guidance in the classroom. This is followed by the presentation phase, where students present their analysis through group presentations and discussions. The learning process ends with a reflection session, where students summarize learning outcomes, connect concepts with real-world applications, and receive constructive feedback from the teacher. Learning activities with STS-based science e-modules are shown in Figure 3.

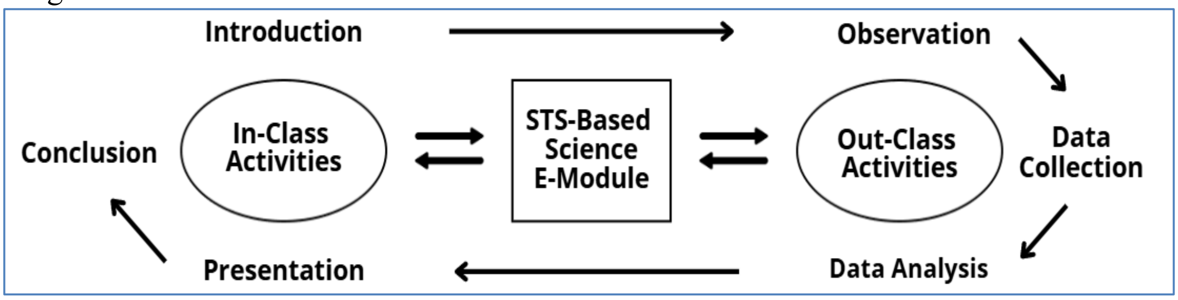

Figure 3. Learning activities with STS-Based science E-Module

The product trial activities were observed by three observers, who were students from the Science Education Study Program at the University of Jember, to obtain practicality data through a learning implementation sheet. The results and data analysis regarding the practicality of the science e-module can be seen in Table 2.

Table 2. Practicality Data of The STS-Based Science E-Module

Activity	Lesson to 1	2	3	4	5	Percentage (%)	Category
Introduction	0.94	0.85	0.92	0.90	0.81	88	Very Practical
Presenting the foundational concepts	0.83	0.92	0.83	0.92	0.88	88	Very Practical
Studying the introduction section	0.92	0.92	0.92	0.83	0.94	91	Very Practical
Linking teaching materials with other materials	0.83	0.92	0.83	0.92	0.75	85	Very Practical
Integrating technology into the application of science concepts	0.92	0.75	0.92	0.83	0.88	86	Very Practical
Using science concepts material in real-world situations	1.00	1.00	1.00	0.92	0.88	96	Very Practical
Conclusion	0.98	0.95	0.92	0.92	0.95	94	Very Practical
Average	**0.92**	**0.90**	**0.91**	**0.89**	**0.87**	**90**	**Very Practical**

The practicality assessment of the e-module based on the learning implementation observation sheet assessed by the observer for five meetings showed an average percentage of practicality reaching 93%, which is categorized as very practical. How practical a learning product is can be seen from how effectively it helps students understand concepts and materials in science learning and how easy it is to use (Wati et al., 2022). Arikunto (2006) also states that learning products are considered very practical if they are easy to use, have clear instructions, and are easy to understand.

Learning using Science-Technology-Society (STS)-based e-modules begins by introducing learning objectives and initial concepts associated with everyday phenomena. Students then study the introduction to understand the overview of the material. Next, students explore the application of concepts in modern technology and analyze how the concepts play a role in everyday life through discussions or simple projects. Learning ends with reflection and evaluation of understanding so that students not only understand the theory but can also relate it to technology and its impact on social life.

Learning with the STS approach helps students solve real problems that are found in everyday life. Students can analyze and describe issues, form understanding through concept exploration, and explain solutions based on the results of exploration (Jayadiningrat et al., 2022b). This process helps students understand the theory and develop analytical thinking and science-based problem-solving, making learning more meaningful and applicable.

Evaluation Stage

The evaluation stage is conducted after using STS-based science e-modules in science learning as the final phase of the ADDIE model, which assesses the effectiveness of utilizing STS-based science e-modules. The effectiveness is evaluated through pre-test and post-test results to determine critical thinking skills after using E-Modul during science learning and through student response questionnaires to gather their feedback after conducting the learning process. The N-Gain score to evaluate the enhancement of critical thinking skills was

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analyzed from the pre-test and post-test results after performing the learning process using the N-Gain calculation, which is presented in Table 3 as follows.

Table 3. Data analysis using the N-Gain Test

Component	Score		N-Gain	Category
	Pre-test	Post-test		
Total Students	33			
Lowest score	20.00	60.00	0.66	Medium
Highest score	60.00	96.70		
Average	40.00	78.35		
Standard Deviation	11.26	10.94		

The effectiveness analysis data calculated using the N-Gain formula reflects students' increased critical thinking skills. Pre-test and post-test were conducted by 33 students, with an increase from each test. The test scores increased from the pre-test with an average of 40 to the post-test score with an average of 78.4, which obtained an N-Gain value of 0.66, including in the medium category. These results show that learning with Science-Technology-Society-based e-modules can help improve students' critical thinking skills.

The standard deviation of the pre-test value is 11.26, and the post-test is 10.94. The more minor post-test standard deviation indicates that students' post-test scores are more centered and evenly distributed than the pre-test. This decrease suggests that students' understanding of the material has also become more uniform, which indicates the effectiveness of e-modules in improving critical thinking skills more consistently among students (Febriani, 2022). Table 4 shows the average N-Gain value for each essential skills of thinking indicator tested in the pre-test and post-test questions.

Table 4. The result of the N-Gain Test

Aspects of Critical Thinking Skills	Mean		N-Gain	Category
	Pre-test	Post-test		
Interpretation	54.8	93.6	0.86	High
Analysis	18.8	67.9	0.60	Medium
Evaluation	61.2	93.3	0.83	High
Inference	12.1	50.9	0.56	Medium
Explanation	34.5	66.7	0.52	Medium

According to Table 4, students are able to classify difficulties based on observations of the presented challenges, as evidenced by the interpretation indicator's N-Gain score of 0.86, which falls into the high range. With an N-Gain score of 0.60, the analytical indicator fell into the medium group, indicating that students are able to recognize issues and provide arguments pertaining to the topics presented (Hidayati et al., 2021). With an N-Gain score of 0.83, the evaluation indicator fell into the high group, demonstrating students' capacity to solve issues rationally by following the right procedures (Rosmalinda et al., 2021). The inference indicator is r is classified as medium with an N-Gain score of 0.56, indicating that students can logically infer the relationship between concepts and information in the problem, supported by empirical evidence. Similarly, the explanation indicator obtained an N-Gain score of 0.52, which is in the moderate category. It indicates that students can draw conclusions logically and provide evidence or justification to support their findings (Chusni et al., 2020).

The interpretation indication received the greatest N-Gain score, according to the analytical data derived from the N-Gain score values for each indicator. The explanation indicator, on the other hand, had the lowest N-Gain score. This outcome indicates that the learning process for STS-based science e-modules is executed successfully. These results align with the opinion of Ichsan et al. (2023) that the effectiveness of a learning process can be evaluated based on the delivery of material based on predetermined learning objectives.

The effectiveness of STS-based science e-modules is also obtained from student response questionnaires filled out by students after carrying out the learning process using STS-based science e-modules. The student response questionnaire contains several statements which are divided into two aspects, namely student assessment of learning activities with e-modules and student assessment of the e-modules used. Data analysis of student response questionnaires that students have filled in are presented in Table 5.

Table 5. Analysis of student response quistioner

Aspect	Total Score	Percentage (%)	Category
Learning activities	658	83	Very Positive
An STS-based science e-module as learning materials	996	84	Very Positive
Average	**827**	**83**	**Very Positive**

Based on Table 5, the analysis of the student response questionnaire shows an average score of 83%, which is included in the very positive category. This indicates that in its implementation, students feel more involved and easier to follow the learning process when using Science-Technology-Society (STS)-based science e-modules. This result aligns with (Hamzah et al., 2022), who stated that the student response questionnaire serves as a measuring tool to find out their perspective on the learning process while evaluating their level of interest and ease in understanding the material being taught. Thus, the use of STS-based e-modules not only increases student participation, but also supports better understanding of the concepts learned, so it can be an effective learning strategy in improving the quality of science learning.

The results of this study show that the use of STS-based science E-Modules that these E-Modules are valid, practical, and effective in science learning. STS-based science E-Modules are able to improve deeper understanding of concepts by encouraging students to explore scientific phenomena in relation to the development of society and technology. This research highlights the importance of real-world context to be integrated in science learning so that it can help students connect scientific concepts with everyday life and understand concepts better through inquiry and problem-solving activities. Practically, this research provides a framework for implementing STS-based science E-Module in science learning. The results show that teachers can utilize interactive digital learning materials to make science lessons more interesting and relevant, which in turn can improve students' critical thinking skills.

Conclusion

The STS-based science e-module, designed to enhance critical thinking skills, achieved a validity test score of 89.4% and was classified as a very valid category. Its practicality was rated as very practical, scoring 90% according to the application of the learning process. The effectiveness achieved a medium predicate with the N-Gain score of 0.66, and a student response questionnaire achieved a very positive category with an effectiveness score of 83%. This result shows science learning using an STS-based science e-module enhances critical thinking skills. The analysis result in this research indicates that the STS-based science e-module is suitable for use in junior high school. This developed e-module can support learning by linking science concepts with phenomena around them. In

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addition, this science e-module can enhance critical thinking skills through its learning activities.

Recommendation

For teachers, it is recommended to use STS-based Scienve E-Modules into science learning to enhance critical thinking skills by connecting science concepts with real-world contexts. In addition, combining digital learning tools with classroom discussions can help students to apply science concepts in everyday life. For future researchers, further research could focus on improving the design and features of STS-based e-modules, by incorporating more interactive elements such as simulations and virtual experiments.

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