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Practicality and Effectiveness of STEM-R Electronic Modules in Improving Students' Mastery of Material on Environmental Conservation

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The development of internet-integrated teaching materials is important in meeting the demands of education in the era of globalization, which allows students to access information quickly and keep it up-to-date. In addition, integrating various branches of science in teaching materials can enrich students' knowledge, improve critical thinking skills, and prepare them to face global challenges. This study aims to analyze the feasibility of STEM-based electronic modules on environmental conservation materials, the practicality of STEM-R-based electronic modules on environmental conservation materials, and the effectiveness of STEM-R-based electronic modules in improving mastery of environmental conservation materials. This study uses the Research and Development (R&D) method with the ADDIE model, which consists of five stages: analysis, design, development, implementation, and evaluation. The subjects of this study involved media experts, material experts, biology teachers, and students, while the object of the study was the STEM-R-based electronic module. Data collection techniques used include Validation sheets to assess the feasibility of the module, practicality questionnaires to evaluate the practicality of the module, and test instruments to measure the module's effectiveness in improving mastery of environmental conservation material concepts. The study results showed that the developed electronic module was declared feasible with an overall Content Validity Ratio (CVR) and Coefficient Validity Index (CVI) value of 1, the developed electronic module was declared very practical with a practicality percentage of 96.17%, and the developed electronic module obtained an N-Gain value of 0.64. The STEM-R-based electronic module is categorized as moderately effective in improving students' mastery of environmental conservation material.

1. Introduction

The 21st century is marked by significant changes in almost every aspect of human life, especially those influenced by the rapidly growing globalization (Stearns, 2023; Folke et al., 2021). Globalization, which has connected the world more, has affected social and economic relations and significantly impacted education systems in various parts of the world (Etistika et al., 2016; Grinin et al., 2021). The education world faces new challenges that require a

paradigmatic shift to adapt to the speed of technological change and evolving social needs (Redhana, 2019; Imamov & Semenikhina, 2021). One of the most prominent changes is the shift towards more technology-based learning, where digital skills are becoming indispensable (Jannah et al., 2020; Alakrash et al., 2021).

Adaptability in the digital era in the world of education is required to align learning with the demands of the times, especially in fields such as biology, which are highly dependent on the development of science and technology (Zubaidah, 2020; Srivastava, 2023). Therefore, using information and communication technology in biology learning is unavoidable (Makuru & Jita, 2022). ICT is a tool to increase access to learning resources and a bridge to create a more interactive and contextual learning experience for students (Blyznyuk, 2019; Alam & Mohanty, 2023; Hernandez-de-Menendez et al., 2020). This transformation has significant implications for developing learning materials and teaching methodologies that must be adjusted to technological developments.

Along with rapid technological advancement, various innovations have enabled biology learning to be carried out more interestingly and efficiently. The use of electronic modules offers various advantages, such as accessibility, time flexibility, and more and more diverse resources (Arnila et al., 2021; Culajara et al., 2022; Castroverde & Acala, 2021; Stecuła & Wolniak, 2022). With multimedia integration in e-modules, students can access various forms of more dynamic learning materials, such as animations, experimental videos, and interactive simulations, making it easier for them to understand complex biological concepts. This aligns with the global trend that encourages technology-based education to be more inclusive and equitable. Technology has developed rapidly, but not all schools in Indonesia can make maximum use of these digital resources. Based on observations at one school in Cirebon Regency, biology learning still uses a traditional approach with limited print media. A classroom technology implementation gap, especially in areas with inadequate infrastructure (Sahlani, 2020; Gupta & Hayath, 2022). This gap hinders the learning process, which should be utilized more optimally to improve students' understanding of the ever-evolving biology material. Therefore, further efforts are needed to improve digital literacy among teachers and students so that technology can be truly integrated into learning effectively.

The integration of technology in learning is not only limited to delivering material. However, it must also involve a broader interdisciplinary approach, such as that offered by the STEM (Science, Technology, Engineering, and Mathematics) approach. The STEM approach has received attention from science education experts and researchers (Firat, 2020). STEM competencies that will prepare students for a productive future (Tyler, 2020). STEM approach is very relevant in biology education because it allows students to connect biological theory with practical applications in the real world (Rubini et al., 2021). The STEM learning approach can potentially develop students' creativity skills (Aguilera & Ortiz-Revilla, 2021). The study results suggest that biology teachers apply the STEM approach in presenting scientific concepts (Županec et al., 2022). In the STEM approach, students learn about biological concepts. They are trained to solve problems related to technology and engineering, which are increasingly relevant in the context of the current global environmental crisis.

21st-century biology education must be more holistic, considering the interactions between various disciplines that can solve global challenges, including increasingly pressing environmental problems. Biology learning at various levels of education shows less than satisfactory results and requires significant improvement. The cause of low conceptual mastery is due to learning that is less meaningful for students and minimal student involvement in learning. A study conducted by Burns et al. (2022) showed that the understanding of basic concepts in biology courses at the university level can be improved through asynchronous online interactive lessons, which provide

more flexibility and engagement to students. Usman et al. (2023) found that implementing STEM problem-based learning significantly improved the achievement of secondary school students in biology in Nigeria. In Serbia, a study by Županec et al. (2022) showed that the STEM approach in teaching biology in primary schools was more efficient than conventional methods. Meanwhile, Irdawati et al. (2023) developed a STEM-based biology e-module, which was proven to improve student learning outcomes. Based on the literature, it is clear that applying STEM-based learning methods, either through interactive learning, problem-based learning, or e-modules, can be an effective solution to overcome low-biological learning and improve overall student learning outcomes.

Biology learning must also integrate environmental issues into every material taught, considering the increasingly real challenges of climate change and environmental damage (Eilam, 2022; Hogan & O'Flaherty, 2021; Molthan-Hill et al., 2022). Environmental-based education is essential for students with strong scientific knowledge, social awareness, and responsibility for environmental sustainability (Purnama, 2020; Yusuf & Fajri, 2022). Learning that integrates environmental issues closely relates to religious aspects (Okyere-Manu, 2022; Abdullah & Keshminder, 2020). Using e-modules that integrate STEM, environmental aspects, sustainability, and religious values, students can learn about theoretical biological concepts and their applications in sustainable natural resource management. This study explores the use of Religious STEM-based e-modules as an innovation in learning to improve students' mastery of environmental conservation concepts. Religious STEM-based electronic modules are designed to enhance mastery of biological concepts and promote environmental sustainability. This study involved several high school students learning using religious STEM-based e-modules. Implementing this module enriches STEM learning and strengthens relevant religious values as an innovative and holistic learning strategy supporting sustainable education.

2. Method

This research and development study implements the ADDIE instructional development model, which consists of five systematic stages: Analysis, Design, Development, Implementation, and Evaluation. At the analysis stage, the researcher conducted a needs assessment through field observations, curriculum reviews, and structured interviews with subject teachers to obtain empirical data on the actual conditions of the learning process and the need to develop relevant teaching media. The design stage was completed by compiling an initial design (blueprint) for an electronic teaching module based on STEM-R, which integrates the principles of scientific literacy and a contextual learning approach. At the development stage, the module was designed using Canva Education and Flip PDF Professional software based on pedagogical and technical considerations, namely the device's ability to produce interactive, aesthetic media and compatibility with students' digital devices. The initial product was then validated by five experts, consisting of 2 academics and three education practitioners, focusing on content feasibility, media design, and language. The product was tested through limited and large-scale field trials at the implementation stage. Limited trials were conducted on a small group of students (n=10) to identify the readability of the content, the quality of the visual display, and the ease of navigation of the module.

Meanwhile, extensive trials involved two groups of students, the experimental group and the control group (n=30 each), using a quasi-experimental nonequivalent control group pretest-posttest design. The research instruments consisted of expert validation sheets, student response questionnaires, and concept mastery tests developed based on previously prepared learning indicators. Analysis of module validity data using CVI, analysis of understanding of biology concepts using N-gain.

3. Result and Discussion

Developing an electronic module begins with a design using the Canva application, which provides various creative features for designing elements, such as covers, pages, and paragraph layouts in learning materials. Canva, as an online graphic design platform, allows researchers to create interactive and attractive designs with easy access and flexibility. After completing the design, the results are downloaded in PDF format and processed using the Heyzine application. This application converts PDF files into a more interactive e-module format, with additional features such as adding video elements, setting navigation, and creating quizzes to make the learning experience more dynamic and adequate for student needs. Once completed, the module is saved as a link that can be shared with students, facilitating the practical and efficient distribution of materials. The next stage is product validation by material and media experts to ensure the quality and suitability of the module with the applicable curriculum. This validation process aims to evaluate the suitability of the material, design quality, and the relevance of the module content in supporting the learning objectives that have been set.

Table 1. Product validation results

	Item 1	**Item 2**	**Item 3**	**Item 4**	**Item 5**	**Item 6**	**Item 7**	**Item 8**	**Item 9**
Ne	5	5	5	5	5	5	5	5	5
CVR	1	1	1	1	1	1	1	1	1
CVI	1	1	1	1	1	1	1	1	1
Conclusion	Relevant	Relevant	Relevant	Relevant	Relevant	Relevant	Relevant	Relevant	Relevant

Based on the validation results of the electronic module structure, as shown in Table 1, all items obtained a Ne score of 5, indicating that the five validators agreed on the relevance of each module component. The Content Validity Ratio (CVR) and Content Validity Index (CVI) values for all items were 1, indicating that each part of the module had very high content validity. This achievement reflects the suitability of the module structure with the learning content eligibility standards, including elements such as the cover, introduction, content, and closing section. Thus, the structure of the electronic module can be categorized as highly relevant and suitable for use in the learning context because it has met substantial criteria based on expert assessments quantitatively and qualitatively.

The electronic module that has been developed has received a very positive assessment based on the results of the Content Validity Ratio (CVR) and Content Validity Index (CVI).

Table 2. Recapitulation of expert validation results

Object	**Average CVR**	**Description**	**CVI Average**	**Description**
Material Aspect	1	Eligible	1	Valid
Media Aspect	1	Eligible	1	Valid

Based on the results of expert validation in Table 2, the structure and content of the module have been developed systematically and by the standards for developing scientifically valid teaching tools (Lawshe, 1975; Zamanzadeh et al., 2015). Furthermore, the suitability of the material in the module with learning outcomes is also shown through the presentation of content that is not only complete but also discussed in depth and contextually. Each topic is packaged with a holistic approach, allowing students to gain a theoretical and applicable understanding.

This aligns with the view of Sabarudin (2018), who emphasizes the importance of selecting materials that align with learning objectives so that students can optimally achieve the expected competencies. This module also avoids misconceptions by selecting accurate illustrations, visualizations, and evaluation instruments, which, according to Kurniawati et al. (2014), are the key to building a deeper and more correct understanding of concepts in students.

Another aspect that stands out is the module's success in arousing students' curiosity by presenting up-to-date material relevant to current environmental issues. By presenting interesting and informative content, this module can increase student engagement in the learning process; as Novelyya (2019) expressed, curiosity plays an important role in motivating and improving student learning outcomes. The high interactivity of the module is also an added value because its features are designed to be easy to use and visually appealing. Dewi (2020) states that interactive teaching materials can significantly increase learning effectiveness and students' understanding of concepts. The feasibility of the module is also strengthened by its flexibility in use on various electronic devices and its neat and professional visual layout. With a consistent and user-friendly appearance, the module can be accessed via smartphones, laptops, or tablets. Integrating visual elements such as videos, images, and scientific articles further enriches the student's learning experience. In line with research by Hambali and Natsir (2023), integrating technology in learning can expand access to information and improve the quality of student understanding. An attractive visual appearance, consistent margins, and a neat layout motivate students to continue learning (Camelia et al., 2023). Thus, based on high content validity and comprehensive module development quality, this module is suitable for STEM-R-based environmental conservation learning.

The student response questionnaire plays an important role in evaluating the effectiveness of the developed electronic module by assessing aspects of ease of use, attractiveness, and creativity of material presentation. This instrument was distributed to 35 students via Google Forms to facilitate filling in and collecting data. The questionnaire results were analyzed to obtain an accurate picture of the students' learning experience and evaluate the extent to which the module could attract attention, was easy to use, and encouraged critical thinking through the innovative presentation.

Table 3. Summary of practical questionnaire results

Average Score Obtained	Maximum Score	Obtained Score	Obtained Score	Interpretation
4.81	1750	1683	96.171%	Very Practical Product

Based on the results of the practicality questionnaire analysis in Table 3, the developed electronic module showed a very high level of practicality with a percentage of 96.171%. This indicates that the module is included in the "convenient" category because it can meet various functional aspects such as readability, ease of use, and effectiveness in conveying information to students. The positive response from students to this module strengthens the validity of its practicality in supporting the learning process efficiently and enjoyably.

Pedagogically, this electronic module has succeeded in facilitating interactive learning that is not only interesting but also encourages students' learning motivation. The material is presented visually and contextually to stimulate students' curiosity and facilitate understanding of concepts. This aligns with the findings of Febliza et al. (2023), which state that interactive modules can

improve students' critical thinking skills and mastery of concepts, making them an effective and innovative learning tool.

The module is also designed with efficiency of use in mind. It can be accessed without special hardware or a stable internet connection, making it suitable for various technical conditions. Maskar and Dewi (2020) stated that the effectiveness of a teaching module is partly determined by the flexibility of its use in limited conditions. Thus, this module is resource-efficient and inclusive for students with limited access to technology. Moreover, this electronic module stands out for its creativity in delivering the material. Integrating photos, videos, enrichment sheets containing Islamic values, and evaluation sheets makes it an informative and educational learning tool. Wilda and Ekawati (2017) emphasized that a high level of creativity in a module can significantly increase students' interest in learning, thus having a positive impact on learning outcomes.

The electronic module was implemented in six meetings in the experimental class with the STEM-R approach, starting with a pretest to measure students' initial abilities, followed by group learning. This module deepens students' understanding through the integration of scientific disciplines. After the session, students took a posttest to evaluate their improvement in understanding. As a comparison, the control class used printed books, and the pretest and posttest results were used to assess the effectiveness of the electronic module.

Table 4. Recapitulation of student scores

Class	Pretest Score Average	Posttest Score Average	N-Gain Score	Score Interpretation
Control	63.714	81.429	0.488	Increased:Moderate
Experimental	71.429	89.714	0.640	Increased:Moderate

Table 4 shows that both control and experimental classes experienced significant improvements in test results, with the difference being more evident in the experimental class. Pretest and posttest analyses showed that the experimental class had higher initial achievement and experienced greater improvement after implementing STEM-based electronic modules. The higher N-Gain value in the experimental class indicated that electronic modules integrated with science, technology, engineering, mathematics, and the inquiry approach had a more substantial positive impact on understanding the material. This approach improves students' knowledge and connects scientific concepts with religious values, providing a more relevant and holistic learning experience.

In developing this teaching material, learning with the STEM approach integrates systematic steps: observation, planning, action, experimentation, evaluation, and reflection. In this process, students actively identify problems around them and design solutions through careful planning. The next step involves practical actions, such as developing tools for experiments, which aim to test the hypotheses that have been formulated. Evaluation is carried out to measure the effectiveness of the proposed solution, and reflection serves as a means to discuss the experimental results obtained. This learning emphasizes theoretical understanding and hones students' critical and analytical thinking skills in dealing with real problems. As stated by Wahono et al. (2020), learning with the STEM approach has proven effective in improving students' higher-order thinking skills and academic achievement. In addition, the STEM

approach that integrates aspects of science, technology, engineering, and mathematics (STEM) encourages students to understand the interrelationships between disciplines, thereby enriching their mastery of concepts in depth. The study results showed that the STEM approach in biology teaching improves student performance and engagement and contributes to reducing students' mental effort (Županec et al., 2022). Teaching with STEM can improve mastery of biological concepts (Burns et al., 2022). Integrating STEM problem-solving into learning will train students in mastering concepts and reasoning (Tan et al., 2023). The STEM approach also supports deep and collaborative learning in students (Miller et al., 2017). The STEM learning environment increases learning motivation and maintains it for an extended period (Fortus & Vedder-Weiss, 2014).

The learning module developed with the STEM approach is designed to stimulate critical thinking, strengthen students' problem-solving skills, and enable them to connect environmental conservation concepts with various disciplines in an interdisciplinary manner. Chen et al. (2024) also showed that integrating science, technology, engineering, and mathematics in learning can improve students' mastery of concepts. This approach provides opportunities for students to access more practical learning experiences, which are not only limited to theory but also involve exploring and applying concepts in real-life contexts. Thus, STEM-based learning improves scientific literacy and higher-order thinking skills, contributing to a more comprehensive understanding of environmental conservation (Prasetyo et al., 2021; Wahono et al., 2020).

The STEM approach in biology learning can improve thinking skills and mastery of biological concepts (Zakiyah et al., 2021), develop students' creativity skills (Aguilera & Ortiz-Revilla, 2021), and biology learning outcomes (Usman et al., 2023). Biology learning that integrates STEM and e-modules can improve student learning outcomes (Irdawati et al., 2023). STEM project-based learning in the science curriculum aims to improve learning achievement and higher-order thinking skills (Le et al., 2023). Problem-based learning and projects integrating STEM are highly recommended in learning (Larkin & Lowrie, 2023). The STEM approach to learning contributes to developing students' thinking skills, improving achievement, and increasing students' interest and motivation in learning (Jawad et al., 2021).

The Realistic Approach to developing teaching materials offers a deep and applicable learning model, prioritizing active student involvement in the learning process. Through this approach, students are not only recipients of information but also active in designing, exploring, and solving problems collaboratively. This is achieved by integrating elements of collaborative learning and guided discovery, which allows students to develop a deeper understanding of the concepts they learn (Güneş et al., 2020). Thus, this approach's teaching materials aim to create an interactive learning environment and enrich students' learning experiences, enhancing their critical and analytical thinking skills. In addition, this approach also provides space for students to develop their models or solutions, which not only strengthens conceptual mastery but also stimulates their creative abilities in solving contextual and relevant problems. The STEM approach can enhance entrepreneurial thinking in students, including self-confidence, thinking skills, risk-taking, leadership, creativity, and foresight (Akrami, 2022). STEM encourages real-world learning that allows the transfer of learning between different levels and disciplines of science, thus facilitating a more interconnected, deeper, and meaningful learning process (Videla et al., 2021)

The teaching module developed using the Realistic Approach presents concrete environmental issues, such as the problem of river pollution and its impact on human life. This issue is relevant

to the real situation faced by the community so that students can experience firsthand how environmental conservation concepts relate to challenges in the real world (Encarnación et al., 2024). This real-world problem-based learning allows students to understand and relate the theory to everyday practices. This approach encourages students to respond to environmental problems with real actions through critical thinking about applicable solutions and developing initiatives that are beneficial for environmental conservation. Therefore, applying the Realistic Approach in the teaching module allows students to become independent and creative learners while strengthening their awareness of social and environmental issues that are very important for their future (Encarnación et al., 2024). Integrating aspects of religious values in biology learning on environmental conservation material provides a new nuance for students. Religious values pay serious attention to environmental and climate change issues (Singh et al., 2021; Mohamad & Ismail, 2023). This aligns with the results of studies stating that education in the Islamic tradition plays a role in environmental conservation (Bsoul et al., 2022; Pasaribu et al., 2022).

4. Conclusion

The developed module has high feasibility with a Content Validity Ratio (CVR) and Content Validity Index (CVI) value of 1, indicating that the material presented is relevant and aligned with the learning objectives. This module is also proven to be practical, with a practical value reaching 96.171%, which reflects ease of use, efficiency, and creativity in its design, thus providing a comfortable and practical learning experience. In addition, this module effectively improves mastery of environmental conservation concepts, as evidenced by the N-Gain value of 0.64, which shows a moderate increase. The STEM approach applied in this module has improved students' critical thinking skills and creativity. As a suggestion, teachers are expected to utilize this module to improve students' understanding of environmental conservation and encourage creativity in integrating technology into learning. Students should utilize this module optimally at school and at home to deepen their understanding of environmental conservation and develop independent learning skills. Further researchers are advised to develop this research by expanding the scope of field trials, using the latest technology, and integrating religion-based STEM more proportionally to improve students' critical thinking skills and creativity.

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