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DEVELOPING SCIENCE E-MODULE BASED ON MANGROVE ECOTOURISM PROJECT TO FOSTER SCIENTIFIC CREATIVITY IN ISLAMIC HIGHER EDUCATION

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ABSTRACT
This study aimed to develop a science e-module based on a mangrove ecotourism project that is feasible, practical, and effective in increasing student scientific creativity in Islamic higher education. This study used the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation). The e-module is designed by integrating interactive technology-based environmental learning materials. Data were collected through questionnaires, observations, tests, and interviews to assess the feasibility, practicality, and effectiveness of a science e-module developed as part of a mangrove ecotourism project to improve students' scientific creativity. The finding showed that the science e-module based on the mangrove ecotourism project was feasible, practical, and effective in enhancing students' scientific creativity. The validation results of the science e-module based on the mangrove ecotourism project were 96.25% included in the category of "very feasible to use". The results of the e-module evaluation showed that most respondents gave a positive assessment. The results of the effectiveness test showed that the use of this e-module significantly improved students' scientific creativity ($p = 0.00$). This is because the use of e-modules can develop students' critical thinking, problem-solving, and creativity in solving environmental problems. This study advocates for the incorporation of electronic modules into the science education curriculum at universities, recognizing their potential to serve as innovative tools supporting the enhancement of students' scientific creativity within the realms of environmental education and technological applications.

Keywords: E-Module; Project-Based Science; Mangrove Ecotourism; Scientific Creativity

INTRODUCTION
Increasing environmental problems, including pollution of mangrove ecosystems, have become an urgent global issue to be addressed (Lovelock et al., 2024). Mangrove ecosystems, which are among the most productive coastal ecosystems, play an important role in maintaining the balance of marine ecosystems (Khan et al., 2024; Wang et al., 2024). Mangroves function as natural protection from abrasion, carbon sinks, habitats for various organisms, and natural filters for waste entering the sea (Hasim, 2021; John et al., 2022). However, these ecosystems are increasingly threatened by pollution from human activities, such as industrial and household waste disposal and land conversion for development.

Mangrove destruction not only impacts the physical environment but also threatens the economic and social sustainability of coastal communities that rely heavily on these ecosystems (Akram et al., 2023; Bhowmik et al., 2022). Ironically, public awareness of the importance of conserving mangroves is still very low, especially among the younger generation (Vo Trung et al., 2020; Bhagarathi & DaSilva, 2024). This is exacerbated by the lack of comprehensive and effective environmental education in conveying the urgency of conserving mangrove

ecosystems (Arifanti et al., 2022; Hussain, 2023; Del Cid-Alvarado et al., 2024). Therefore, environmental education plays a strategic role in building ecological awareness in the community about the importance of mangrove ecotourism (Hayati et al., 2024; Mardianton, 2024; Sucilestari et al., 2023a), especially among the younger generation, who will be decision-makers in the future.

However, the environmental learning approach applied so far tends to be conventional and oriented towards the delivery of knowledge alone (Vasconcelos & Orion, 2021). This traditional approach is less effective in encouraging students to develop the scientific creativity needed to deal with complex environmental challenges, including mangrove ecosystem pollution (Mualimin & Pamungkas, 2024). Scientific creativity includes the ability to think critically, innovatively, and collaboratively to solve multidimensional problems (Siriphatcharachot et al., 2025). Scientific creativity refers to the capacity to produce novel ideas, implement innovative solutions to problems, and develop original approaches for addressing various issues, particularly those concerning the environment (Adeoye & Jimoh, 2023). In the context of environmental challenges, scientific creativity is an important skill that must be instilled early on through education.

Based on the literature review, there is a gap in environmental learning methods that can integrate digital technology to encourage students' scientific creativity. Most of the prior studies concentrated on the development of a knowledge-based learning module that emphasizes solely theoretical aspects. (Ates & Aktamis, 2024; Chappell & Hetherington, 2024). However, research on developing 21st-century skills, such as scientific creativity, remains limited. The development of scientific creativity is significant in preparing the younger generation to deal with complex environmental problems (Oschepkov et al., 2022; Dilnoza, 2023), such as mangrove ecosystem pollution, which requires an interdisciplinary approach (Horn et al., 2022).

This research aims to fill the gap by developing a science e-module based on the mangrove ecotourism project, specifically designed to foster students' scientific creativity in the context of environmental education. The e-module is designed not only to provide information on mangrove ecosystem pollution but also to integrate interactive activities, case studies, and project-based assignments. This approach is designed to challenge students to develop creative and innovative solutions to environmental pollution problems.

The novelty of this research lies in the approach used, the development of a science e-module based on a mangrove ecotourism project, a combination of digital technology, the development of scientific creativity, and a focus on real cases of mangrove ecosystem pollution. By integrating technology into the learning process, this research not only provides a more engaging learning experience for students but also prepares them with relevant skills in the digital era. In addition, this research makes a theoretical contribution by offering new insights into how educational technology can support the development of 21st-century skills, particularly in environmental education.

The implications of this research are vast. Practically, the developed e-module can be adopted by educators as an innovative learning tool, especially in coastal areas affected by pollution. This module is expected to increase students' awareness of the importance of protecting mangrove ecosystems while equipping them with the skills to take concrete actions in environmental conservation. Theoretically, the results of this study will enrich the literature on ecotourism-integrated project-based pedagogical approaches and the utilization of technology in environmental education and serve as a basis for further research in the field of science education. Thus, this research is expected not only to provide solutions to current environmental learning problems but also to contribute to the preservation of mangrove ecosystems for future generations.

METHOD

This research uses Research and Development (R&D) with the ADDIE model (Analyze, Design, Develop, Implement, and Evaluate) (Mdodana-Zide, 2024). The R&D approach was chosen because this research aims to develop a product, namely a science e-module based on a mangrove ecotourism project that can be used to increase scientific creativity in environmental education, especially on mangrove ecosystem pollution material. The ADDIE model was chosen for its suitability in a systematic and structured instructional development process (Aydin et al., 2023).

Figure 1 explains the stages of ADDIE development, including: **Analyze**. At this stage, the problems in environmental education related to mangrove ecosystem pollution were identified through surveys, interviews, and discussions with teachers, students, and experts. The analysis also included the characteristics of the target students and the material to be taught, aiming to determine the needs and challenges that the e-module must address; **Design**. After the needs analysis, the design stage focuses on planning the e-module, including learning objectives, content, and activities to support scientific creativity. The design features interactive elements such as videos, quizzes, simulations, and case studies on mangrove ecosystem pollution, as well as media, interface layout, and features for independent experiments, observations, and problem-solving. **Develop**. In this stage, the e-module is developed and programmed based on the previous design, using a suitable platform for easy accessibility. Digital content such as text, images, animations, and videos is created, and coding is used to add interactivity. The initial prototype is tested in small groups to gather feedback on readability, functionality, and learning effectiveness; **Implement**. The implementation stage occurs after improving the e-module based on pilot test results. The finalized e-module is used in the selected college, with teacher training on its use in learning activities. Students are given independent or small group access to the module and tasks related to mangrove ecosystem pollution to encourage their scientific creativity; **Evaluate**. The evaluation stage aims to assess the effectiveness of the e-module through formative evaluation during development and implementation, and through summative evaluation after implementation. The summative evaluation collects data on students' creativity and satisfaction through questionnaires, interviews, and teacher feedback. The results of the evaluation are used for final improvements to the e-module.

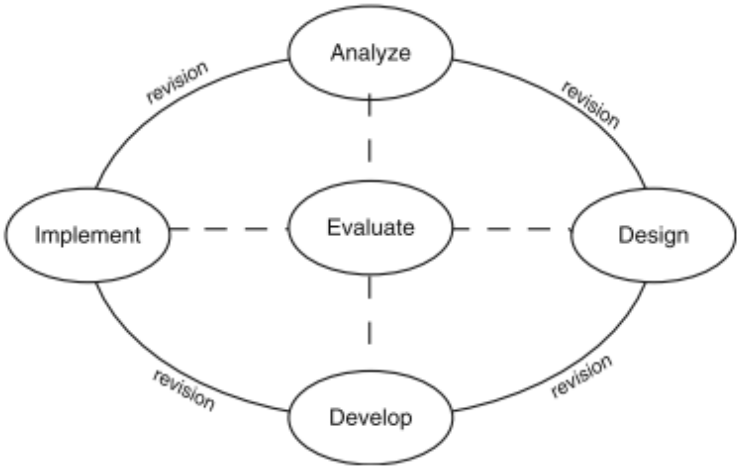


Figure 1: The ADDIE Concept (Branch, 2009)

This development research involved three experts for the validation test of the developed e-module. This research also involved 218 students of the Pendidikan Guru Madrasah Ibtidaiyah (PGMI) Study Program at Universitas Islam Negeri Mataram, with 186 females and 32 males.

The implementation stage of the developed e-module involved 41 students, while the evaluation stage of the e-module involved 74 students divided into 2 different classes. Especially students who take courses related to science, who are in coastal areas, facing the problem of mangrove ecosystem pollution. This selection aims to provide a relevant and applicable context for the environmental issues under study.

The instruments used in this study include several methods to measure various aspects of learning. First, a questionnaire was used to measure student satisfaction with the e-module that had been implemented. In addition, a scientific creativity test was conducted to assess the effectiveness of using the e-module. Observations were conducted to assess students' participation in the activities provided by the e-module. In contrast, interviews with students and lecturers were held to gather feedback on their experience using the e-module.

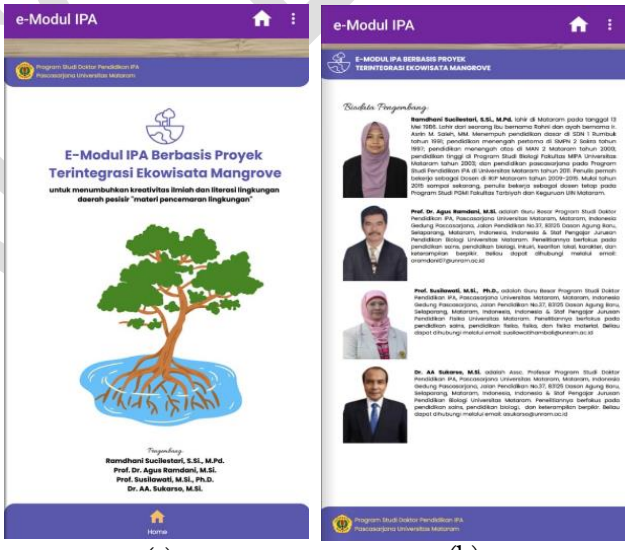
RESULTS AND DISCUSSION

Analyze

The results of the needs analysis in learning related to mangrove ecosystem pollution show that the existing material is difficult for students to understand due to a lack of engaging and interactive resources. Students prefer technology-based learning that is contextual and applicable. Most students have limited knowledge about mangrove pollution and require a more dynamic and relevant approach to everyday life, such as using multimedia in the e-module. The developed e-module is expected to present the material in an easier-to-understand manner, raise students' awareness of the importance of mangrove conservation, and address the challenges in learning about mangrove ecosystem pollution.

Design

Figure 2 describes the front and back covers of the module. The front cover of the module features an illustration of a mangrove tree that reflects the module's main focus. The back cover of the e-module features the authors' profiles, showcasing their academic backgrounds and contributions to the development of this material.

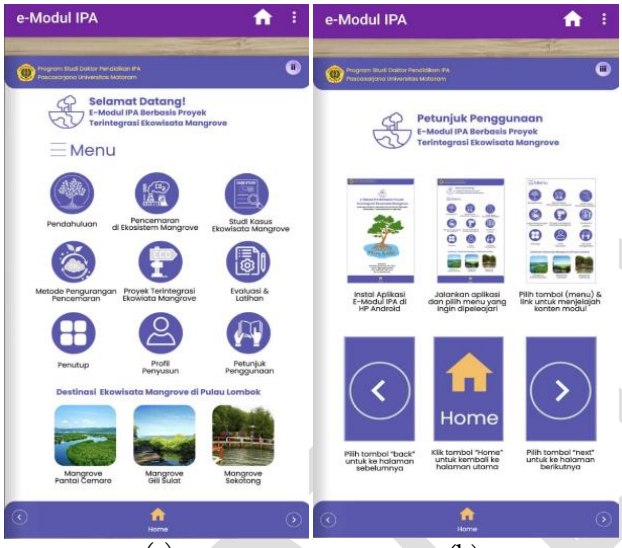


(a) (b)

Figure 2: E-modul cover: (a) Front cover e-modul, (b) Back cover e-modul

Figure 3 shows the prominent display of the module, which presents an interactive navigation menu with icons that make it easy for users to access various materials, including the introduction, mangrove ecosystem, evaluation, and exercises. The e-module also provides a user

guide that explains how to access its features, including installing the required application and navigating pages using the "Home" and "Next" buttons. Overall, the design of this e-module is attractive, intuitive, and easy to use, with a combination of blue and purple colors that give a professional impression, as well as the use of icons that clarify the learning.



(a) (b)

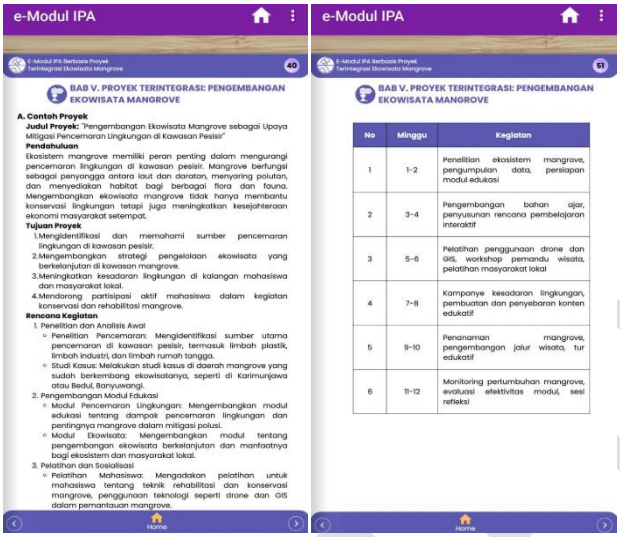
Figure 3. (a) Menu display, (b) Instructions for using the e-module

Figure 4 shows one of the materials in the e-module, namely Pollution in Mangrove Ecosystem. The description of the material is presented concisely. The material is also presented, complete with images and video links related to the material. The video link displayed can be easily accessed by students.

(a) (b)

Figure 4. Material pollution in the mangrove ecosystem: (a) Mangrove ecosystem, (b) Impact of pollution

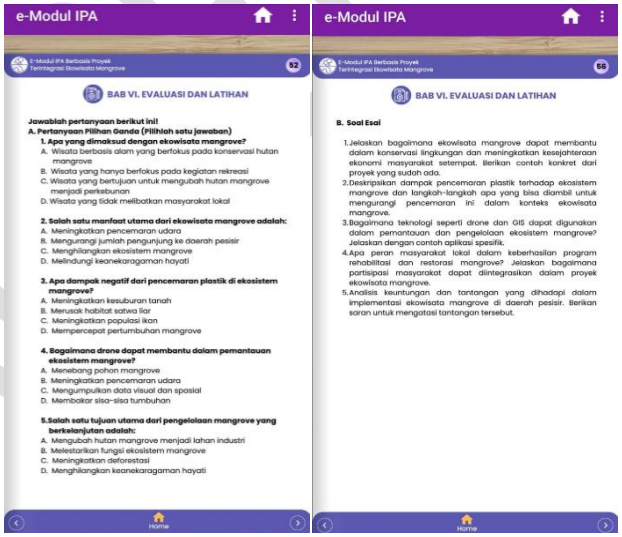
Figure 5 shows projects students can undertake to develop mangrove ecotourism. In this material, examples of projects students can choose from are presented, so they can determine the topic of the project they will carry out during the learning process.



(a) (b)

Figure 5. Mangrove ecotourism project: (a) Example of mangrove ecotourism project work, (b) Mangrove ecotourism project theme

Figure 6 contains the evaluation of the developed e-module. The evaluation consists of multiple-choice questions and essay questions.



(a) (b)

Figure 6. E-module evaluation questions: (a) Multiple choice question, (b) Essay question

Develop

Table 1 explains that this e-module is effective in enhancing students' scientific creativity and is suitable for use in project-based learning. The results of the validation of the science e-module based on the mangrove ecotourism project show an average score of 3.85 (96.25%), which is included in the "very feasible to use" category. The content and material aspect scored high on the suitability of learning objectives and systematic presentation, although it needs improvement in content accuracy and updating. In the presentation and design aspect, the visual

design, navigation, and layout are rated very well, but the effectiveness of multimedia use can be improved. The ecotourism integrated project-based learning aspect shows that the ecotourism project has encouraged active learning and student collaboration, though it still needs improvement in fostering problem-solving skills. The scientific creativity enhancement aspect encourages creative thinking and exploration, but the development of creative product-based projects can be further optimized.

Table 1. Validation test results of the e-module

No	Aspect	Statement	Score (1-4)			Mean
			A	B	C	
1	Content and Material Aspects	The material in the e-module follows the learning objectives	4	4	4	4
		The e-module content is accurate and up-to-date	3	4	3	3.33
		The material is presented systematically and logically	4	4	4	4
		The projects presented are relevant to the science material	4	3	4	3.67
2	Presentation and Design Aspects	Content encourages the development of student creativity	4	4	4	4
		The e-module design is attractive and suitable for students.	4	4	4	4
		Content layout and organization are easy to follow	4	4	4	4
		Effective use of multimedia (images, videos, animations)	3	4	4	3.67
		Navigation in the e-module is easy and intuitive	4	4	4	4
		The text in the e-module is easy to read and understand	4	4	4	4
3	Aspects of Ecotourism Integrated Project-Based Learning	The ecotourism projects presented encourage active learning	4	4	4	4
		Project instructions are clear and easy to follow	4	4	4	4
		Ecotourism projects facilitate the development of environmental problem-solving skills	3	4	3	3.33
		Ecotourism projects encourage collaboration between students	4	4	4	4
		Evaluation of the ecotourism project following the learning objectives	4	4	4	4
4	Aspects of Enhancing Scientific Creativity	E-module encourages students' creative thinking	4	4	4	4
		Activities in the e-module stimulate new ideas	4	3	4	3.67
		E-module provides space for exploration and experimentation	4	4	4	4
		Projects encourage the use of creative approaches	4	4	4	4
		E-module facilitates creative product development	3	4	3	3.33
Sum			76	78	77	77

No	Aspect	Statement	Score (1-4) A	B	C	Mean
Average			3.80	3.90	3.85	3.85 (96.25%)
Category			very feasible to use			

The score range is filled with numbers as follows:

4 = very feasible to use	Score 76-100% : very feasible to use
3 = feasible to use	Score 51-75% : feasible to use
2 = less feasible for use	Score 26-50% : less feasible for use
1 = not feasible for use	Score ≤ 25% : not feasible for use

Implement

Table 2 explains student responses to the implementation of limited trials from 41 respondents who came from students in the PGMI Study Program at Universitas Islam Negeri Mataram. They generally positively responded to the development of a science e-module based on the mangrove ecotourism project.

Table 2. Data on student responses to the use of the e-module

No.	Aspects	Statement	Likert Scale Points 1	2	3	4
1.	Content and Presentation	The material in the e-module is presented systematically and is easy to understand.	0%	0%	43.90%	56.10%
		The e-module presents relevant and regularly updated information	0%	2.44%	31.71%	65.83%
		The e-module design is attractive and interactive	0%	0%	24.39%	75.61%
		Navigation in the e-module is intuitive and easy to use	0%	2.44%	41.46%	56.10%
		The use of multimedia, such as images, videos, and animations, enriches the learning experience	0%	0%	31.71%	69.29%
2	Ecotourism Integrated Project-Based Learning	The project in the e-module is interesting, challenging, and relevant to ecotourism.	0%	0%	46.34%	53.66%
		The project instructions are clear and easy to follow.	0%	0%	39.02%	60.98%
		The project helps to understand science concepts in an environmental context.	0%	0%	39.02%	60.98%
		I am motivated to complete the project because it is applicable and real.	0%	0%	41.46%	58.54%
		The project encourages cooperation with friends in learning.	0%	0%	41.46%	58.54%
3	Increased Scientific Creativity in the Environmental Field	The e-module encourages me to think creatively about environmental issues.	0%	0%	34.15%	65.85%
		The e-module activity helped me generate new ideas.	0%	0%	41.46%	58.54%
		I am more confident in expressing creative ideas.	0%	0%	43.90%	56.10%

	The projects in the e-module allow me to experiment.	0%	0%	46.34%	53.66%
	E-module helps develop creative solutions to science problems.	0%	0%	43.90%	56.10%

Based on the data presented in Table 2, the evaluation results of the e-module show that most respondents gave a positive assessment, with a score of 4 (strongly agree) on the majority of statements. In the content and presentation aspects, more than 65% of respondents stated that the e-module material is presented systematically, is relevant and interesting, and that the use of multimedia is effective in enriching the learning experience. Concerning ecotourism-integrated project-based learning, the projects were identified as engaging, demanding, and pertinent to ecotourism. Over 58% of respondents reported feeling motivated to complete these projects and to collaborate with their peers. On the other hand, regarding enhancing scientific creativity in the environmental field, more than 56% of respondents felt the e-module encouraged creative thinking and helped generate new ideas and solutions related to environmental issues. Overall, this e-module shows excellent effectiveness in supporting project-based learning and enhancing scientific creativity in environmental education.

The results of interviews with students regarding the science e-module for the mangrove ecotourism project indicate that it is highly appreciated and considered very useful in the learning process. This e-module received a positive response, with the hope that it will continue to develop and become increasingly useful in supporting more active, interesting, and relevant science learning. JH stated that this e-module is easy to understand, interesting, and helps improve understanding of science material (JH, personal communication, May 15, 2024). Students suggested that this e-module continue to be developed, with the addition of more detailed example questions and more challenging projects. Students also appreciated the ease of access to the e-module, which allows them to learn anytime, anywhere, and facilitates interaction between lecturers and students in digital learning (ADA, personal communication, May 15, 2024). EI also stated that visualization through images, videos, and animations in e-modules made the material easier to understand, and project-based methods were considered to stimulate creativity and curiosity (EI, personal communication, May 15, 2024).

Evaluate

Figure 7 compares the average pre-test, post-test, and N-gain scores for student scientific creativity between the experimental and control groups, which received different treatments. In the experimental group, the average pre-test score was 49, while the post-test score was 72, yielding an N-gain of 47. This shows a significant increase in students' scientific creativity after treatment with a project-based e-module. Meanwhile, in the control group, the pre-test value was 50, the post-test was 64, and the N-gain was 30. Although there was an increase, the N-gain in the control group was lower than that in the experimental group, indicating that the treatment in the experimental group increased students' scientific creativity. Overall, this graph shows that the treatment with the project-based e-module has a greater impact on increasing scientific creativity than the untreated group.

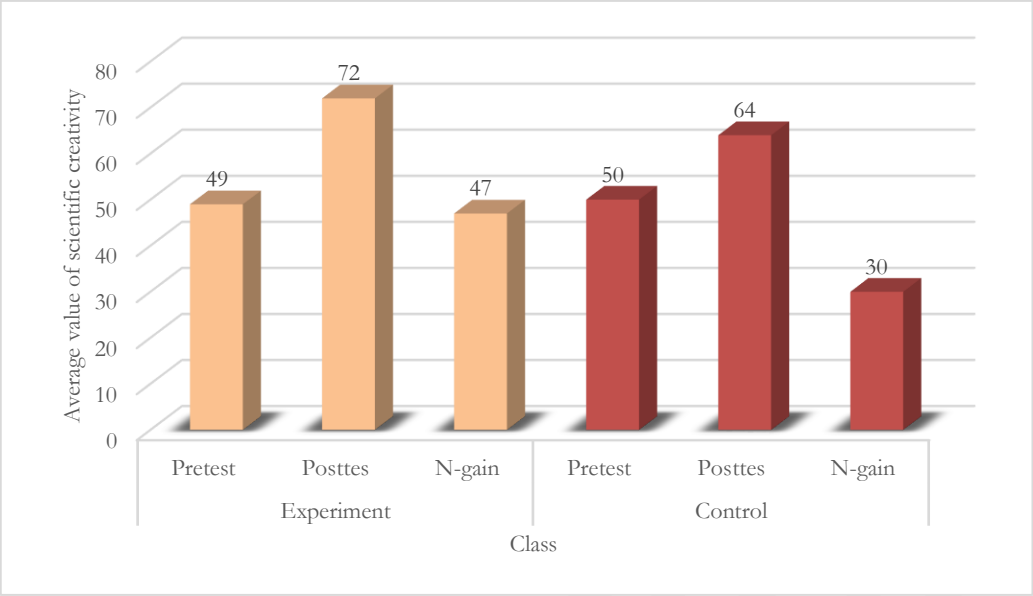


Figure 7. Average pre-test, post-test scores, and n-gain of scientific creativity students

Table 3 shows that the experimental group had a mean scientific creativity score of 72.18 (SD = 10.24) out of 37 students. The control group had a mean of 64.47 and a standard deviation of 8.97 across 37 students. Overall, the mean value of students' scientific creativity was 68.33, with a standard deviation of 10.32 across 74 students, indicating that the experimental group achieved higher scores than the control group.

Table 3. Description of student scientific creativity data

Class	Mean	Std. Deviation	N
Experiment	72.185	10.244	37
Control	64.471	8.973	37
Total	68.328	10.321	74

Chi-Square test results with Asymp. Sig. 0.083 indicates that the data is insignificant at the 0.05 level, which means the data can be considered normally distributed. The results of Levene's Test with F = 1.982 and Sig. = 0.163 indicates that the null hypothesis is not rejected, which means there is no significant difference in the homogeneity of variance between groups. Thus, the assumption of homogeneity of variance is met.

Table 4 shows the ANOVA test: class has F = 66.864, Sig. = 0.000, indicating that the difference between treatment classes significantly affects scientific creativity. This means that the group that uses a science e-module based on the mangrove ecotourism project has a real and different effect on students' scientific creativity level compared to the group without using the e-module.

Table 4. Tests of between-subjects effects on scientific creativity

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected model	6390.453[a]	2	3195.226	163.545	.000
Intercept	160.080	1	160.080	8.194	.006
Pretest	5289.606	1	5289.606	270.744	.000
Class	1306.346	1	1306.346	66.864	.000
Error	1387.149	71	19.537		
Total	353259.549	74			
Corrected total	7777.602	73			

a. R Squared = .822 (Adjusted R Squared = .817)

The results of this study indicate that the science e-module based on the mangrove ecotourism project as a whole has excellent quality for learning, with an average score of 3.85 (96.25%), placing it in the "very feasible to use" category. This finding is consistent with the constructivist theory that prioritizes active student involvement in the learning process (Lin et al., 2023). Constructivism emphasizes the importance of hands-on experience in learning (Ainjärv & Laas, 2024; Sayaf, 2023). Science e-modules based on mangrove ecotourism projects offer an approach that aligns with this principle; students can actively participate in ecotourism-based projects relevant to the real world.

The content and material aspects of this e-module received high ratings, especially for the suitability of the material to the learning objectives and its systematic presentation. This leads to a deeper understanding for students, a finding that is in line with information processing theory, which states that systematically organized information will be more easily understood and absorbed by learners (Bolkan & Goodboy, 2024). However, while the content is considered accurate and relevant, regular updates are needed to ensure the material remains the latest with the ever-evolving science. This is in line with several findings that emphasize the importance of updating materials in supporting the quality of learning (Davis, 2021; Smith & Delaney, 2023).

The presentation and design aspects also showed positive results, especially in terms of visual design and navigation, which were considered intuitive and attractive. This is in accordance with the theory of multimedia instructional design, which states that good design can increase student understanding and involvement in learning (Jongmans, 2022). Nonetheless, the effectiveness of using multimedia, especially in terms of images, videos, and animations, still needs to be improved to enrich the learning experience (Kleftodimos, 2024). This relates to other findings that show that more interactive multimedia elements can strengthen engagement and facilitate better (Lampropoulos & Kinshuk, 2024; Balalle, 2024).

Project-based learning integrated with ecotourism encourages collaboration and active learning among students (Hartati et al., 2025). This reflects the cooperative learning principle that collaboration in projects enhances students' social and cognitive skills (Zhou & Colomer, 2024). However, while these projects were successful in encouraging collaboration, problem-solving skills still needed to be improved. This shows the importance of designing projects that are not only relevant and engaging but also cognitively challenging to facilitate the development of better problem-solving skills (Asyari et al., 2024; Das et al., 2025; Zhu et al., 2024).

Increased scientific creativity in the context of ecotourism is also a significant finding of this study. This e-module encourages students to think creatively, explore new ideas, and develop creative solutions to environmental issues, which is the main goal of project-based learning. This aligns with creativity theory, which states that an environment that supports exploration and experimentation will facilitate greater creativity (Indriati et al., 2024; Jia et al., 2023). However, the development of creative product-based projects can still be improved,

especially in the implementation of creative ideas into tangible products that can be assessed and implemented (Cheng et al., 2022; Sucilestari et al., 2023b).

This research contributes to developing project-based e-module integrated with ecotourism, a relatively new topic in educational research. The novelty of this research is the application of a project-based e-module in the context of science learning connected to environmental issues, especially mangrove ecotourism, which provides theoretical knowledge and practical skills relevant to real-world needs. In addition, this study shows that project-based learning, supported by an interactive e-module, can significantly improve students' scientific creativity, which is an important aspect of science education today.

Although this e-module shows high effectiveness, some limitations need to be noted. First, although this e-module has been piloted with positive results, the number of respondents limited to one institution (Universitas Islam Negeri Mataram) may limit the generalizability of these findings. Secondly, although multimedia development is effective, the use of images, videos, and animations still needs to be improved to further optimize the learning experience. Thirdly, although the ecotourism-based project was interesting, there were shortcomings in integrating a more in-depth, creative product-based project. These limitations need to be addressed in the further development of this e-module.

To overcome the existing limitations, a wider trial involving more diverse institutions and respondents is recommended to better generalize these findings. Further development of multimedia elements, such as the addition of more interactive animations and simulations that can strengthen understanding, is also a priority to increase the effectiveness of the e-module. In addition, more relevant and challenging creative product-based projects need to be introduced to help students develop stronger problem-solving and innovation skills.

Based on the above findings, there are several recommendations for future research and educational practice. First, given the importance of creativity development in scientific education, integrating more interactive multimedia elements in the e-module can enrich the learning experience and improve student understanding. Second, to increase the effectiveness of project-based learning, it is necessary to add more challenging and creative product-based projects, which demand theoretical knowledge and practical skills that can be applied in real life. Third, it is important to continuously evaluate this e-module by involving more educational institutions to obtain more diverse input and improve its quality. Finally, with the growing education trend towards technology and environment-based learning, this project-based e-module can be a relevant model in supporting active, creative, and contextualized learning.

CONCLUSION

This study successfully developed a science e-module based on a mangrove ecotourism project that was proven to be feasible, practical, and effective in improving students' scientific creativity in Islamic universities. Based on the ADDIE development model (Analysis, Design, Development, Implementation, Evaluation), this e-module was designed by integrating interactive technology-based learning materials related to the environment. The study found that this e-module was feasible, practical, and effective in improving students' scientific creativity. The validation results showed that this e-module was very feasible to use, with a 96.25% success rate. The evaluation of the e-module also received positive ratings from most respondents. In addition, the effectiveness test showed that using the e-module can significantly improve students' scientific creativity ($p = 0.00$), as reflected in critical thinking, problem-solving, and solution development related to environmental problems. Therefore, integrating this e-module into universities' science education curricula is highly recommended to support the development of students' scientific creativity in environmental education and technology use.

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