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Analysis of project-based science E-module development integrated with mangrove ecotourism for scientific creativity and environmental literacy

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Abstract: Developing project-based e-modules integrated with mangrove ecotourism is essential for fostering students' scientific creativity, particularly within the context of learning in the digital era. This study aims to examine student perceptions of project-based science e-modules integrated with ecotourism and their impact on scientific creativity and environmental literacy. Data were collected through an online Likert scale questionnaire administered to 409 students from eight universities across Indonesia. The data analysis employed a descriptive quantitative approach followed by path analysis. The results revealed that most respondents held a positive perception of the project-based e-module. Most participants agreed that the e-module effectively enhances scientific skills and environmental literacy while promoting critical thinking on environmental issues. Additionally, the e-module was perceived to provide relevant examples of local environmental conditions and to raise awareness about individual contributions to environmental conservation. These findings suggest that ecotourism-integrated project-based e-modules have significant potential to improve students' scientific creativity and environmental literacy. By integrating real-world environmental issues, this e-module enriches students' understanding of the interplay between science and environmental conservation, encouraging greater engagement with environmental sustainability. This research offers valuable insights into the development of contextualized and practical learning approaches in science education.

Keywords: *E-modules, Environmental literacy, Mangrove ecotourism, Project, Scientific creativity.*

1. Introduction

Complex global challenges such as climate change and environmental degradation are being faced. Therefore, it is important to raise awareness about environmental conservation, and foster scientific creativity among students. Environmental literacy is a key factor in preparing individuals capable of thinking critically, acting responsibly, and contributing to environmental conservation [1]. It encompasses not only knowledge of environmental issues but also the ability to understand and address environmental problems sustainably [2]. One ecosystem that plays a crucial role in maintaining the balance of nature is the mangrove forest, which serves as a coastal abrasion barrier, a carbon sink, and a habitat for diverse species [3-5]. In Indonesia, mangrove ecosystems are undergoing significant degradation, while the importance of mangrove ecotourism as both a conservation strategy and a means of economic empowerment for local communities is receiving growing attention [6-8]. However, despite the importance of environmental literacy being increasingly recognized, many students still have a limited understanding of mangrove ecosystems and their role in environmental sustainability. Learning that focuses solely on theoretical knowledge without incorporating practical experience often proves less effective in fostering students' practical skills and creativity [9-11]. Therefore, there is an urgent need for more innovative learning approaches that integrate field experiences and hands-on applications to enhance students' environmental literacy.

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As a crucial aspect of developing students' intellectual capacity, scientific creativity is essential for devising new solutions to the increasingly urgent environmental challenges. It involves the ability to generate novel ideas and test them within a broader context [12-14]. Scientific creativity enables individuals to think innovatively and solve problems in new and effective ways [15-17]. In the modern era, these skills are essential as scientific and environmental challenges become increasingly complex [18-20].

In the context of mangrove ecotourism, students must integrate their scientific knowledge with field practice, which demands thinking creatively, identifying data-driven solutions, and applying innovative ideas to real-world projects. This project-based e-module offers students the opportunity to engage in creative processes, allowing them to design ecotourism programs that not only emphasize economic factors but also prioritize sustainable environmental conservation.

One effective approach is the development of a project-based e-module that integrates the concept of mangrove ecotourism. Project-based e-modules enable students to actively participate in planning, researching, and implementing ecotourism projects.

This enhances their understanding of mangrove ecosystems and fosters creative thinking skills in addressing environmental challenges. Through this approach, students are encouraged to think critically and creatively in devising innovative mangrove conservation solutions while also developing practical skills in managing environmentally sustainable ecotourism.

Quality science education focuses not only on delivering scientific information but also on developing critical skills and scientific creativity [21-23]. In this context, project-based science e-modules offer an innovative approach to increase student engagement and deepen their understanding of science materials [18, 24-26].

However, a thorough understanding of the need for appropriate and relevant teaching materials is essential to effectively achieve these objectives. Therefore, learning methods that stimulate students' scientific creativity are critical.

The use of project-based e-modules is one such strategy to accomplish this goal. Project-based science e-modules integrate digital technology with project-based learning models, offering interactive materials that enable students to learn independently and actively engage in practical projects [27, 28]. By incorporating project-based elements, these e-modules enable students to apply scientific concepts in real-world situations, enhance practical skills, and foster creativity [29-31].

Mangrove ecosystems, with their crucial role in maintaining ecological balance, provide a rich context for science education [32].

Mangrove ecotourism, which combines environmental conservation with tourism activities, offers students an opportunity to explore the impact of human activities on ecosystems and to learn how mitigation strategies can be applied. The integration of this topic into science e-modules not only enriches the learning content but also fosters environmental awareness among students [33, 34].

Environmental pollution is a global issue that requires attention and innovative solutions [35-37]. This material is important in the science curriculum because it covers the direct impact of human activities on ecosystems and sustainability [38-40].

However, learning about environmental pollution is often limited to theoretical content, without providing students the opportunity to apply their knowledge in real-world contexts. By utilizing a project-based e-module integrated with mangrove ecotourism, students can gain a deeper understanding of the impacts of pollution and explore mitigation strategies through relevant, practical projects.

The use of e-modules in this context enables students to engage in interactive learning and participate in projects directly related to environmental pollution issues.

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These e-modules can incorporate various resources, such as videos, simulations, and project tasks, which encourage students to analyze and develop solutions for environmental pollution problems within mangrove ecosystems. Although project-based science e-modules hold significant potential, their success largely depends on their design and content.

Therefore, it is crucial to conduct a comprehensive analysis of the requirements for effective teaching materials to achieve the desired learning outcomes. This includes identifying key components within the e-module, such as interactive features, content related to environmental pollution and mangrove ecotourism, and strategies to stimulate students' scientific creativity.

2. Literature Review

2.1. Project-Based Learning (PBL) and Its Impact on Scientific Creativity

Project-based learning has emerged as a significant educational approach, where students engage in active learning through the completion of real-world projects. The PBL model encourages critical thinking, problem solving, and collaboration, all of which are essential components of scientific creativity [41].

The ability of PBL to enhance scientific creativity has been widely studied, with researchers emphasizing its role in encouraging students to apply scientific concepts in practical scenarios. PBL not only promotes scientific knowledge but also fosters creativity by allowing students to explore topics in depth and solve complex problems creatively [42, 43].

Recent studies have developed these ideas by integrating technology into PBL, such as e-modules, to enhance the learning experience.

E-modules are digital learning materials that support self-paced learning, which have been shown to increase engagement and knowledge retention [44]. The development of e-modules that integrate PBL with scientific concepts has been shown to increase students' interest in science and their ability to generate innovative ideas [45, 46].

2.2. E-Modules in Education and Their Role in Enhancing Learning

The integration of technology, especially e-modules, in education has grown rapidly in recent years. E-modules offer flexible and interactive learning environments that can engage students in self-directed learning while catering to a variety of learning styles [47, 48].

Several studies have shown that e-modules not only enhance the learning experience but also support students in developing higher-order thinking skills, including analysis, evaluation, and creativity [49-51].

In particular, e-modules used in environmental science education allow students to explore complex environmental issues interactively, which helps them better understand ecological systems and conservation efforts [52, 53].

Incorporating PBL into e-modules has been shown to be an effective approach to promoting environmental literacy. By connecting theoretical concepts to real-world environmental challenges, students are more likely to engage with the material and develop a deeper understanding of environmental issues [54-56].

Additionally, the use of digital platforms allows students to access up-to-date scientific data and research, which enriches their learning experience and increases their environmental awareness [57, 58].

2.3. Environmental Literacy and the Role of Ecotourism in Education

Environmental literacy is defined as the knowledge, attitudes, and behaviors necessary for individuals to understand and address environmental issues [59, 60].

Improving environmental literacy has become a major goal in science education, as it provides students with the tools to make informed decisions about environmental conservation and

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sustainability. Studies have shown that project-based approaches that integrate environmental issues, such as mangrove conservation, can significantly increase students' environmental awareness [61, 62].

Mangrove ecosystems, which provide essential environmental services such as coastal protection, biodiversity conservation, and carbon sequestration, are an essential part of environmental education.

Several research findings emphasize the importance of integrating mangrove conservation into educational programs, especially in areas where ecosystems are threatened by deforestation and climate change [63, 64]. Mangrove ecotourism offers a unique opportunity to engage students in real-world applications of environmental concepts, while also building a deeper appreciation for the environment. Ecotourism, when used as an educational tool, has been shown to improve students' environmental literacy by connecting them directly to the ecosystems they are studying [65, 66].

2.4. Integration of Mangrove Ecotourism in Science Education for Scientific Creativity and Environmental Literacy

Recent studies have explored the integration of ecotourism in science education, highlighting its potential in promoting scientific creativity and environmental literacy. Ecotourism experiences provide hands-on learning opportunities that enhance students' understanding of complex environmental systems, while encouraging creative thinking about sustainable solutions [1]. When combined with PBL, mangrove ecotourism can provide students with opportunities to engage in field-based research projects, allowing them to apply their scientific knowledge to real-world ecological challenges [61].

The integration of mangrove ecotourism with PBL through e-modules has the potential to create a comprehensive and immersive learning experience. This combination allows students to explore both theoretical and practical aspects of environmental conservation, which in turn fosters a sense of responsibility for preserving natural ecosystems. Studies on environmental education have shown that such an integrated approach not only enhances scientific creativity but also instills a lasting commitment to environmental protection [67].

2.5. Future Trends and Directions in Environmental Education and Technology Integration

The integration of technology in environmental education, particularly through the use of e-modules, is a growing trend. Researchers are increasingly focused on creating interactive, multimedia-rich learning experiences that can better engage students in environmental issues [68, 69].

In addition, the growing emphasis on sustainability in education is driving the development of new curricula and educational tools that integrate environmental issues, such as climate change, conservation, and sustainable development, with multiple scientific disciplines [70, 71].

Future research in this area should focus on evaluating the long-term effectiveness of e-modules in enhancing environmental literacy and fostering scientific creativity. Additionally, exploring the potential of combining different types of ecotourism (e.g., mangrove, forest, marine) with PBL may open up new opportunities for research and curriculum development in environmental education.

3. Research Methodology

This research employs a quantitative approach to comprehensively understand student needs regarding learning resources and the development of project-based science e-modules within the context of mangrove ecotourism. This approach was selected to facilitate an in-depth analysis of student preferences and to assess the potential of science e-modules in fostering scientific creativity and enhancing environmental literacy.

The data for this study were collected through an online questionnaire distributed to 409

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students from eight universities relevant to the research topic. The profile of the respondents who constituted the research sample is presented in detail in Table 1.

This data collection strategy was designed to ensure that the information gathered is representative and can support accurate statistical analyses related to developing the proposed e-modules.

Table 1.
Respondent Profile.

No.	Sample Profile	Description
1	College Region of Origin	Consists of 3 Western Indonesia regions and 5 Eastern Indonesia regions
2	Type of College	4 religious universities and 4 public universities
3	Higher Education Accreditation	5 Universities accredited as "Excellent", 2 accredited as "Excellent", and 1 accredited as "B".
4	College Status	4 public universities and 4 private universities
5	Gender Composition of Respondents	329 female respondents and 80 male respondents

The questionnaire used in this study employed a Likert scale to identify the learning resources utilized by students to understand the concept of mangrove ecotourism and explore their needs regarding the development of project-based e-modules. The variables measured included: 1) Interest and need for e-module development (X1); 2) Integration of ecotourism in contextualized science learning (X2); 3) Collaborative projects in e-modules (X3); 4) Scientific creativity (Y1); and 5) Environmental literacy (Y2). The aspects and indicators measured in this questionnaire are presented in Table 2.

Table 2.
Aspects and Indicators of the Questionnaire.

No.	Aspects Measured	Indicators	No. Statement
1	Interest in E-Module Development	Students' interest in the use of ecotourism project-based e-modules in science learning.	1, 2, 3
2	Scientific Creativity in Science Learning	Students' ability to develop scientific creativity through project-based learning.	4, 5, 6
3	Interactive Material Needs in E-Modules	Students' need for interactive content to support scientific creativity and science learning.	7, 8, 9
4	Ecotourism Integration in Science Learning	Students' perceptions of the benefits of ecotourism integration in science learning to improve environmental literacy.	10, 11, 12
5	Creativity Development through Ecotourism	Students' understanding of the importance of ecotourism in enhancing scientific creativity.	13, 14, 15
6	Collaborative Project in E-Modules	Students' need for collaborative projects to enhance scientific creativity and environmental literacy.	16, 17, 18
7	Application of Science in Real Life	Students' awareness of the importance of applying science in real life through ecotourism.	19, 20, 21
8	Environmental Literacy Assessment through E-Modules	Students' needs for environmental literacy evaluation in ecotourism project-based e-modules.	22, 23
9	Student Contribution to Environmental Sustainability	Students' understanding of how to contribute to environmental sustainability through science learning.	24, 25

The collected data were analyzed using a descriptive quantitative approach [72] followed by path analysis [73] assisted by software applications. Descriptive statistical analysis and confirmatory factor analysis (CFA) were performed using Microsoft Excel 2021 and SPSS version 29 [74] while path analysis was conducted using Smart PLS version 3. CFA was applied to ensure the validity and reliability of the instruments used in this study [75].

Path analysis, on the other hand, aimed to identify the factors influencing the development of

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project-based science e-modules integrated with mangrove ecotourism and their impact on students' scientific creativity and environmental literacy.

Hypothesis testing was conducted using statistical tests to measure the significance of the influence of independent variables on the dependent variable, with a p-value<0.05 considered significant. With this comprehensive analytical approach, it is hoped that the research will make a meaningful contribution to developing project-based science e-modules integrated with mangrove ecotourism while enhancing students' scientific creativity and strengthening environmental literacy as part of efforts to support sustainability.

4. Results and Discussion

In the first stage of analysis, data were obtained through the distribution of an online questionnaire using Google Forms, which was shared via the WhatsApp application. This questionnaire aimed to gather information on the need to develop project-based e-modules integrated with ecotourism. The data collected offers an overview of the respondents' needs and preferences regarding the e-module's development, as presented in Table 3.

The questionnaire used in this study aimed to gather respondents' perceptions regarding the need for developing project-based science e-modules integrated with ecotourism, utilizing a Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree). Based on the analysis presented in Table 3, it can be inferred that respondents expressed a high level of interest in the development of project-based e-modules that integrate science learning with ecotourism. The majority of respondents agreed or strongly agreed that this approach has the potential to enhance their understanding of scientific concepts and their relevance to environmental conservation.

The statement regarding the integration of ecotourism as a learning context received significant agreement. Respondents indicated that this integration not only helps students understand the impact of science on environmental issues but also motivates them to think creatively and develop a sense of responsibility toward environmental conservation. This underscores the urgent need for a contextualized and applicable learning approach, enabling students to connect scientific concepts with real-world challenges.

Additionally, respondents emphasized the importance of interactive elements and flexibility in the use of e-modules. Interactive content was viewed as an effective tool for facilitating creative learning and promoting active student engagement. Flexible accessibility was also deemed essential for supporting independent learning, allowing students to learn at their own pace and convenience.

Respondents also highlighted the significance of the collaborative project included in the e-module. This project was considered beneficial in fostering students' scientific creativity while enhancing their environmental literacy. Thus, the collaborative project is seen as a valuable opportunity to deepen students' understanding of the connections between science and global environmental issues.

Based on these findings, it can be concluded that the development of an e-module adopting a project-based approach, integrated with ecotourism and contextualized learning, offers an effective solution to address students' learning needs. This approach is expected not only to enhance students' academic understanding but also to positively contribute to the development of their scientific creativity and environmental awareness.

Table 4 presents the results of the analysis of respondents' perceptions regarding project-based e-modules designed to enhance scientific creativity and environmental literacy. Respondents rated various aspects of the e-module using a Likert scale, with values ranging from 1 (strongly disagree) to 5 (strongly agree). Overall, most respondents agreed that the project-based e-module could improve scientific skills and environmental literacy (36.67% agreed; 32.09% strongly agreed).

The e-module was also considered effective in encouraging critical thinking on environmental issues (33.74% agreed; 20.09% strongly agreed), although there were some variations in the responses.

Moreover, the application of field-based project learning related to ecotourism was seen as

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facilitating the development of students' creative ideas (33.98% agreed; 30.81% strongly agreed). In terms of environmental literacy, the e-module was regarded as effective in providing an evaluation tool to measure respondents' environmental literacy skills (34.47% agreed; 30.07% strongly agreed). The project-based approach used in this e-module was also perceived as helping students understand the scientific method in the context of addressing environmental problems (36.43% agreed; 28.12% strongly agreed).

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Table 3.
Data on the Needs Survey Results of Ecotourism Integrated Project-Based E-Modules.

No.	Variables	Aspects	Statement	Likert Scale Points				
				1	2	3	4	5
1.	Interest and Need for E-Module development (X1)	Interest in Development	I am interested in using e-modules that combine science and ecotourism learning for	3.18%	7.09%	30.07%	31.05%	28.61%
			Project-based learning can help me develop my creativity in understanding science concepts.	2.44%	5.86%	29.34%	31.78%	30.56%
			The integration of ecotourism in science learning will increase my understanding of the importance of	1.47%	3.91%	24.45%	30.56%	39.61%
		Interactive Material Needs in	I believe project-based science e-modules can help improve my ability to develop scientific projects.	1.71%	5.37%	27.87%	38.14%	26.89%
			The interactive content in the e-modules will make it easier for me to learn more creatively and engage actively.	1.22%	5.38%	30.32%	35.69%	27.36%
			The project-based science e-module should provide clear guidance on how to develop the	0.49%	6.36%	26.41%	32.27%	34.47%
2	Ecotourism Integration in Science Learning Contextual (X2)	Ecotourism Integration in Learning	The use of project-based e-modules will help me apply science concepts in ecotourism-related projects.	1.71%	5.13%	30.07%	35.94%	27.14%
			I believe that the integration of ecotourism in the e-module can help me understand the impact of science on environmental sustainability.	1.22%	4.16%	26.89%	35.21%	32.52%
			The project-based e-modules will encourage me to be more aware of environmental issues around me.	1.47%	4.89%	26.89%	39.36%	27.38%
		Application of Science in Real Life	I feel it is important to learn science concepts in the context of ecotourism to better understand environmental conservation.	1.22%	5.13%	24.45%	35.21%	33.98%
			I want the projects given in the e-modules to help me apply science knowledge in real life.	1.22%	4.89%	24.45%	33.74%	35.69%
			The interactive and project-based e-modules will make me more motivated to think creatively in solving environmental problems.	1.22%	4.64%	27.63%	35.21%	31.29%
3	Collaborative Project in E-Modules (X3)	Collaborative Project in	Project-based science e-modules should provide collaborative tasks to enhance creativity and environmental literacy.	0.98%	5.38%	33.98%	33.74%	25.92%
			Using ecotourism project-based e-modules will help me better understand the linkages between science and global environmental issues.	1.22%	5.13%	24.25%	35.20%	33.98%
			I need an e-module that can be accessed anytime to help develop my scientific creativity independently.	1.47%	4.89%	27.14%	32.03%	34.47%

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Table 4.
Data from the E-Module Needs Survey on Creativity and Environmental Literacy.

No.	Variables	Aspects	Statement	Likert Scale Points				
				1	2	3	4	5
1	Scientific Creativity (Y1)	Scientific Creativity in Science Learning	I needed an e-module designed to hone scientific skills and environmental literacy.	1.71%	4.40%	25.18%	36.67%	32.09%
			The project-based e-modules will encourage me to think critically about environmental issues.	1.47%	5.38%	30.32%	33.74%	20.09%
			I find it easier to develop creative ideas through field project-based science learning related to ecotourism.	1.22%	5.38%	28.61%	33.98%	30.81%
2	Environmental Literacy (Y2)	Environmental Literacy Assessment through E-Modules	I need an e-module that provides evaluation or assessment to measure my environmental literacy skills.	0.98%	4.16%	30.32%	34.47%	30.07%
			I feel that e-modules with a project approach can help me better understand the scientific method in solving environmental problems.	1.22%	5.38%	28.85%	36.43%	28.12%
		Student Contribution to Sustainability	I hope that ecotourism-based science e-modules provide real examples that are relevant to local environmental conditions.	1.22%	3.42%	25.92%	33.49%	35.94%
			The project-based e-modules will improve my understanding of how I can contribute to environmental sustainability.	1.22%	3.91%	24.21%	38.39%	32.27%

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The majority of respondents noted that the ecotourism-based e-modules provided examples relevant to local environmental conditions (33.49% agreed; 35.94% strongly agreed) and enhanced their understanding of individual contributions to environmental sustainability (38.39% agreed; 32.27% strongly agreed).

The results of this analysis indicate that project-based e-modules have significant potential to support the development of scientific creativity and environmental literacy. The integration of real environmental issues, along with a project-based approach centred on ecotourism, notably improved respondents' understanding of their personal roles and contributions to environmental conservation efforts. Therefore, the development of e-modules that integrate project-based learning and environmental literacy is an effective strategy for enhancing students' scientific creativity and environmental awareness.

Additionally, the Kaiser-Meyer-Olkin (KMO) value and Bartlett's test were tested to assess the overall relationships between variables, excluding other factors. The assumption for this test is that the MSA value must be greater than 0.5, and the significance value should be less than 0.05.

Table 5.
KMO and Bartlett's Test.

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**0.914**
Bartlett's Test of Sphericity	Approx. Chi-Square	2974.881
	df	10
	Sig.	0.000

The results of the Kaiser-Meyer-Olkin (KMO) and Bartlett's Test (Table 5) indicate excellent sample adequacy, with a KMO value of 0.914, exceeding the minimum threshold of 0.5 [76]. This value indicates that the data is suitable for factor analysis, as it shows that the variables have a sufficient level of correlation to be grouped into meaningful factors. In addition, the Bartlett's Test of Sphericity results with a Chi-Square value of 2974.881 and a significance level of 0.000 indicate that the correlation matrix between variables is statistically significant, so the data has a structure that can be further analysed using the factor analysis method [75]. This finding is consistent with previous research showing that KMO values above 0.8 signify excellent sample adequacy, and significant values on Bartlett's Test support the suitability of the data for exploratory factor analysis [77]. Thus, the data in this study fulfils the requirements for the development of a valid factor model.

The results of the Anti-image Matrices analysis (Table 6) show high Measures of Sampling Adequacy (MSA) values on all variables, with values above the 0.8 thresholds, indicating that the data meet the criteria for adequate sample adequacy for factor analysis [75].

These high MSA values indicate that the variables analysed have fairly low partial correlations compared to the overall correlation, making them suitable for use in exploratory factor analysis. In particular, the highest MSA value was recorded for the Collaborative Project variable (0.937), which indicates that this variable has a strong contribution to the factor components to be extracted. The relatively small anti-image correlation values between variables support the conclusion that redundancy between variables can be minimised in accordance with the guidelines [77].

Negative anti-image correlations, as seen in some variable pairs, are a reasonable characteristic in data designed for factor analysis, as they reflect residual correlations after the influence of other variables has been controlled for. This finding is consistent with the literature, which states that MSA values above 0.8 indicate that the variables are independent enough to provide valid factor analysis results [76]. Therefore, these results confirm that the data are ready to proceed to a more in-depth factor analysis stage to identify the underlying latent structure.

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Table 6.
Anti-image Matrices.

		Interests and Needs	Ecotourism Integration	Collaborative Project	Scientific Creativity	Environmental Literacy
Anti-image Covariance	Interests and Needs	0.140	-0.035	-0.037	-0.044	0.003
	Ecotourism Integration	-0.035	0.101	-0.024	-0.025	-0.062
	Collaborative Project	-0.037	-0.024	0.150	-0.040	-0.018
	Scientific Creativity	-0.044	-0.025	-0.040	0.115	-0.026
	Environmental Literacy	0.003	-0.062	-0.018	-0.026	0.164
Anti-image Correlation	Interests and Needs	0.919[a]	-0.292	-0.254	-0.349	0.019
	Ecotourism Integration	-0.292	0.889[a]	-0.194	-0.228	-0.480
	Collaborative Project	-0.254	-0.194	0.937[a]	-0.308	-0.114
	Scientific Creativity	-0.349	-0.228	-0.308	0.913[a]	-0.189
	Environmental Literacy	0.019	-0.480	-0.114	-0.189	0.915[a]

The results of the Anti-image Matrices analysis showed high Measures of Sampling Adequacy (MSA) values on all variables, with values above the 0.8 threshold, indicating that the data met the criteria for adequate sample adequacy for factor analysis [75].

These high MSA values indicate that the variables analysed have fairly low partial correlations compared to the overall correlation, making them suitable for exploratory factor analysis. In particular, the highest MSA value was recorded for the Collaborative Project variable (0.937), which indicates that this variable strongly contributes to the factor components to be extracted.

The relatively small values of anti-image correlations between variables support the conclusion that redundancy between variables can be minimised [77]. Negative anti-image correlations, as seen in some variable pairs, are a natural characteristic in data designed for factor analysis, as they reflect residual correlations after the influence of other variables has been controlled for. This finding is consistent with the literature, which states that MSA values above 0.8 indicate that the variables are independent enough to provide valid factor analysis results [76]. Therefore, these results confirm that the data is ready to proceed to a more in-depth factor analysis stage to identify the underlying latent structure.

Table 7.
Communalities.

	Initial	Extraction
Interest and Need for E-Module development	1.000	0.902
Ecotourism Integration in Contextualised Science Learning	1.000	0.933
Collaborative Project in E-Modules	1.000	0.900
Scientific Creativity	1.000	0.926
Environmental Literacy	1.000	0.878

Testing research data using the inner model aims to analyse the relationship between constructs, measure the significance value, and calculate the R-square value for the research model (Table 7). This model will be evaluated using R-square to test the dependent construct, as well as testing the significance of the parameter coefficients on the structural path (Table 8).

Table 8.
R-Square.

Variable	R Square	R Square Adjusted
Y1	0.885	0.884
Y2	0.830	0.829

The analysis results show high R-Square values for the dependent variables Y1 (0.885) and Y2 (0.830), reflecting the model's very strong predictive ability. R-Square value above 0.75 is considered substantial, indicating that most of the variance in the dependent variable can be explained by the

independent constructs in the model [75].

An Adjusted R-Square value close to the R-Square also indicates that the model is stable and does not experience overfitting, which means that the analysis results are not overly influenced by the sample [78].

This finding is consistent with the theory that structural models with high R-Square have good predictive power, so they can be used to test the causal relationships between variables in more depth. Thus, this model is valid to explain the relationship between latent constructs in the research context.

Table 9.
The F Square value analysis.

	X1	X2	X3	X4	Y1	Y2
X1					0.158	0.003
X2					0.152	0.424
X3					0.121	0.034
Y1						
Y2						

The results of the F Square value analysis show the contribution of the independent variables to the dependent variable with varying degrees of influence (Table 9). Variable X1 has a moderate effect on Y1 (0.158) and a very small effect on Y2 (0.003), indicating that X1 is more relevant in influencing Y1. In contrast, variable X2 has a large effect on Y2 (0.424) and a medium effect on Y1 (0.152), placing it as the variable with the most significant influence, particularly on Y2. The variable X3 shows a small effect on Y1 (0.121) and Y2 (0.034), showing less relevance than X1 and X2. Cohen [79] large F Square values (≥ 0.35) reflect strong, medium (0.15-0.34), and small (0.02-0.14) influence, so X2 dominates in explaining Y2 variability, while X1 is more significant for Y1.

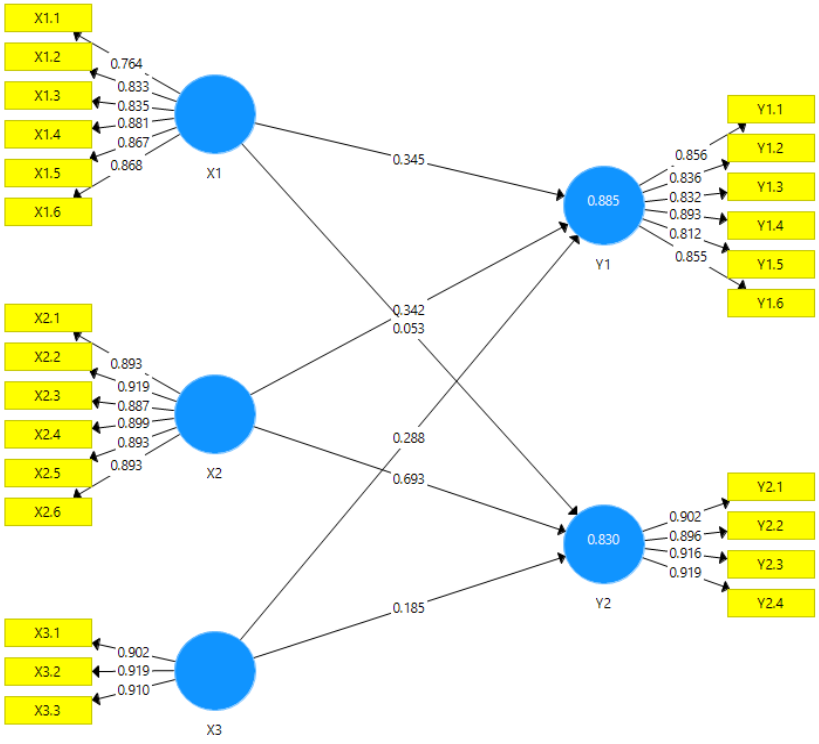

Figure 1.
Results of Path Analysis with Smart PLS.

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The results of path analysis with Smart PLS (Figure 1) revealed significant relationships between latent variables X1, X2, X3, and dependent variables Y1 and Y2, supported by indicators with high loading factors. The loading factor values indicate good measurement quality, with indicator X1.6 having the highest contribution to variable X1 (62.364), X2.2 to X2 (80.906), and X3.3 to X3 (84.666). This indicates that these indicators consistently represent their respective latent variables, where a high loading factor (>0.7) indicates strong convergent validity [75].

In the relationship between variables (Figure 2), X1 has a dominant influence on Y1 with a path coefficient of 6.356, indicating the significant role of X1 in explaining the variance in Y1. In contrast, X2 has a smaller relationship with Y1, with path coefficients of 5.160 and 0.541. These findings suggest that while X2 is relevant in influencing Y1, its influence is smaller than that of X1, which may reflect the more relevant characteristics of the X1 variable in the context of Y1.

For the dependent variable Y2, X2 shows the greatest influence with a path coefficient of 6.565, indicating the dominant role of X2 in explaining the variance in Y2. This influence is much greater than X1 and X3, which have smaller contributions. The dominance of X2 on Y2 confirms the relevance of this variable in influencing the outcome on Y2, which is consistent with previous studies highlighting the significant role of the main variables in explaining the dependent construct [78].

Overall, the model shows strong and meaningful relationships between latent variables. Indicators with high loading factors support measurement validity, while significant path coefficients indicate the strength of the structural relationships between variables. The findings provide empirical support that X1 is more dominant in influencing Y1, while X2 has a major role in influencing Y2.

These results are consistent with the principles of structural analysis that emphasise the importance of path coefficients and loading factors in interpreting PLS model results [75] .

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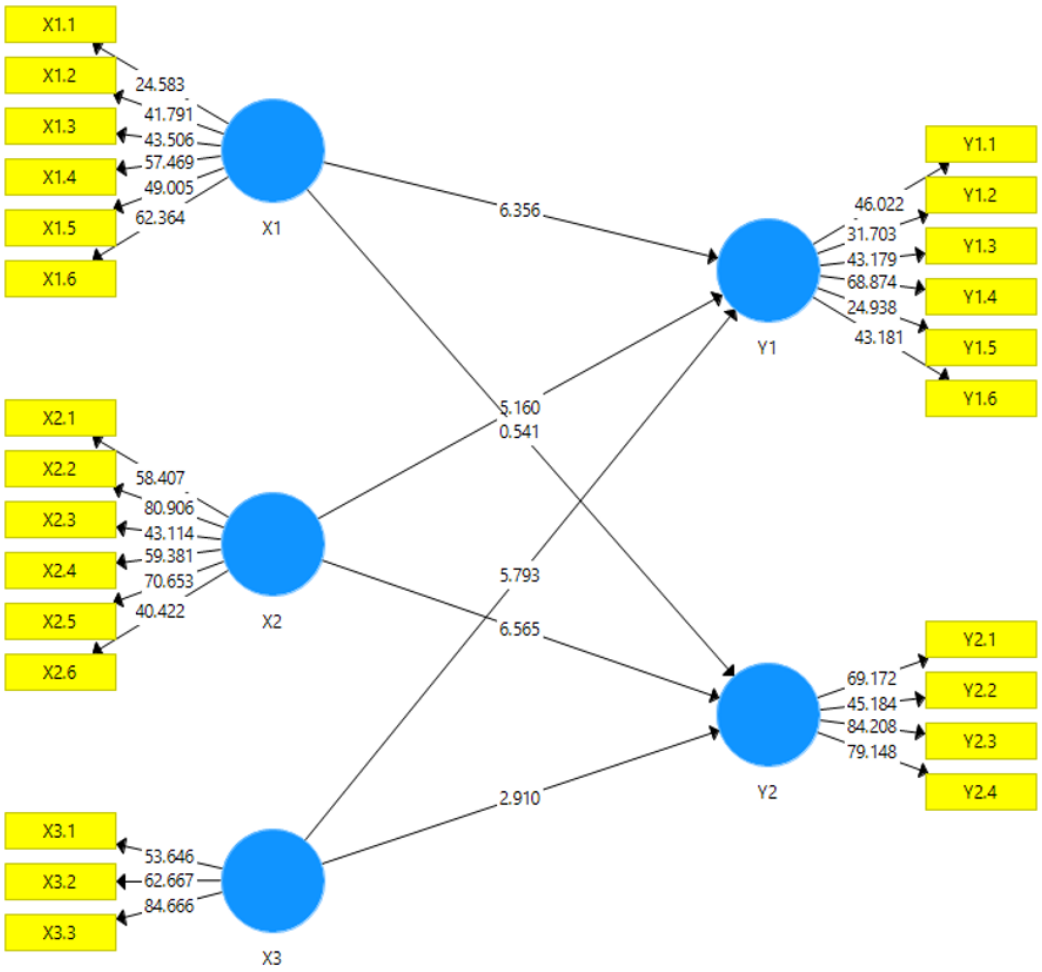

Figure 2.
Path Coefficients after Boostrapping.

Table 10 shows that all latent variables (X1, X2, X3, Y1, and Y2) fulfil the Fornell-Larcker criterion, which assesses discriminant validity based on a comparison between the square root of the Average Variance Extracted (AVE) and the correlation between variables. Each latent variable has an AVE root value (shown on the diagonal of the table) that is greater than its correlation with other latent variables, indicating that each variable has a unique and distinct construction. AVE value greater than 0.5 indicates that the construct is able to explain more than half of the variance of its indicators, which supports convergent validity.

In detail, the latent variable Y2 has the highest AVE root value (0.908), which is greater than its correlations with other variables such as X2 (0.906) and X3 (0.849). Similarly, the latent variable Y1 has an AVE root value of 0.909, which is greater than its correlations with X2 (0.910) and X3 (0.900). The latent variable X3 shows discriminant validity, with an AVE root value of 0.910, which is higher than its correlation with X2 (0.890). Additionally, X2 has an AVE root value of 0.901, which exceeds its correlation with X1 (0.842), and X1 has an AVE root value of 0.842, which is still higher than its correlations with other variables. In conclusion, the model demonstrates discriminant validity, indicating that each latent variable is well-measured and significantly distinct from the others. This confirms that the model is reliable for further analysis.

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Table 10.
Discriminant Validity.

	X1	X2	X3	Y1	Y2
Y2	0.842	0.906	0.849	0.872	0.908
Y1	0.909	0.910	0.900	0.848	
X3	0.888	0.890	0.910		
X2	0.901	0.898			
X1	0.842				

The analysis results show that all indicators on each latent variable have an outer loading value above 0.7 (Table 11) which fulfils the convergent validity criteria. This shows that each indicator is able to represent its latent variable well. Thus, this model has strong measurement quality for further analysis.

Table 11.
Outer Loading.

	X1	X2	X3	Y1	Y2
X1.1	0.764				
X1.2	0.833				
X1.3	0.835				
X1.4	0.881				
X1.5	0.867				
X1.6	0.868				
X2.1		0.893			
X2.2		0.919			
X2.3		0.887			
X2.4		0.899			
X2.5		0.893			
X2.6		0.893			
X3.1			0.902		
X3.2			0.919		
X3.3			0.910		
Y1.1				0.856	
Y1.2				0.836	
Y1.3				0.832	
Y1.4				0.893	
Y1.5				0.812	
Y1.6				0.855	
Y2.1					0.902
Y2.2					0.896
Y2.3					0.916
Y2.4					0.919

The reliability and validity test results show that all latent variables (X1, X2, X3, Y1, and Y2) have excellent reliability and validity (Table 12). The Cronbach's Alpha, rho A, and Composite Reliability values for all variables are above 0.7, indicating high internal consistency. In addition, the AVE values for each variable exceeded 0.5, indicating adequate convergent validity, with variables X3 and Y2 having the highest AVE values (0.829 and 0.825). Based on these results, the measurement model demonstrated excellent reliability and validity, fulfilling all statistical criteria required for further analysis. With strong convergent validity and consistent reliability, this model can be trusted to be used in structural analyses to test the relationships between latent variables.

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Table 12.
Reliability and validity test results.

	Cronbach's Alpha	rho_ A	Composite Reliability	Average Variance Extracted (AVE)
X1	0.918	0.922	0.936	0.710
X2	0.952	0.952	0.961	0.806
X3	0.897	0.897	0.936	0.829
Y1	0.921	0.923	0.939	0.719
Y2	0.929	0.929	0.950	0.825

The Figure 3 shows the Composite Reliability for the latent variables (X1, X2, X3, Y1, and Y2) in the model. All variables have Composite Reliability values above 0.7, which is the minimum threshold to indicate good reliability. The high green bars indicate that each construct has an excellent level of reliability, close to 1.0. Overall, the model shows that the indicators on each latent variable are consistent in measuring their constructs. This strengthens the measurement quality in the model and ensures that the data can be relied upon for further analysis.

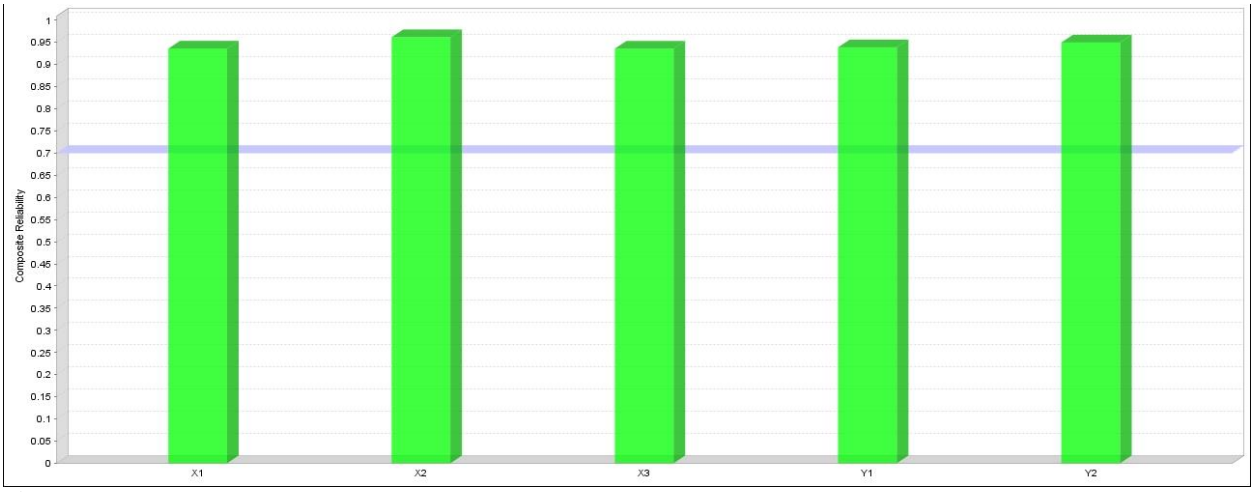

Figure 3.
Composite Reliability for latent variables (X1, X2, X3, Y1, and Y2) in the model.

The results of the relationship analysis between latent variables (Table 13) show that most relationships are statistically significant, except for the relationship between X1 and Y2, which has a P-value of 0.589, so it is considered insignificant. Variable X1 has a positive and significant influence on Y1 with a path coefficient of 0.345 and a T-Statistics value of 6.356, but its influence on Y2 is very small and insignificant. The X2 variable shows a strong influence on both dependent variables, especially on Y2, with the highest path coefficient of 0.693, T-Statistics value of 6.565, and P-value of 0.000, indicating a highly significant relationship. In addition, X2 also has a significant effect on Y1, with a path coefficient of 0.342. Variable X3 has a positive and significant influence on both dependent variables, with a stronger influence on Y1 (coefficient 0.288, T-Statistics 5.793) than on Y2 (coefficient 0.185, T-Statistics 2.910). Overall, the X2 variable showed the largest effect, especially on Y2, while X1 had a more significant effect on Y1 than Y2.

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Table 13.
Results of relationship analysis between latent variables.

	Original Sample (O)	Sample Mean (M)	Standard Deviation (STDEV)	T Statistics (|O/STDEV|)	P Values
X1 -> Y1	0.345	0.347	0.054	6.356	0.000
X1 -> Y2	0.053	0.052	0.098	0.541	0.589
X2 -> Y1	0.342	0.342	0.066	5.160	0.000
X2 -> Y2	0.693	0.693	0.106	6.565	0.000
X3 -> Y1	0.288	0.287	0.050	5.793	0.000
X3 -> Y2	0.185	0.188	0.064	2.910	0.004

Overall, variable X2 (Ecotourism Integration in Contextualised Science Learning) showed the greatest influence, especially on environmental literacy (Y2). This suggests that a learning approach that integrates ecotourism as a context in science can significantly improve students' understanding of environmental issues and their contribution to sustainability. Meanwhile, X1 (Interest and Need for E-Module Development) had a more significant influence on scientific creativity (Y1) than environmental literacy (Y2), which may indicate that students are more moved to develop scientific creativity when they feel their needs for project-based learning are met. Finally, X3 (Collaborative Projects in E-Modules) had a positive effect on both dependent variables, with a stronger contribution to scientific creativity.

These findings provide important implications for the development of project-based e-modules that integrate ecotourism. Emphasis on ecotourism integration in science learning can significantly improve students' environmental literacy, while the development of e-modules that support students' interests and needs and collaborative projects can further enhance their scientific creativity. Therefore, a project-based learning approach integrated with real-world contexts such as ecotourism can be an effective solution to improve both important aspects of science education: scientific creativity and environmental literacy.

Several recent studies have shown that project-based learning can significantly improve students' understanding of creativity [80, 81]. Project-based learning opens opportunities to integrate environmental issues, such as ecotourism. The importance of integrating environmental contexts in science education to strengthen environmental literacy [82]. The use of statistical software such as SPSS and Smart PLS for path analysis and CFA in this study also reflects recent trends in more in-depth data-driven learning evaluation [32]. Thus, these findings support the importance of contextual and project-based approaches in the development of learning that can strengthen students' scientific creativity and environmental literacy in accordance with global trends in higher education.

5. Conclusion

This research shows that the development of ecotourism-integrated project-based e-modules has great potential to improve students' scientific creativity and environmental literacy. Most respondents showed high interest in this learning approach, which is considered to improve understanding of science concepts and its relevance to environmental conservation and encourage creative thinking and care for environmental issues. The integration of ecotourism in project-based e-modules significantly increases students' active involvement, supports contextual learning, and makes a real contribution to developing scientific skills.

The development of ecotourism integrated project-based e-modules must ensure interactive and flexible features to support creative and independent learning. Educational institutions are advised to adopt this e-module to increase the relevance of science learning in real life, especially related to local environmental issues. The development of e-modules should also highlight the integration of ecotourism to maximize students' understanding of environmental conservation and environmental literacy. In addition, training for lecturers and students is needed so that e-modules

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can be optimally utilized in project-based learning. Further research is also important to evaluate the effectiveness of e-module implementation on a wider scale and a more diverse population.

Transparency:

The author confirms that the manuscript is an honest, accurate, and transparent account of the study; that no vital features of the study have been omitted; and that any discrepancies from the study as planned have been explained. This study followed all ethical practices during writing.

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