



Design of a Biology E-Module Based on Education for Sustainable Development (ESD) Integrated with Ethnoscience to Support the Implementation of Deep Learning

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Abstract: This research aims to developing a biology e-module based on education for sustainable development (ESD) integrated with ethnoscience and analysing the developed product's validity and practicality. This research is a research and development (R&D) with the ADDIE development model. This research was conducted at SMAN 1 Bireuen and SMAN 1 Peusangan. Data collection instruments and techniques used expert validation test and questionnaires. The expert validation was used to measure the validity of the developed e-module. The questionnaire was used to measure the practicality of the developed e-module. Data analysis was carried out by processing validator responses and Likert scales. The validity test results showed that the average Aiken Index (V) of biology e-module based on ESD integrated with ethnoscience according to media experts and media experts was 0.81 and 0.89, respectively, with the category of very valid. The average percentage of practicality test results for the biology e-module at SMAN 1 Bireuen and SMAN 1 Peusangan were 90.5% and 85.9%, with the category of very practical. It can be concluded that the biology e-module based on ESD integrated with ethnoscience is valid and practical for use as a teaching material to support the implementation of deep learning.

Keywords: Biology e-modul; Deep learning; Education for Sustainable Development (ESD); Ethnoscience

Introduction

ESD is part of the Sustainable Development Goals (SDGs), contributing significantly to education by guiding students to think futuristically and systematically, develop awareness of the global environment and sustainable values, and cultivate critical thinking and responsibility (Clarisa et al., 2020; Novianti et al., 2023). UNESCO introduced the concept of Education for Sustainable Development (ESD) in education in 2022 as a learning approach that supports sustainable development (Clarisa et al., 2020). Learning in the context of ESD directs students to be able to solve problems in learning while paying attention to the

impact on the environment, society, and economy (Ferguson et al., 2021; Lasekan et al., 2023).

Schools are the primary step in realizing ESD (Filho et al., 2019; Sunthonkanokpong & Murphy, 2019; Ekamilasari & Pursitasari, 2021; Suryani & Hamdu, 2021; Eliyawati et al., 2022; Mardiyanti, 2024). In Indonesia, the integration of ESD concepts has been implemented in the 2013 curriculum so that students have social competence, skills in science and technology, and the ability to think and act creatively, critically, productively, communicatively, and collaboratively to support sustainable community life (Rachmadanti & Gunansyah, 2020; Firda et al., 2023). The ESD principle improves student competence by empowering ways of thinking and behaving (Mohammadnia & Moghadam,

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2019; Ahmad et al., 2023; Mokski et al., 2023; Rahman et al., 2024).

In the 21st century, ESD must be implemented in schools, especially high schools (Kiswandini et al., 2023), because through ESD, students are guided to understand the consequences of their action on the environment and society, develop critical thinking skills, collaborate, and make decisions based on sustainability considerations (Purwadi & Hamdu, 2021; Vioeza et al., 2022; Vioeza et al., 2023). Science facilitates the development of global thinking, which is essential for ESD (Al Darayseh & Alhawamdeh, 2024). Therefore, teachers, as educators, must contribute to the implementation of ESD by innovating learning tools based on ESD values, one of which is ESD-based teaching materials.

Developing teaching materials is crucial to support the competencies to be achieved, taking into account the needs and characteristics of students and their relevance to the curriculum (Yanti & Hanif, 2021; Ismail et al., 2022) and in accordance with the deep learning approach, which emphasizes conceptual understanding and in-depth exploration, knowledge integration, and application in real-life situations (Kovac et al., 2023). Furthermore, technological advancements encourage innovation in the development of teaching materials, including electronically packaged modules (e-modules). The integration of digital technology has a positive impact on the implementation of deep learning (Wu, 2024).

The problem is the lack of application of innovative teaching materials in the form of ESD-based e-modules, particularly in biology learning. This is based on the results of an analysis of student textbooks from an ESD perspective, which shows that they are still very limited and require the development of teaching materials that meet ESD standards (Eliyawati et al., 2022). Furthermore, the results of a needs analysis indicate that the current e-modules do not meet student needs, with the teaching materials used being 100% textbooks, 66.7% student worksheets, and 33.3% learning modules (Yanti & Hanif, 2021). Based on these issues, it is necessary to develop ESD-based e-module teaching materials.

In addition, local culture and wisdom really need to be implemented in biology learning so that students can learn biology in a more meaningful, relevant, and contextual way and they can connect scientific knowledge with real science in their environment (Fuadi & Irdalisa, 2024). Local wisdom-based learning, known as ethnosience, integrates local and cultural knowledge into the subject matter (Adam et al., 2024). The integration of ethnosience is expected to introduce and broaden students' insight regarding environmental phenomena through integration with subject matter. The integration of ethnosience into e-modules

facilitates students' understanding and application of the knowledge learned and acquired in their daily lives (Nuralita et al., 2020; Rahmawati & Atmojo, 2021; Irdalisa et al., 2023). Ethnosience products are used as learning resources for students through a process of reconstruction and scientific explanation by linking ethnosiences products with science learning (Fahrudin et al., 2023). However, there is limited information regarding a biology e-module based on ESD integrated with ethnosience, which is why researcher are using this as a benchmark in developing and designing these teaching materials. This ethnosience-based e-modules could be an alternative media that provides learning experiences with local cultural content.

The use of an ESD context in biology modules is expected to equip students with sustainability awareness and local wisdom. ESD emphasizes problem-solving and collaboration skills to create innovative solutions to support sustainable development. This aligns with the deep learning approach used in the Merdeka curriculum, which prioritizes creativity and innovation in developing sustainable and more adaptive skills to face real-world challenges.

This research aimed to developing a biology e-module based on education for sustainable development (ESD) integrated with ethnosience to support the implementation of deep learning and analysing the developed product's validity and practicality.

Method

This research is a research and development (R&D) with the ADDIE development model. The development procedure consists of five stages, namely analysis, design, development, implementation dan evaluation with developed by Molenda (2003) and Branch (2009). This research was conducted at SMAN 1 Bireuen and SMAN 1 Peusangan. The research locations were determined using a purposive sampling method, based on the school's objectives and availability. This study used primary data from validity and practicality tests.

Development of a biology e-module based on education for sustainable development (ESD) integrated with ethnosience begins with an analysis of the curriculum, student and teacher needs, and previous research. The results of this identification serve as the initial step in developing the e-module material concept and designing it. The developed product will undergo validity testing by subject matter experts and subject matter experts.

The e-module will then be revised based on the expert validation results. To assess the quality of the e-module, a practicality test will be conducted on students of class XI IPA and biology teachers. Based on these

results, the e-module will be evaluated and revised to obtain the final product. The research flow is described in the chart below (Figure 1).

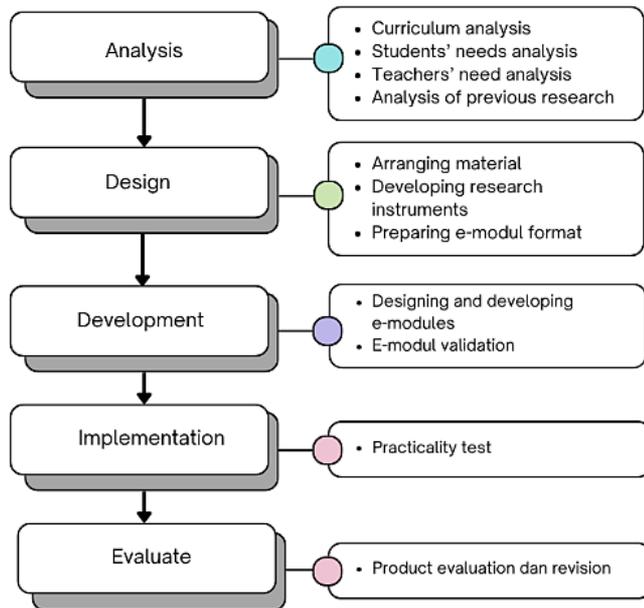


Figure 1. The research flowchart

The data collection instruments and techniques used were expert validation test sheets and questionnaires. The expert validation sheets were used to measure the validity of the developed e-module. The questionnaires were used to measure the practicality of the developed e-module. Data analysis was carried out by processing validator responses and Likert scales, then converting them into qualitative data. The Likert scale used consisted of four alternative answers: very good, good, not good, and very bad. The e-module validity criteria were based on the level of expert agreement as measured by the Aiken V index (Sabaruddin et al., 2022), as follows:

$$V = \frac{\sum S}{[n(c - 1)]} \tag{1}$$

Information:

V = Aiken validity

S = assessor score minus the lowest in the category

n = number of validators

c = highest validity assessment number

After obtaining the validation score, the score is then interpreted based on the instrument validity category standards, as in Table 1.

The practicality of the e-module is reviewed from the results of the student and biology teacher response questionnaire regarding product use. To determine the practicality of the e-module, the average score for each response was calculated using the following formula (Noorhidayati et al., 2021).

$$V = \frac{TS_e}{TS_h} \times 100\% \tag{2}$$

Information:

V = percentage value

TS_e = total answer score

TS_h = expected maximum total score

Table 1. Validity criteria for expert tests

Mark	Criteria
0.8 - 1.0	Very valid
0.61 - 0.80	Valid
0.41 - 0.60	Fairly valid
0.21 - 0.40	Less valid
0.00 - 0.20	Invalid

Based on these calculations, researchers will group the assessment criteria based on practicality criteria as follows:

Table 2. Practically percentage category criteria

Category	Mark
Very practical	81 - 100
Practical	61 - 80
Enough	41 - 60
Less practical	21 - 40
Impractical	0 - 20

Source: Irdalisa et al. (2023)

Result and Discussion

This development research produced biology e-module based on education for sustainable development (ESD) integrated with ethnoscience using the ADDIE development model, consisting of analysis, design, development, implementation, and evaluation. In the analysis stage, curriculum analysis, student and teacher need analysis, and previous research were conducted to identify and select teaching materials according to the curriculum scope. Furthermore, problems and needs of teachers and students were identified, particularly those related to the use of teaching materials in schools. The results of this analysis became the basis for designing an ESD-based biology e-module integrated with ethnoscience on ecosystems and environmental change. The results of this analysis serve as the basis for designing a biology e-module based on ESD integrated with ethnoscience on ecosystems and environmental change. This aligns with Yuliana & Barlian (2021) statement that the development of teaching materials must be tailored to the curriculum and student needs.

In the design stage, initial product design is carried out, referring to curriculum learning outcomes and learning objectives aligned with the concepts of ecosystems and environmental change. The e-module presents environmental issues relevant to the learning

material. At this stage, instruments are also developed, including expert validation sheets and teacher and student response questionnaires to assess the practicality of the developed product.

In the development stage, the e-module product was developed in the form of an application that can be accessed by students via smartphone or laptop. The content of a biology e-module based on ESD integrated with ethnoscience consists of 2 subtopics, namely the components and interactions between ecosystem components and environmental change and pollution. In addition to the material description, this e-module is also equipped with videos to clarify the material presented and enhance the ESD components to increase students' sustainability awareness. The e-module also presents case studies related to real conditions of their surrounding environment so that they recognize environmental issues so they can determine attitudes to overcome problems that occur and determine preventive solutions to these problems. The design of biology e-module based on ESD integrated with ethnoscience is presented in Figure 2.

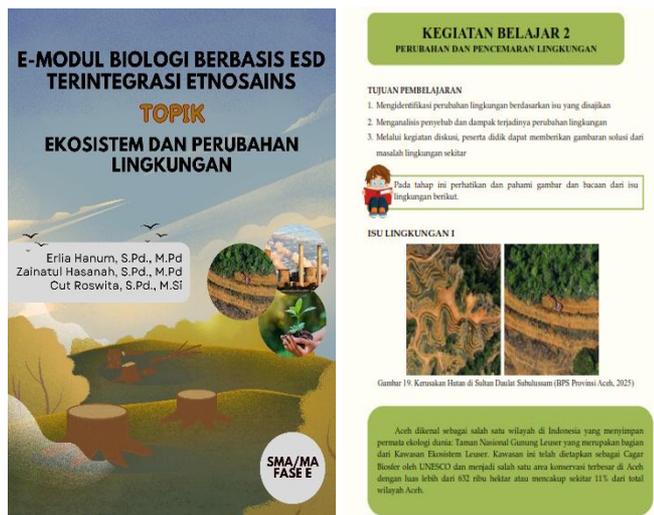


Figure 2. Design e-module

Table 3. Aiken index coefficient results of media expert

Assessment Aspects	Aiken Index (V)	Category
Display and quality of the e-module	0.80	Very valid
Technical quality	1	Very valid
Legibility	1	Very valid
E-module attractiveness	0.79	Valid
Alignment with the concepts of ESD and ethnoscience	0.83	Very valid
Average	0.81	Very valid

The developed e-module product was then validated by material experts and media experts. The validity of the developed biology e-module based on

ESD integrated with ethnoscience was measured using the expert agreement index based on the Aiken index (V). The results are presented in Tables 3 and 4.

In Table 3, it can be seen that the average Aiken Index (V) of biology e-module based on ESD integrated with ethnoscience according to media experts is 0.81 with a very valid category.

Table 4. Aiken index coefficient results of material expert

Assessment Aspects	Aiken Index (V)	Category
Subject matter	0.83	Very valid
Language quality	0.75	Valid
Auxiliary information	0.83	Very valid
Average	0.89	Very valid

In Table 4, it can be seen that the average Aiken Index (V) of the biology e-module based on ESD integrated with ethnoscience according to material experts is 0.89 with a very valid category. Based on the results of expert validation, it shows that the developed e-module has a very valid level of validity with an Aiken index > 0.4 for each assessment aspect. Thus, the developed e-module product is suitable for use in the learning process with minor revisions.

The revised e-module was then tested for practicality to determine the quality of the biology e-module based on ESD integrated with ethnoscience whether it is practical or not to use as a teaching material. The practicality assessment aspects include cognitive content, adaptiveness, user friendliness, benefits and the appearance of the e-module. The results of the practicality test of the biology e-module based on ESD integrated with ethnoscience based on the views of teachers and students can be seen in Table 5 and Table 6.

Table 5. Practicality test results for teachers

Assessment Aspects	Total Score	Practicality Percentage (%)
Cognitive content		90
Adaptive	216	93.50
User friendly	187	95.83
Utility	115	83.13
Display quality	113	94.17
Average	113	91.33
Conclusion		Very practical

Table 6. Practicality test results for students at SMAN 1 Bireuen

Assessment Aspects	Total Score	Practicality Percentage (%)
Cognitive content	216	88.93
Adaptive	187	92.86
User Friendly	115	89.29
Utility	113	90.71
Display quality	113	90.71
Average		90.50
Conclusion		Very practical

Table 5 shows that the developed biology e-module is very practical for each assessment aspect. Table 6 shows that the average percentage of the results of the practicality test of the biology e-module at SMAN 1 Bireuen was 90.50% with a very practical category.

Table 7. Practicality test results for students at SMAN 1 Peusangan

Assessment Aspects	Total Score	Practicality Percentage (%)
Cognitive content	200	86.21
Adaptive	202	87.07
User friendly	387	83.41
Utility	613	88.07
Display quality	392	84.48
Average		85.85
Conclusion		Very practical

Table 7 shows that the average percentage of practicality test results for the biology e-module at SMAN 1 Peusangan was 85.85%, categorized as very practical. Thus, the developed ethnosience-based ESD-integrated biology e-module is very practical based on the views of students and teachers as users. The research results indicate that the developed product is feasible and practical for use in learning. If the product's assessment by experts, teachers, and students is categorized as good, then the product is suitable for implementation in learning (Arafah et al., 2023).

The problem-solving approach and strategy implemented using the ESD context in teaching materials, particularly electronically packaged learning modules integrated with ethnosience, are expected to equip students with sustainable values, fostering an awareness of preserving and appreciating the surrounding environment and local wisdom. Integrating ethnosience into teaching materials will raise students' awareness of cultural heritage as they learn scientific concepts, making learning more engaging and meaningful (Prasadi et al., 2020). Furthermore, ethnosience has a significant impact on resource management and conservation efforts and helps build a more cohesive science education method (Majumdar & Chatterjee, 2021), making it suitable for integration into e-modules on ecosystems and environmental change. Ethnosience enriches students' experiences by introducing local wisdom and cultural diversity that exist in the surrounding community (Fuadi & Irdalisa, 2024).

Through the implementation of ESD, students are equipped with knowledge, skills, and attitudes that guide them actively, responsibly, and consciously recognize themselves as subjects capable of realizing sustainable development through sustainable values (Najwa & Suhartini, 2023). The ethnosience approach integrates local community knowledge with science,

making it easy to integrate into learning (Munawaroh et al., 2022). Ethnosience learning is effective because it integrates local culture with the material students learn in school, enabling them to easily understand the subject matter (Rahmawati & Atmojo, 2021).

Biology e-module based on ESD integrated with ethnosience on ecosystem and environmental change material has been developed in the form of an application that can be accessed by students using smartphones. Based on the results of student responses, it shows that the developed biology e-module is easy to access and very useful for them because it makes it easier for them to understand the concepts learned through environmental issues presented according to the teaching material.

Biology e-module based on ESD integrated with ethnosience can support the implementation of deep learning because it presents biological concepts that are closely related to real problems so that students are invited to find solutions based on local wisdom through environmental issues, thus creating a meaningful learning atmosphere through the development of critical thinking and problem-solving skills. Deep learning is very important in the context of education because it emphasizes a comprehensive understanding of concepts, the development of critical thinking skills and applicable problem-solving abilities (Jafar et al., 2025). Deep learning emphasizes in-depth conceptual understanding by interpreting information and connecting learning experiences with real life so as to develop the thinking insights needed in the 21st century (Hikmah et al., 2023; Taufik et al., 2025). Deep learning requires teaching modules that not only emphasize the delivery of material but also integrate critical thinking, problem-solving and comprehensive exploration of concepts (Haryono et al., 2025).

Conclusion

Based in the result of the study, Biology e-module based on ESD integrated with ethnosience is valid and practical for use as teaching material to support the implementation of deep learning where the average Aiken Index (V) according to according to media experts and media experts was 0.81 and 0.89, and the average percentage of practicality test results for the biology e-module at SMAN 1 Bireuen and SMAN 1 Peusangan were 90.5% and 85.9%. This e-module is an online learning resource for students, especially for ecosystems and environmental change.

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Author Contributions

Writing original draft of article manuscript, data collection and review of results, E.H.; methodology, discussion, conclusion, Z.H.; analysis, provided feedback and editing C.R. and E.H.

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Conflicts of Interest

The funders had no role in the design of the study; in the collection, analyses, or interpretation of data; in the writing of the manuscript; or in the decision to publish the results.

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