# Development of an Ethnoscience-Integrated Interactive Flipbook E-Module to Enhance Junior High School Students' Environmental Literacy in Support of Sustainable Development Goals

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**Abstract:** This study aimed to develop and evaluate an Ethnoscience-integrated interactive flipbook-based e-module on environmental pollution to improve junior high school students' environmental literacy. The research employed a Research and Development approach using the ADDIE model, encompassing analysis, design, development, implementation, and evaluation. The subjects were seventh-grade students of a public junior high school in Padang, Indonesia. Data were collected through expert validation sheets, practicality questionnaires, and environmental literacy tests. The results showed that the e-module achieved a very high validity level (0.87). Practicality testing indicated that teachers rated the e-module as very practical (88%), while students rated it as practical (79%). The lower student score was influenced by minor technical constraints, such as device limitations and internet access during implementation. Effectiveness testing was conducted using the Mann–Whitney U test, as normality and homogeneity assumptions were not fully met. The results revealed a significant difference in environmental literacy between the experimental and control groups (p < .001), with a higher mean rank in the experimental group. The improvement was further supported by a moderate effect size (d = 0.35). These findings indicate that the Ethnoscience-integrated interactive flipbook-based e-module is valid, practical, and effective in enhancing students' environmental literacy and is suitable for contextual science learning aligned with the Merdeka Curriculum.

**Keywords:** Environmental literacy; Environmental pollution; Ethnoscience; Flipbook; Interactive e-module

## Introduction

In recent years, the world has been confronted with an escalating environmental crisis that is increasingly complex, systemic, and interconnected. Global climate change is no longer perceived as a long-term threat; rather, it has generated tangible impacts, including the increased frequency and intensity of hydrometeorological disasters, environmental degradation, food and water insecurity, and heightened socio-ecological vulnerability (Stringer et al., 2021). Recent reports indicate that human activities constitute the dominant driver accelerating environmental deterioration through unsustainable natural resource exploitation, pollution, and land-use change. This condition underscores that technical and policy-based solutions alone are insufficient without a fundamental transformation in human ways of thinking, attitudes, and behaviors toward the environment.

In the global context, environmental education is positioned as a strategic instrument for building human capacity to respond to ecological crises (Jickling et al., 2008). Education is expected not only to produce individuals who understand environmental concepts but also to cultivate critical, reflective, and responsible decision-makers whose actions support ecosystem sustainability (Ekamilasari et al., 2021). Consequently, environmental literacy has emerged as a key twenty-first-century competence, comparable to scientific, digital, and civic literacy. Environmental literacy encompasses an understanding of contemporary environmental issues, the ability to analyze human–nature relationships, and an ethical awareness to act sustainably.

However, recent studies reveal that the implementation of environmental education in schools continues to face substantial challenges. Environmental instruction frequently remains confined to a cognitively oriented, concept-memorization approach, with limited reinforcement of affective and psychomotor domains (Diaz & Vela, 2025). As a result, a discrepancy emerges between students' environmental knowledge and their actual behavior in daily life. This phenomenon, widely referred to as the knowledge–action gap, reflects a situation in which individuals recognize the importance of environmental protection but lack the awareness and commitment to act accordingly (Steg & Vlek, 2009).

In Indonesia, these challenges are further compounded by environmental vulnerability resulting from development pressures, rapid population growth, and accelerated socio-economic change. Water pollution from domestic and industrial waste, declining urban air quality, and ecosystem degradation due to land-use conversion remain persistent environmental concerns (Nisva, 2025). At the junior secondary level, several studies indicate that students' environmental literacy generally falls within the low to moderate categories. Research conducted by Ririn et al. (2021), employing the Middle School Environmental Literacy Survey (MSELS), reported that students' environmental literacy was categorized as moderate, with an average percentage of 58.48%. Similarly, Erfan (2025) found that students' environmental literacy had not developed comprehensively, particularly in conceptual understanding and environmental issue analysis. Other studies suggest that although students may demonstrate pro-environmental attitudes and behaviors, their knowledge base and environmental critical-thinking skills remain relatively limited.

These findings indicate that environmental literacy among junior secondary students has not yet developed optimally, particularly in cognitive and analytical dimensions. Consistent with Hayandi (2025), environmental literacy tends to develop partially, where pro-environmental attitudes and behaviors are not accompanied by sufficient conceptual understanding and analytical capacity. This condition is reflected in students' limited concern for school environmental cleanliness and sustainability, weak critical analysis of environmental issues, and minimal active participation in environmental conservation efforts.

One of the underlying causes of low environmental literacy lies in instructional approaches and teaching materials used in schools. Science learning, particularly on environmental pollution topics, is still predominantly delivered through abstract conceptual explanations detached from students' real-life contexts. As a result, learning content is perceived as distant from students' daily experiences, limiting their ability to construct meaning and relevance (Najwa & Suhartini, 2023). Effective environmental education, however, requires a direct linkage between scientific concepts, local environmental phenomena, and students' personal experiences to foster sustainable ecological awareness.

Within this framework, the ethnoscience approach offers a relevant and contextual pedagogical perspective (Saputra et al., 2021). Ethnoscience integrates local knowledge, cultural values, and community practices as integral components of science learning (Azhar et al., 2023). This approach recognizes that communities have long possessed adaptive and sustainable environmental management knowledge. Integrating ethnoscience into science instruction enables students to understand environmental pollution concepts through authentic examples in their surrounding environment, such as traditional waste management practices, local resource utilization, and cultural values emphasizing harmony between humans and nature (Indriyani et al., 2022). As highlighted by Komarudin (2025), ethnoscience-based e-modules that integrate local wisdom with modern scientific concepts can serve as effective learning resources, presenting content concisely, visually, interactively, and contextually. For example, the Rimbo Larangan Nagari Paru forest in Sijunjung, West Sumatra, represents a community-managed customary forest preserved collectively by local residents, embodying scientific principles of conservation in practice. Thus, ethnoscience not only enriches instructional content but also strengthens the affective and ethical dimensions of environmental education.

Concurrently, digital transformation in education offers new opportunities to facilitate interactive, flexible, and student-centered learning (Otto et al., 2024). The rapid expansion of digital technologies, particularly in the post-pandemic era, has encouraged the use of electronic teaching materials as alternatives and complements to printed resources. E-modules provide advantages in supporting independent learning, integrating multimedia elements, and facilitating

differentiated instruction tailored to students' needs (Logan et al., 2021). One increasingly popular format is the digital flipbook-based e-module, which presents learning materials in an interactive book-like interface enriched with animations, videos, audio, and evaluative quizzes.

Previous studies demonstrate that flipbook-based e-modules effectively enhance learning motivation, student engagement, and scientific literacy. Awwaliyah et al. (2018) reported that the implementation of flipbook-based e-modules significantly improved students' learning motivation. The developed modules were considered valid and practical, increasing student engagement through interactive and appealing content that encouraged active and autonomous learning. Nevertheless, most existing studies focus primarily on technological aspects and cognitive learning outcomes, without deeply integrating local values and students' environmental contexts. Research combining flipbook-based e-modules with an ethnoscience approach to enhance environmental literacy, particularly on environmental pollution topics at the junior secondary level, remains limited. The proposed e-module in this study incorporates ethnoscientific elements to enhance contextual relevance, alongside interactive question-response features and embedded instructional videos.

Furthermore, Indonesia's national education policy through the Kurikulum Merdeka emphasizes contextual learning, character strengthening, and the development of twenty-first-century competencies. The curriculum provides flexibility for teachers to design meaningful instructional materials aligned with students' characteristics and needs. Accordingly, the development of an ethnoscience-integrated interactive flipbook e-module is consistent with national educational policy directions and contemporary learning demands.

Based on the foregoing discussion, the development of an ethnoscience-integrated interactive flipbook e-module represents a strategic necessity in environmental education. This innovation is expected to bridge the gap between environmental knowledge and pro-environmental behavior among students while addressing global ecological challenges through contextual, transformative, and sustainable education. Therefore, this study contributes not only to the advancement of innovative instructional materials but also offers theoretical and empirical contributions to strengthening environmental literacy among junior secondary students in the era of environmental crisis and digital transformation.

## Method

This study employed a Research and Development (R&D) approach aimed at designing, validating, and evaluating the effectiveness of an educational product in the form of an interactive flipbook-based e-module integrated with ethnoscience. The R&D approach was selected because the study did not merely focus on hypothesis testing; rather, it emphasized a systematic and iterative process of designing, developing, and refining an instructional product to ensure its feasibility and effectiveness in real learning contexts.
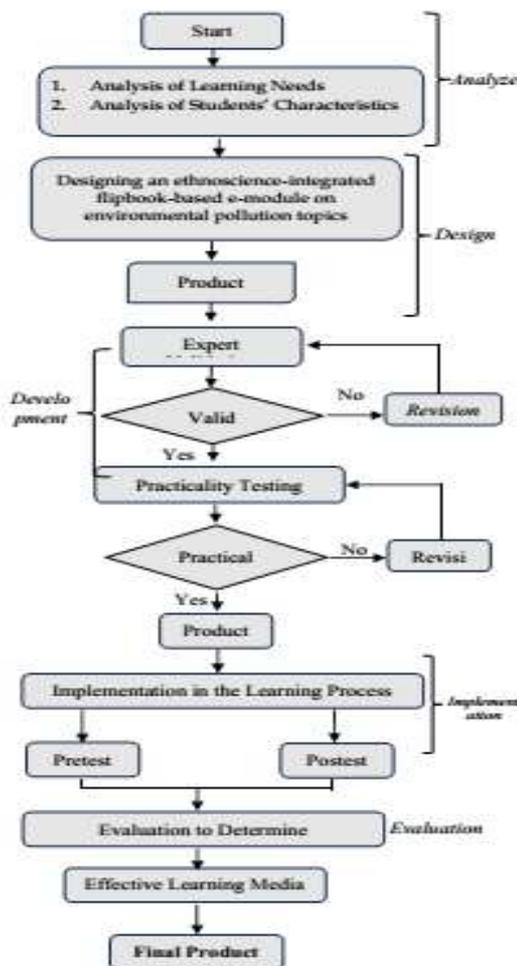


**Figure 1.** Research flow diagram

The development model adopted in this study was the ADDIE model, which consists of five principal stages: Analysis, Design, Development, Implementation, and Evaluation (Branch, 2009). The ADDIE model represents a systematic instructional design framework oriented toward solving instructional problems through structured and sequential procedures. Each stage is interrelated and functions to ensure that the developed learning product aligns with students' needs, contextual characteristics, and predetermined learning objectives. The research flowchart illustrating the implementation of the ADDIE stages in this study is presented in the figure 1.

The subjects of this study were seventh-grade students of SMP Negeri 29 Kota Padang in the

2024/2025 academic year. The total number of participants was 66 students, comprising 33 students in the experimental class and 33 students in the control class. The students were aged between 12 and 13 years and had relatively homogeneous academic backgrounds based on school records.

The sampling technique employed was purposive sampling, taking into account the equivalence of class characteristics and recommendations from the science teacher. Two intact classes were selected to preserve the integrity of the instructional process and to comply with the school's academic policies. The designation of the experimental and control classes was determined based on the science teacher's recommendation, considering the comparability of students' academic characteristics. Furthermore, to minimize potential bias resulting from the absence of individual randomization, students' prior ability was controlled through the administration of an environmental literacy pretest in both classes before the treatment was implemented.

### Research Stages
#### Analysis
The analysis stage was conducted to identify learning needs, students' characteristics, and problems encountered in science learning on environmental pollution topics. The analysis was carried out through curriculum review, teacher interviews, and classroom observations. The results indicated the need for interactive digital instructional materials integrated with local contexts (ethnoscience).

#### Design
At the design stage, the researchers developed the structure and design of the e-module, including learning objectives, environmental pollution content, integration of ethnoscience materials, and environmental literacy assessment instruments. The visual design and navigation of the e-module were adapted to junior high school students' characteristics and the principles of contextual learning.

#### Development
The development stage involved the creation of an interactive flipbook-based e-module in accordance with the predetermined design. The developed product was then validated by subject matter, language, and design experts to assess content relevance, linguistic clarity, and visual presentation. Feedback from the validators was used as the basis for product revision.

#### Implementation
The revised e-module was implemented in science learning at the junior high school level. At this stage, practicality testing was conducted by teachers and students, and effectiveness testing was carried out through pretest and posttest administration to measure improvements in students' environmental literacy after using the e-module.

#### Evaluation
The evaluation stage was conducted through formative and summative evaluations to determine the validity, practicality, and effectiveness of the e-module. The evaluation results were used as a basis for further product refinement.

## Result and Discussion

The results of the development and implementation of the ethnoscience-integrated interactive flipbook-based e-module are presented by examining its contribution to improving junior high school students' environmental literacy. The analysis focused on three principal dimensions: validity, practicality, and effectiveness of the e-module as a digital instructional material on environmental pollution topics.

The development process of the interactive e-module was conducted using Canva and Heyzine applications. Canva was utilized to design the visual layout of the e-module, including page structure, illustrations, typography, color schemes, and graphic elements to ensure visual coherence and attractiveness. Meanwhile, Heyzine was employed to convert the finalized design into an interactive digital flipbook format, enabling features such as page-flipping effects, embedded multimedia (videos and interactive quizzes), and online accessibility. The workflow of product development, from the initial design phase to the publication of the interactive flipbook, is illustrated in Figure 2.
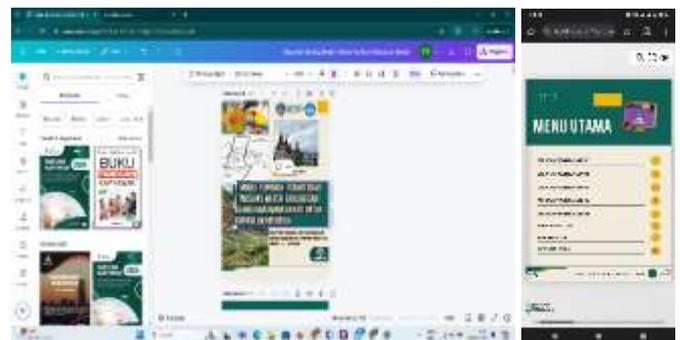


**Figure 2.** Product design using heyzine and canva

Expert validation results indicated that the developed e-module demonstrated a high level of feasibility, with an average validity score of 0.87, categorized as very valid. This finding suggests that the instructional content aligns with science learning competencies, is presented using clear and

communicative language, and is supported by an engaging visual design and user-friendly navigation system.

Moreover, the integration of ethnoscience elements strengthened the linkage between scientific concepts and local cultural contexts, thereby enhancing the contextual relevance and meaningfulness of the learning material for students (Afdarina et al., 2024). The validity results are presented in the following figure 3.
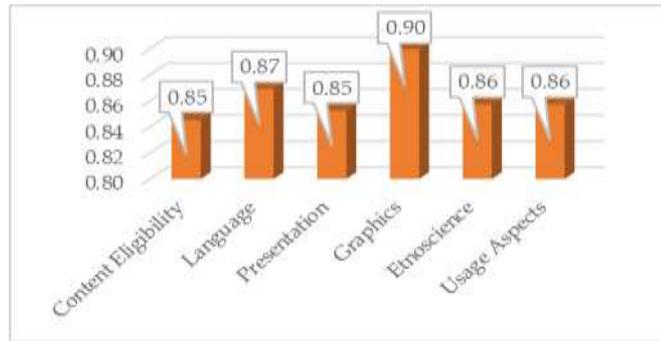


**Figure 3.** Product validity results

In addition to being valid, the developed e-module demonstrated a high level of practicality. The results of the practicality evaluation conducted by teachers yielded an average score of 88%, categorized as very practical, while student assessments resulted in an average score of 79%, categorized as practical. These findings indicate that the e-module is easy to use, efficient for classroom implementation, and supports teachers in delivering environmental pollution content in a systematic manner. From the students' perspective, the inclusion of interactive features such as visual illustrations, videos, and evaluative quizzes enhanced their interest and engagement in the learning process. These results are consistent with previous studies reporting that interactive digital instructional materials can improve students' learning motivation and active participation (Nurmayani et al., 2025).
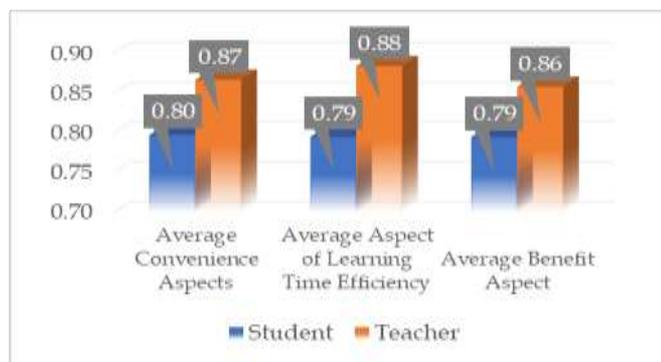


**Figure 4.** Practicality assessment results

Following the practicality testing phase, the instrument was implemented in one public junior high school in Padang, namely SMP Negeri 29 Kota Padang, to examine its effectiveness. The study involved two intact classes: the experimental class utilized the ethnoscience-integrated flipbook-based e-module, whereas the control class employed conventional printed textbooks.

To measure students' environmental literacy, the researchers administered a test consisting of 30 items. Prior to its use in the main study, the test instrument was piloted with 30 students outside the research sample to evaluate its validity and reliability. The pilot data were analyzed using IBM SPSS version 23. Instrument reliability was assessed using the Pearson correlation coefficient. The analysis results indicated that all 30 items met the criteria for validity and reliability and were therefore deemed appropriate for use in the effectiveness testing phase.

**Table 1.** Validity test results

| Question Number | r count (Pearson Correlation) | Sig. | Decision |
| --- | --- | --- | --- |
| 1 | 0.539 | 0.002 | Valid |
| 2 | 0.730 | 0.000 | Valid |
| 3 | 0.391 | 0.033 | Valid |
| 4 | 0.400 | 0.028 | Valid |
| 5 | 0.453 | 0.012 | Valid |
| 6 | 0.143 | 0.451 | Invalid |
| 7 | 0.461 | 0.010 | Valid |
| 8 | 0.730 | 0.000 | Valid |
| 9 | 0.404 | 0.027 | Valid |
| 10 | 0.436 | 0.016 | Valid |
| 11 | 0.615 | 0.000 | Valid |
| 12 | 0.615 | 0.000 | Valid |
| 13 | 0.391 | 0.033 | Valid |
| 14 | 0.062 | 0.747 | Invalid |
| 15 | 0.422 | 0.020 | Valid |
| 16 | −0.103 | 0.589 | Invalid |
| 18 | 0.370 | 0.044 | Valid |
| 19 | 0.410 | 0.024 | Valid |
| 20 | 0.420 | 0.021 | Valid |
| 22 | 0.152 | 0.021 | valid |
| 23 | 0.551 | 0.002 | Valid |
| 24 | 0.545 | 0.002 | Valid |
| 25 | 0.518 | 0.003 | Valid |
| 26 | 0.607 | 0.000 | Valid |
| 27 | 0.544 | 0.002 | Valid |
| 28 | 0.506 | 0.004 | Valid |
| 29 | 0.370 | 0.044 | Valid |
| 30 | 0.572 | 0.001 | Valid |
| 32 | 0.436 | 0.016 | Valid |
| 33 | 0.460 | 0.010 | Valid |
| 34 | 0.574 | 0.001 | Valid |
| 35 | 0.695 | 0.000 | Valid |
| 36 | 0.447 | 0.013 | Valid |

Furthermore, the reliability test results indicated that the Cronbach's Alpha coefficient was 0.884 for a total of 30 items. A Cronbach's Alpha value exceeding

0.80 reflects a very high level of internal consistency. This result confirms that all items within the instrument consistently measure the same construct and demonstrate a strong degree of reliability.

Therefore, the questionnaire is considered appropriate for use as a data collection instrument in this study, as it is capable of producing stable, consistent, and trustworthy data.

**Table 2.** Reliability test results

| Reliability Statistics[a] | |
| --- | --- |
| Cronbach's Alpha | N of Items |
| .884 | 30 |



**Figure 5.** Documentation of research activities

After confirming that the test items were valid and reliable, the instrument was administered to the research participants. A pretest was first conducted in both the experimental and control classes to measure students' initial environmental literacy levels. Following the instructional intervention, a posttest was administered to assess changes in students' literacy after the learning process.

The collected data were subsequently analyzed using IBM SPSS version 23. Prior to hypothesis testing, prerequisite analyses were performed to ensure that the data met the assumptions required for parametric statistical testing. The results of the normality test are presented in the following table.

**Table 3.** Results of the Normality Test (Kolmogorov–Smirnov and Shapiro–Wilk)

| Tests of Normality | | | | | | | |
| --- | --- | --- | --- | --- | --- | --- | --- |
| Class | | Kolmogorov-Smirnov[a] | | | Shapiro-Wilk | | |
| | | Statistic | df | Sig. | Statistic | df | Sig. |
| Results | 1 | 0.218 | 33 | 0.000 | 0.848 | 33 | 0.000 |
| | 2 | 0.186 | 33 | 0.005 | 0.896 | 33 | 0.004 |
| | 3 | 0.164 | 33 | 0.025 | 0.932 | 33 | 0.041 |
| | 4 | 0.140 | 33 | 0.099 | 0.941 | 33 | 0.074 |

a. Lilliefors Significance Correction

The normality of the data in this study was assessed using the Shapiro–Wilk test, as the sample size was fewer than 100 participants. The results indicated that the significance values for Result 1 (Sig. = 0.000), Result 2 (Sig. = 0.004), and Result 3 (Sig. = 0.041) were lower than 0.05, leading to the conclusion that these datasets were not normally distributed. In contrast, Result 4 yielded a significance value of 0.074, which exceeded 0.05, indicating that this dataset was normally distributed.

Therefore, overall, the research data did not fully satisfy the normality assumption, as the majority of the datasets were not normally distributed. Subsequently, a homogeneity test was conducted, the results of which are presented in the following table.

**Table 4.** Results of the Homogeneity of Variance Test (Levene's Test)

| Test of Homogeneity of Variance | | Levene Statistic | df1 | df2 | Sig. |
| --- | --- | --- | --- | --- | --- |
| Results | Based on Mean | 8,240 | 3 | 128 | .000 |
| | Based on Median | 5,852 | 3 | 128 | .001 |
| | Based on Median and with adjusted df | 5,852 | 3 | 99,877 | .001 |
| | Based on trimmed mean | 7,451 | 3 | 128 | .000 |

The homogeneity of variance in this study was examined using Levene's test at a significance level of 0.05. The results indicated that the significance values based on the mean (Sig. = 0.000), median (Sig. = 0.001), median with adjusted degrees of freedom (Sig. = 0.001), and trimmed mean (Sig. = 0.000) were all below 0.05. These findings demonstrate that the variances between groups were not homogeneous. Therefore, it can be concluded that the data did not meet the assumption of homogeneity of variance.

The product effectiveness test was conducted using an independent samples t-test if the prerequisite assumptions—normality and homogeneity—were satisfied. However, if the data did not meet the normality assumption, the non-parametric Mann–Whitney U test was employed as an alternative. The normality test was conducted to determine whether the data distribution followed a normal pattern, whereas the homogeneity test was performed to assess whether the variances across groups were equal. Based on these analytical considerations, the research hypotheses were formulated as follows:

$H_0$: There is no significant difference in students' environmental literacy before and after learning using the ethnoscience-integrated interactive flipbook-based e-module on environmental pollution topics.

H$_1$: There is a significant difference in students' environmental literacy before and after learning using the ethnoscience-integrated interactive flipbook-based e-module on environmental pollution topics.

Based on the results of the prerequisite tests, the Mann–Whitney U test was employed for hypothesis testing, as the data did not meet the assumptions of normal distribution and homogeneity of variance. The use of this non-parametric test was considered appropriate because it does not require normally distributed data and is robust against violations of variance homogeneity.

**Table 5.** Hypothesis test results

| Ranks | | | | |
|---|---|---|---|---|
| Class | | N | Mean Rank | Sum of Ranks |
| Results | Post test Experiment | 33 | 46.14 | 1522.50 |
| | Post Test Control | 33 | 20.86 | 688.50 |
| | Total | 66 | | |

**Table 6.** Mann-Whitney U test results

| Test Statistics[a] | |
|---|---|
| | Results |
| Mann-Whitney U | 127,500 |
| Wilcoxon W | 688,500 |
| Z | -5,365 |
| Asymp. Sig. (2-tailed) | .000 |
| a Grouping Variable: Class | |

Hypothesis testing in this study was conducted using the Mann–Whitney U test, as the data did not meet the assumptions of normality and homogeneity of variance. The analysis revealed a significance value of p < .001, which is lower than the 0.05 threshold. Therefore, the null hypothesis (H$_0$) was rejected and the alternative hypothesis (H$_1$) was accepted.

Furthermore, the mean rank for the experimental group's posttest (46.14) was higher than that of the control group (20.86), indicating that students in the experimental class demonstrated superior environmental literacy compared to those in the control class. These findings confirm that the use of the ethnoscience-integrated interactive flipbook-based e-module had a statistically significant effect on improving students' environmental literacy.

To determine the magnitude of the treatment effect, an effect size analysis was also conducted. The effect size (*d*) test serves as a follow-up statistical measure to quantify the strength of the intervention's impact, thereby providing a more comprehensive interpretation beyond statistical significance alone.

$$d = \frac{m_{max} - m_{min}}{\sigma}$$

$$d = \frac{74.30 - 86.06}{3363.758017} = 0.349609.$$

The magnitude of the effect size was interpreted based on the criteria proposed by Cohen (1988), as follows:

d < 0.20 : small effect

0.20 ≤ d < 0.80 : medium effect

d ≥ 0.80 : large effect

Based on the calculation of the effect size using Cohen's d, a value of 0.35 was obtained. Referring to Cohen's (1988) criteria, this value falls within the medium effect category. This indicates that the treatment exerted a meaningful influence on the observed variable; however, the magnitude of the effect can be considered moderate rather than strong.

Conceptually, the improvement in environmental literacy observed in the experimental class can be explained by the interactive, contextual, and experiential characteristics of the developed e-module. This interpretation is supported by Saputri (2025), who reported that students' environmental literacy develops more effectively when learning experiences are situated within authentic environmental contexts closely related to their daily lives. Similarly, Liunima (2025) found that low levels of environmental literacy are often attributable to decontextualized instruction, resulting in fragmented knowledge that students are unable to apply to real-world environmental problem-solving. The integration of ethnoscience enables students to connect environmental pollution concepts with familiar local practices and phenomena, thereby engaging not only cognitive processes but also affective dimensions and ecological awareness (Sari et al., 2025). In this sense, the e-module functions not merely as a medium for delivering information but also as a tool for fostering environmental attitudes and responsibility.

The findings of this study reinforce previous research highlighting the potential of interactive digital instructional materials to enhance learning quality and environmental literacy. Daulay et al. (2024) reported that digital teaching materials integrated with environmental contexts and local wisdom facilitate conceptual understanding while simultaneously strengthening students' environmental awareness (Fitri et al., 2024). These results suggest that interactive digital materials hold substantial potential for supporting meaningful science learning oriented toward environmental literacy development. The present study contributes further by emphasizing the integration of local values through an ethnoscience approach, ensuring that instructional innovation is not only technologically advanced but also socially and culturally relevant. This aligns with Lawe (2025), who emphasized that ethnoscience-based

learning requires structured and contextual learning resources to be implemented effectively in schools.

The enhancement of environmental literacy among students in the experimental group was also supported by the interactive features embedded within the flipbook e-module, including videos and animations. These features assisted students in visualizing abstract environmental pollution processes—such as water contamination mechanisms and their ecological impacts—thus promoting deeper conceptual understanding. This finding is consistent with Husamah (2025), who mapped the development of digital learning media, including video and interactive platforms, and concluded that such media contribute significantly to improved conceptual comprehension and environmental literacy in environmental education.

Beyond interactivity, the integration of local values (ethnoscience) within the flipbook contributed meaningfully to students' literacy development. The presentation of local wisdom closely related to daily life—such as community practices in maintaining environmental cleanliness and conserving natural resources—encouraged students to contextualize learning content within their own environmental settings. This is corroborated by Sihombing (2025), who demonstrated that integrating local wisdom through ethnoscience not only enhances conceptual understanding but also strengthens cultural appreciation and ecological responsibility among students.

Despite its contributions, this study has several limitations. First, the implementation of an interactive flipbook-based e-module requires adequate digital devices and internet access, which may limit its optimal application in schools with insufficient technological infrastructure. Second, the effectiveness of the e-module is influenced by teachers' readiness and competence in managing technology-based instruction. Additionally, the study was conducted in a single school context, limiting the generalizability of the findings.

Nevertheless, the results have important implications for science learning, particularly in environmental education. The ethnoscience-integrated interactive flipbook e-module can serve as an alternative digital instructional resource that supports contextual and student-centered learning. Future research is recommended to involve a broader range of schools and to examine the long-term impact of such e-modules on students' pro-environmental behavior.

## Conclusion

This study concludes that the ethnoscience-integrated interactive flipbook-based e-module on environmental pollution topics is highly valid, practical, and effective as a science instructional material at the junior high school level. The validity of the e-module was demonstrated by a Moment Kappa coefficient of 0.87, which falls within the very valid category. High achievement was observed across multiple aspects, including content feasibility (0.85), language clarity (0.87), presentation (0.85), graphical design (0.90), ethnoscience integration (0.86), and usability (0.86). These results indicate that the developed e-module meets academic, linguistic, visual, and contextual standards required for quality instructional materials. In terms of practicality, teacher evaluations yielded an average score of 88% (very practical), while student evaluations reached 79% (practical). These findings suggest that the e-module is user-friendly, supports classroom implementation, and facilitates structured learning processes. Effectiveness testing using the Mann–Whitney U test revealed a statistically significant difference in students' environmental literacy between the experimental and control groups ($p < .001$). Students who utilized the ethnoscience-integrated flipbook e-module demonstrated higher environmental literacy levels compared to those who relied on conventional printed textbooks. These findings indicate that the integration of digital technology through a flipbook format, combined with a contextual ethnoscience approach, effectively enhances students' environmental literacy. Therefore, the developed e-module is suitable for use as an innovative instructional alternative aligned with twenty-first-century learning demands and the principles of the Kurikulum Merdeka.

### Author Contributions

Conceptualization, A.A. and S.D.; methodology, A.A.; instructional material development, A.A.; software and digital media design, A.A. and H.Y.S.; formal analysis, A.A.; investigation, A.A.; data curation, A.A.; writing—original draft preparation, A.A.; writing—review and editing, S.D. and F.A.; visualization, A.A. and H.Y.S.; supervision, S.D. and F.A.; project administration, A.A. All authors have read and agreed to the published version of the manuscript.

## References

Afdarina, O., Chatri, M., Helendra, & Irdawati. (2024). Pengaruh Model Pembelajaran Flipped Classroom Dengan Pendekatan Etnosains Terhadap Kemampuan Berpikir Kritis Siswa. *Jurnal Penelitian Pendidikan IPA*, *10*(5), 2363–2370. https://doi.org/10.29303/jppipa.v10i5.7191

Awwaliyah, H. S., Rahayu, R., & Muhlisin, A. (2018). Pengembangan E-Modul Berbasis Flipbook Untuk Meningkatkan Motivasi Belajar Siswa Smp Tema Cahaya. *Indonesian Journal of Natural Science Education (IJNSE)*, *01*(1), 24–29. https://doi.org/10.31002/ijnse.v4i2.1899

Azhar, A., Yanto, F., Putri, E., Primasari, M., & Syukri, D. (2023). Construction of an E-Module for online learning of Natural Science using an Ethnoscientific approach. *Journal of Law and Sustainable Development*, *11*(12), e1741-e1741. https://doi.org/10.55908/sdgs.v11i12.1741

Branch, R. M. (2009). *Instructional Design: The ADDIE Approach* (Vol. 32, Issue 3). Springer US. https://doi.org/10.1007/978-0-387-09506-6

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences (2nd ed.)*. Lawrence Erlbaum Associates.

Diaz, K. G. B., & Vela, J. A. H. (2025). Impact Of Environmental Education On The Development Of Environmental Awareness: A Systematic Review. *International Journal of Environmental Sciences*, *11*(21), 1992–2003. https://doi.org/10.64252/vvjwn305

Ekamilasari, E., Permanasari, A., & Pursitasari, I. D. (2021). Critical thinking skills and sustainability awareness for the implementation of education for sustainable development. *Journal of Science Education Research*, *5*(1), 46-53. https://doi.org/10.21831/jser.v5i1.41753

Erfan, M., Suranti, N. M. Y., Ibrahim, Istiningsih, S., & Dewi, N. K. (2025). Integrating Ethnopedagogy-Based E-Learning to Enhance Creativity of Prospective Elementary School Teachers: Student and Lecturer Perceptions. *Jurnal Penelitian Pendidikan IPA*, *11*(5), 950–959. https://doi.org/10.29303/jppipa.v11i5.11067

Fitri, M. N., Asrizal, Amnah, R., Hidayati, Emiliannur, & Helma. (2024). Development of Global Warming E-Module Integrated with PBL Model and Ethnoscience to Promote Students' Environmental Literacy. *Jurnal Penelitian Pendidikan IPA*, *10*(11),

8276–8289. https://doi.org/10.29303/jppipa.v10i11.9059

Hayandi, A. U., Sriyati, S., Rochintaniawati, D., & Ramadhany, S. S. M. (2025). Development of Interactive Learning Media Based on Lamang Tapai Ethnoscience in Science Material as an Effort to Increase Students' Sustainability Awareness. *Jurnal Penelitian Pendidikan IPA*, *11*(6), 709–717. https://doi.org/10.29303/jppipa.v11i6.11119

Husamah, H., Rahardjanto, A., Permana, T. I., & Lestari, N. (2025). Learning Media for Environmental Education, What Can the Scopus Database Tell Us? A Review. *Al Jahiz: Journal of Biology Education Research*, *6*(1), 93–114. https://doi.org/10.32332/al-jahiz.v6i1.10401

Indriyani, H. K., Purwaningsih, D., & Khaokhajorn, W. (2022). Integrasi Etnosains dalam Pembelajaran IPA sebagai Sumber Belajar yang Inovatif bagi Siswa Kelas VII: Kajian Literatur. *Jurnal Pendidikan MIPA*, *12*(1), 1–7. https://doi.org/10.37630/jpm.v15i1.2498

Jickling, B., & Wals, A. E. J. (2008). Globalization and environmental education: looking beyond sustainable development. *Journal of Curriculum Studies*, *40*(1), 1–21. https://doi.org/10.1080/00220270701684667

Komarudin, K., Akhsan, H., & Wiyono, K. (2025). Preminilary Study of E-modul Based on Ethnoscience Lake Ranau to Improve Literacy skills of Students on Renewable Energy Topic. *Jurnal Penelitian Pendidikan IPA*, *11*(3), 1183–1193. https://doi.org/10.29303/jppipa.v11i3.10653

Lawe, Y. U., Dolo, F. X., & Uta, A. (2025). Analysis of the Implementation of An Ethnoscience-Based Learning Approach in Elementary Science Education. *Jurnal Penelitian Pendidikan IPA*, *11*(10), 939–948. https://doi.org/10.29303/jppipa.v11i10.12450

Liunima, I. R., Ellianawati, & Widiyatmoko, A. (2025). Development of Interactive E-Modules with STEM-PBL Approach on Ecology and Biodiversity to Improve Critical Thinking Skills and Student Learning Outcomes. *Jurnal Penelitian Pendidikan IPA*, *11*(6), 478–486. https://doi.org/10.29303/jppipa.v11i6.11423

Logan, R. M., Johnson, C. E., & Worsham, J. W. (2021). Development of an e-learning module to facilitate student learning and outcomes. *Teaching and Learning in Nursing*, *16*(2), 139–142. https://doi.org/10.1016/j.teln.2020.10.007

Najwa, H. A., & Suhartini. (2023). Development of E-Module Integrated with Education for Sustainable Development (ESD) on Enviromental Change Material. *Jurnal Penelitian Pendidikan IPA*, *9*(12), 12130–12138.

https://doi.org/10.29303/jppipa.v9i12.6105

Nisva, O. N. N. (2025). Dampak Pencemaran Air terhadap Ekosistem Perairan dan Kesehatan Masyarakat. *KABELO, 1*(1), 22-28. Retrieved from https://journal.innoscientia.org/index.php/kabelo/article/view/115

Otto, S., Bertel, L. B., Lyngdorf, N. E. R., Markman, A. O., Andersen, T., & Ryberg, T. (2024). Emerging Digital Practices Supporting Student-Centered Learning Environments in Higher Education: A Review of Literature and Lessons Learned from the Covid-19 Pandemic. *Education and Information Technologies*, *29*(2), 1673–1696. https://doi.org/10.1007/s10639-023-11789-3

Ririn, S., Fenny, R., & Joko, S. (2021). Analisis Literasi Lingkungan Siswa SMP. *JPPS (Jurnal Penelitian Pendidikan Sains)*, *10*(02), 1976–1982. https://doi.org/10.26740/jpps.v10n2.p1976-1982

Saputra, H. Y., Kurniawan, F., Kurniawan, Putri, I. P., Pitri, M. P., Deltrya, N., Syaifullah, R., & Novia, W. A. (2021). Seeing The Local Wisdom Of The Minang Kabau Community, Precisely In Cirobong Village, Padang City In The Field Of Family Medicinal Plants In Scientific Studies. *Science Education Journal Departement of Science Education Universitas Negeri Padang* , *4*(2), 112–117. https://doi.org/10.24036/semesta/vol4-iss2/68

Saputri, W., Astriani, M., Nurhayati, S., Budi, S., & Hidayati, N. (2025). Living Near Oil Palm Plantations: Students' Environmental Literacy by Gender and Grade Level. *Jurnal Penelitian Pendidikan IPA*, *11*(5), 741–748. https://doi.org/10.29303/jppipa.v11i5.10652

Sari, M. K., Suastra, I. W., Tika, I. N., & Redhana, I. W. (2025). Tinjauan Sistematis Efektivitas Pembelajaran Berbasis Etnosains dalam Meningkatkan Literasi Sains pada Pendidikan Dasar dan Menengah. *Jurnal Penelitian Pendidikan IPA*, *11*(10), 72–82. https://doi.org/10.29303/jppipa.v11i10.12092

Sihombing, R. A., Anwar, S., Liu, S.-Y., Muslim, M., Winarno, N., & Sihombing, P. J. (2025). Integrating Local Wisdom into Environmental Education: A Systematic Review of Ethnoscience Research in Indonesia. *Journal of Natural Science and Integration*, *8*(1), 57. https://doi.org/10.24014/jnsi.v8i1.35762

Steg, L., & Vlek, C. (2009). Encouraging pro-environmental behaviour: An integrative review and research agenda. *Journal of Environmental Psychology*, *29*(3), 309–317. https://doi.org/10.1016/j.jenvp.2008.10.004

Stringer, L. C., Mirzabaev, A., Benjaminsen, T. A., Harris, R. M. B., Jafari, M., Lissner, T. K., Stevens, N., & Tirado-von der Pahlen, C. (2021). Climate change impacts on water security in global drylands. *One Earth*, *4*(6), 851–864. https://doi.org/10.1016/j.oneear.2021.05.010