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The Effectiveness of an Environment-Based Biodiversity Flipbook E-Module on Students' Biology Understanding and Scientific Process Skills in Grade X of SMA Negeri 21 Medan

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Abstract: This study aimed to analyze the effectiveness of an environment-based Biodiversity Flipbook E-Module in improving tenth-grade students' understanding of biology and their scientific process skills at SMA Negeri 21 Medan. The study employed a one-group pretest–posttest design involving 36 students. Research instruments included a validated biology comprehension test and an observation sheet used to assess students' scientific process skills during three environment-based learning sessions. Data were analyzed using the N-gain score and descriptive statistics. The results showed that the mean pretest score of 33.81 increased to 83.88 in the posttest, resulting in an N-gain score of 0.76, which falls into the high category. Students' scientific process skills were classified as very good across all learning sessions and demonstrated an increasing trend during the final meeting. These findings indicate that the environment-based Biodiversity Flipbook E-Module is effective in enhancing students' understanding of biological concepts and their scientific process skills through contextual learning grounded in real environmental exploration.
Keywords: E-module; biodiversity; scientific process skills; environment-based learning

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INTRODUCTION

The development of digital technology has driven significant transformation in biology teaching practices in schools. Twenty-first-century learning demands strengthening scientific literacy, critical thinking, collaboration, creativity, and the effective use of information technology (OECD, 2019; Partnership for 21st Century Skills, 2015). In the context of science education, technology integration is not merely a visualization tool but also a means of fostering authentic inquiry-based learning experiences. The Technological Pedagogical Content Knowledge framework emphasizes that effective technology integration must align with content and pedagogical strategies to enhance the learning quality (Mishra & Koehler, 2006).

One rapidly developing digital innovation is the interactive flipbook-based e-module. E-modules enable systematic, interactive, and multimodal presentation of materials, including text, images, videos, and animations, and offer flexibility in their use (Suarsana & Mahayukti, 2013). Studies have shown that e-modules can enhance students' motivation to learn, conceptual understanding, and learning independence compared to conventional printed modules (Fajriani et al., 2022; Ramanda et al., 2023). Furthermore, e-modules based on local potential and the environment have been proven to strengthen environmental literacy and connect biological concepts with students' real-life contexts (Azmi et al., 2023; Remindima et al., 2024).

In biodiversity research, a contextual approach is essential because concepts at the genetic, species, and ecosystem levels require the ability to observe and analyze real environments. A study by Gladys & Fitri (2024) showed that environment-based digital media can help students better understand the relationships among levels of biodiversity. This finding is consistent with constructivist theory, which emphasizes that knowledge is constructed through direct experience and interaction with the environment (Fosnot, 2013). However, in classroom practice, instruction remains predominantly textbook-based and lecture-centered, limiting the optimal development of students' scientific inquiry activities.

This challenge is present in Grade X biology classes, where students biodiversity understanding is low and scientific activities are limited to answering questions. Nurhadiani et al. (2020) reported that students' scientific process skills were in the moderate to low category when instruction did not involve direct observation and contextual exploration. In fact, scientific process skills such as observing, classifying, formulating hypotheses, designing investigations, analyzing data, and communicating results are core competencies in science learning (Rezba et al., 2015).

Several studies have developed flipbook-based e-modules and contextual approaches in various biology topics (Ramanda et al., 2023; Septia et al., 2024). However, most of these studies focused primarily on product validity and practicality testing, while empirical testing of effectiveness in improving learning outcomes remains limited. In addition, studies that simultaneously examine the impact of e-modules on two key variables, namely biology conceptual understanding and scientific process skills at the senior high school level, are still rarely reported. The systematic integration of school environmental observation as an authentic laboratory within biodiversity e-modules has also not been widely implemented.

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In fact, the school environment has great potential as a learning context,, particularly for biodiversity topics. Environment-based learning enables students to conduct direct observations of flora and fauna around the school, making learning more authentic and meaningful (Ardoin et al., 2020). Integrating such activities into digital e-modules can combine the advantages of technology with a scientific approach, aligning with the Merdeka Curriculum, which emphasis on project-based learning and contextual exploration.

In this study, biological understanding is operationally defined as students' ability to explain, classify, and analyze biodiversity concepts, as measured by pretest and posttest scores. Meanwhile, scientific process skills are defined as students' ability to carry out scientific practices, including observing, planning investigations, collecting and analyzing data, and communicating results, measured using observation sheets during the learning process.

METHOD

This study employed a quantitative one-group pretest–posttest design to analyze the effectiveness of an environment-based Biodiversity Flipbook E-Module on students' understanding of biology and scientific process skills. The e-module in this study had previously been developed using the ADDIE model, consisting of Analysis, Design, Development, Implementation, and Evaluation stages, and had been validated by experts prior to classroom implementation. The stage reported in this article focuses on testing the product effectiveness during the implementation phase

The research subjects were 36 Grade X students of SMA Negeri 21 Medan selected through purposive sampling. The class was chosen based on the alignment of the material with the Learning Objectives Flow of the Merdeka Curriculum and the students' readiness to use digital devices. The learning process was conducted over three meetings, using the school environment as the primary learning resource through observation activities, data analysis, and presentation of findings.

The research instruments included a biology understanding test and a scientific process skills observation sheet. The biology understanding test was developed based on the learning achievement indicators and underwent validity, reliability, difficulty level, and discrimination index testing prior use. The test was administered as a pretest and posttest to measure improvement in learning outcomes. The scientific process skills observation sheet was used to assess students' abilities in observe, plan investigations, analyzie data, and communicate results during the learning process.

Biology understanding data was analyzed through several stages. First, a Shapiro–Wilk normality test was conducted to determine whether the pretest and posttest data were normally distributed. This test was selected because the sample size was fewer than 50 students. The data were considered normally distributed if the significance value (p) was greater than 0.05 (Ghasemi & Zahediasl, 2012). If the normality assumption was met, the analysis was continued with a paired sample t-test to assess the significance of the difference between pretest and posttest scores. This test was used to examine the effectiveness of the treatment in a one-group pretest–posttest design with a significance level of 0.05.

Furthermore, the level of improvement in learning outcomes was calculated using the N-gain formula as follows:

$$N\text{-}gain = \frac{Skor\ posttest - Skor\ pretest}{Skor\ maksimum - Skor\ pretest}$$

The formula refers to Hake (1999), which is used to measure proportional learning improvement. The interpretation of the N-gain values is classified into three levels, as presented in Table 1.

Table 1. N-Gain interpretation criteria

N-Gain Score	Criteria
g ≥ 0,70	High
0,30 ≤ g < 0,70	Currently
g < 0,30	Low

Scientific process skills data were analyzed descriptively with average scores for each indicator and for each learning session. The obtained scores were interpreted using a four-point scale, very poor, poor, good, and very good (Widoyoko, 2012). This descriptive analysis was employed because the measurement was conducted through authentic observation during the learning process, aiming to describe the development of students' scientific process skills.

RESULTS AND DISCUSSION

The analysis of learning effectiveness in this study is based on two main indicators, improvement in students understanding of biological concepts and the development of scientific process skills.

The Effectiveness of E-Module on Biology Understanding

The effectiveness of the environmental-based Biodiversity Flipbook E-Module in improving understanding of biology was analyzed using a one-group pretest-posttest design involving 36 students from class X at SMA Negeri 21 Medan. The results of the analysis are presented in Table 2.

Table 2. Results of the pretest and posttest on biology understanding

Jumlah Siswa	Pretest		Posttest		N-Gain
	Mean	Standard Deviation	Mean	Standard Deviation	
36	33.81	14.61	83.88	13.31	0.76

The analysis results in Table 2 show that the average pretest score was 33.81 (SD = 14.61), and the posttest score increased to 83.88 (SD = 13.31) . Based on the normalized gain (N-gain) calculation, a value of 0.76 was obtained, which falls within the high category. This indicates a significant improvement in biological understanding after the use of the e-module.

Table 3. Paired-sample t-test result

Variabel	t	df	Sig. (2-tailed)
Pretest–Posttest	19.41	35	< 0.001

To test the significance of the score improvement, a normality test was first conducted using the Shapiro-Wilk test. The results indicated that both the pretest and posttest data were normally distributed ($p > 0.05$), allowing further analysis with a paired-sample t-test at the 0.05 significance level. The test results showed a highly significant difference between the pretest and posttest scores ($t(35) = 19.41$; $p < 0.001$), indicating that the e-module led to a meaningful improvement in the students' understanding of biology..

This study's findings suggest that the use of the environmental-based Biodiversity Flipbook E-Module significantly improved students' understanding of biology. The high level of improvement was influenced not only by the material presented in an interactive digital format but also by the integration of direct observation activities of biodiversity objects in the school environment. Students' involvement in observation, data recording, and interpretation of findings allowed them to build concepts based on empirical evidence. This process aligns with the principles of science learning, which emphasize scientific practice and the ability to interpret data meaningfully (National Research Council, 2012)

From a constructivist perspective, learning becomes more effective because students actively construct knowledge through interaction with real-world contexts and discussion of their observations, rather than passively receiving information. Additionally, the flipbook design, which integrates text, illustrations, and a structured layout, supports information processing through both verbal and visual channels simultaneously. This is consistent with the multimedia learning theory, which states that combining visual and verbal representations can optimize understanding and reduce cognitive load (Mayer, 2020). The environmental-based approach also aligns with the principles of Education for Sustainable Development, as it connects biodiversity concepts with sustainability values and ecological responsibility, making learning relevant and applicable to real-life contexts (UNESCO, 2017).

The findings of this study are consistent with those of Azmi et al. (2023) and Wahyuningsih et al. (2020), which show that e-modules based on local and environmental potential can significantly improve learning outcomes by making the material more contextually relevan and easier to understand. Other studies also report that e-modules on biodiversity with local potential content can be enhance literacy and understanding through inquiry and investigation activities (Remindima et al., 2024; Lasih et al., 2025). From a media perspective, using flipbook platforms such as Heyzine and Canva has been shown to increase student engagement and facilitate independent navigation of the material, positively impacting cognitive achievement (Fatahilla et al., 2024; Dwianggreni et al., 2025).

Unlike studies that focus solely on visual interactivity, the strength of this research lies in the combination of the digital flipbook media and direct observation in the school environment as an authentic learning source. This synergy resulted in a greater and more measurable improvement in understanding, as reflected in the high N-gain category and very strong statistical significance ($p < 0.001$). Thus, the environmental-based Flipbook E-Module can be considered effective because it combines the advantages of multimedia—through systematic structure and visualization—with a contextual learning approach based on field observation to deepen students' understanding of biology (Mayer, 2020; National Research Council, 2012; UNESCO, 2017).

Effectiveness of E-Modules on Scientific Process Skills

The effectiveness of the E-Module was also evaluated based on the development of scientific process skills, which were measured using observation sheets during three learning sessions. The interpretation of the categories refers to the four-point scale criteria proposed by Widoyoko (2012). The results showed that all indicators of scientific process skills were in the "very good" category.

The effectiveness of the E-Module was further assessed by measuring students' scientific process skills, through observation sheets during three learning sessions. The categorization of achievement was based on the four-point scale criteria as outlined by Widoyoko (2012). The analysis results are presented in Tables 4, 5, and 6.

Table 4. Average scientific process skills material 1

No	Indicator	Average score	Category
1	Observing	3.58	Very good
2	Questionong and predicting	3.72	Very good
3	Planning an investigation	3.56	Very good
4	Conducting an investigation	3.56	Very good
5	Processing and analyzing data	3.58	Very good
	Average	**3.60**	**Very good**

Table 5. Average scientific process skills material 2

No	Indicator	Average score	Category
1	Investigating potential and threats	3.72	Very good
2	Processing and analyzing data	3.56	Very good
3	Evaluating and reflecting	3.56	Very good
4	Communicating results	3.53	Very good
	Average	**3.59**	**Very good**

Table 6. Average scientific process skills material 3

No	Indicator	Average score	Category
1	Planning conservation actions	3.56	Very good
2	Using data for action	3.56	Very good
3	Reflection and evaluation	3.53	Very good
4	Communicating the results of the action	4.00	Very good
	Average	**3.66**	**Very good**

Based on the average total per session, there is a noticeable trend of improvement in the third session, as shown in Figure 1. This indicates that scientific process skills developed as students became more involved in observation activities, analysis of biodiversity potential and threats, and the creation of data-driven conservation action plans.

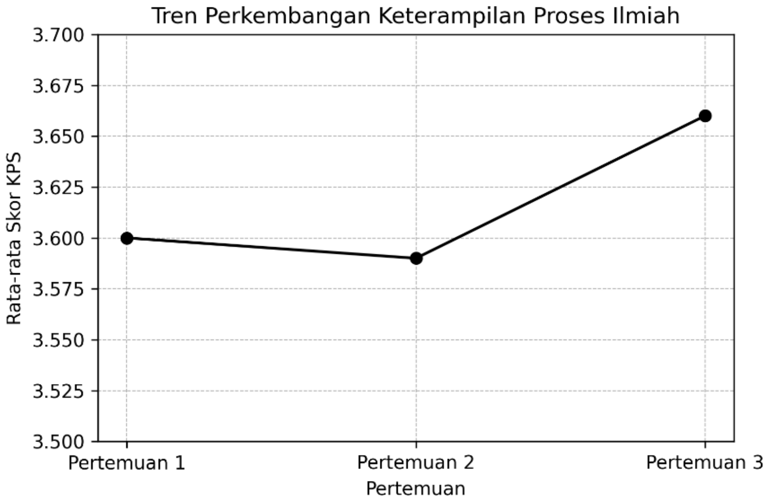

Figure 1. Average development of students' scientific process skills

This finding aligns with the studies conducted by Nurhadiani et al. (2020) and Remindima et al. (2024), which indicate that contextual learning grounded in the surrounding environment can significantly strengthen students' scientific practices. In such learning approaches, students are not positioned merely as passive recipients of information; instead, they actively participate in a series of investigative activities that include observing natural phenomena, collecting and processing data, and presenting the results of their investigations. Through these processes, students are encouraged to construct their own understanding based on direct experience and empirical evidence obtained from their environment. As a result, the learning process becomes more meaningful because students are directly involved in authentic scientific activities that resemble the practices of real scientists.

Similar findings have also been reported in several studies concerning the development of digital learning resources, particularly e-modules or flipbooks that integrate local potential as a contextual learning source. In these studies, students are positioned as the central actors in the investigation process rather than merely as users of instructional materials. The learning activities embedded within such media guide students to explore their surroundings, formulate questions, observe relevant objects or phenomena, and analyze the data obtained from their observations. This learner-centered approach has been shown to support the development of scientific process skills more effectively than conventional text-based learning methods that rely heavily on reading and memorization (Azmi et al., 2023; Ramanda et al., 2023). By engaging students in activities such as observing environmental conditions, analyzing patterns, and presenting their findings, the learning process encourages deeper conceptual understanding as well as the development of essential scientific competencies.

However, the present study introduces a distinctive element compared with previous research. In this study, the school environment itself is utilized as an authentic laboratory where students conduct their investigations directly. Rather than relying solely on simulated examples or abstract descriptions, students interact with real objects and phenomena found within the school surroundings. This approach allows students to collect empirical data firsthand, which they then analyze and interpret before presenting their conclusions systematically. The use of the school environment as a learning laboratory not only increases the authenticity of the investigative process but also enhances students' engagement and curiosity during learning activities.

This pattern of learning is consistent with the framework of scientific practices that emphasizes investigation based on evidence, systematic data analysis, and the communication of scientific findings as core components of science education (National Research Council, 2012; Padilla, 2016). Within this framework, students are encouraged to develop their ability to observe phenomena carefully, interpret the data they obtain, and communicate their conclusions in a structured and scientifically acceptable manner. Consequently, the learning process does not focus solely on mastering theoretical concepts but also emphasizes the development of skills that enable students to apply scientific reasoning in real-world contexts.

The achievement of scientific process skills in this study, which falls within the good to very good categories, can also be explained by the structured learning activities embedded within the E-Module. Each learning session follows the stages of the scientific process, beginning with observation, followed by analysis, and culminating in action or communication. Through this systematic sequence of activities, students repeatedly practice essential scientific skills, including identifying relevant phenomena, interpreting collected data, and presenting their findings in a logical and organized form. Such structured learning experiences provide students with consistent opportunities to apply scientific reasoning throughout the learning process.

Furthermore, this design allows the assessment of students' skills to become more contextual and authentic. Instead of merely evaluating students' ability to recall concepts through written tests, the assessment focuses on how students apply scientific procedures during investigative activities. This approach enables educators to evaluate not only conceptual understanding but also the development of higher-order thinking skills and practical scientific competencies.

The results of this study also confirm that the effectiveness of digital learning media is not determined solely by visual attractiveness or interactive features. Although visual interactivity plays an important role in maintaining students' attention, the true educational value of digital media lies in its ability to integrate meaningful investigative tasks into the learning process. When digital media incorporate activities that encourage students to explore, analyze information, and communicate their findings, the learning experience becomes more engaging and cognitively demanding. In the context of this study, students were encouraged to produce scientific communication products, such as posters or infographics, which required them to synthesize data, organize information, and present their conclusions clearly (Mayer, 2020; National Research Council, 2012).

Therefore, the environmental-based Flipbook E-Module developed in this study demonstrates its potential not only to improve students' cognitive understanding but also to support the development of essential scientific skills. These skills include the ability to process empirical data, think scientifically and critically, and communicate findings in a systematic and structured manner. Such competencies are widely recognized as fundamental components of 21st-century science education, where students are expected to possess not only knowledge but also the ability to apply scientific reasoning in addressing real-world problems (Padilla, 2016; UNESCO, 2017). Through the integration of environmental exploration, investigative learning activities, and digital learning media, this approach provides a comprehensive learning experience that supports the holistic development of students' scientific competencies.

Implications of the Effectiveness of Enviroment-Based Learning

The findings of this study indicate that the effectiveness of the environmental-based Biodiversity Flipbook E-Module in enhancing understanding of biology and scientific process skills is closely related to the use an environmental-based learning approach during the implementation. Direct observation of the flora and fauna around the school provided students with the opportunity to construct biodiversity concepts through empirical experiences and real interactions with learning objects. This strategy aligns with the framework for scientific practices, which emphasizes active engagement in investigation, data processing, and scientific communication as the foundation for meaningful science learning (National Research Council, 2012; Padilla, 2016). From a constructivist perspective, these authentic experiences help students connect new concepts with prior knowledge, thereby strengthening and deepening conceptual understanding (Mayer, 2020). Additionally, environmental-based learning supports the development of awareness about sustainability and ecological responsibility, as mandated by the Education for Sustainable Development framework (UNESCO, 2017), Students not only understand biodiversity theoretically but also reflect on the importantance of preserving the enviroment around them.

This finding confirms that the effectiveness of digital media in biology learning is optimized when integrated with real-life contexts that closely align with students' learning experiences. Several studies have shown that e-modules grounded in local potential or environmental contexts can improve learning outcomes and science literacy through authentic and contextual learning experiences (Azmi et al., 2023; Remindima et al., 2024; Lasih et al., 2025). In this study, the E-Module not only served as a medium for presenting material in a visual and interactive manner but also as a tool for facilitating structured scientific activities, from field observation and analysis of biodiversity potential and threats, to formulating data-driven conservation action plans. The synergy between the digital flipbook and the exploration of the school environment provided a more comprehensive learning impact compared to e-modules that only emphasized visual interactivity (Fatahilla et al., 2024; Dwianggreni et al., 2025). This combination strengthened the knowledge construction process while systematically and sustainably promoting the development of students' scientific practices

Therefore, the implementation of the environmental-based Biodiversity Flipbook E-Module can be recommended as an effective alternative learning strategy to improve students' biology understanding and scientific process skills at the high school level. Utilizing the school environment as an authentic learning resource reinforces the function of digital media as a means of knowledge construction and strengthening scientific practices, rather than just a tool for material presentation. This approach demonstrates that the integration of digital technology with real-life environmental contexts is a relevant learning model for strengthening scientific competence while fostering sustainability awareness at the secondary education level (National Research Council, 2012; UNESCO, 2017; Remindima et al., 2024).

CONCLUSION

Based on the research findings, it can be concluded that the environmental-based Biodiversity Flipbook E-Module has proven effective in enhancing biology understanding and scientific process skills among students of class X at SMA Negeri 21 Medan. The implementation of the module, which integrates direct observation activities in the school environment, has made a significant contribution to improving learning outcomes while also fostering the development of scientific skills through activities such as observation, data analysis, and structured communication of findings. These results indicate that the combination of interactive digital media and authentic environmental contexts can create biology learning that is more contextual, meaningful, and based on real-life experiences. Therefore, the environmental-based Flipbook E-Module is recommended as a relevant alternative learning media to support the implementation of the Merdeka Curriculum and strengthen 21st-century scientific competencies.

RECOMMENDATION

Further research is recommended to test the effectiveness of the environmental-based Flipbook E-Module on a larger and more diverse sample, including schools with different environmental characteristics, to strengthen the generalization of the findings. The use of an experimental design with a control group is also recommended to enhance internal validity. Additionally, future studies could examine the long-term impact of module usage on students' environmental literacy and scientific competencies, as well as develop more sustainable project-based evaluations.

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