



Development of Flipbook E-Modules to Enhance Science Literacy in the Living Things and Environment Topic

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Abstract: Scientific literacy is an essential competency in 21st-century education, particularly in vocational schools where students are expected to apply scientific knowledge in real-life and professional contexts. This study aimed to develop an interactive e-book module to enhance students' scientific literacy on the topic of Living Organisms and the Environment by integrating batik ecoprint as a contextual learning medium. The novelty of this research lies in positioning batik ecoprint not merely as a practical skill activity but as a systematic scientific context within digital-based vocational learning. The study employed a Research and Development approach using the 4-D model, consisting of the define, design, develop, and disseminate stages. The e-book flipbook module was validated by experts in content, media, language, and instructional design using the Content Validity Index (CVI). Its effectiveness was examined using a quasi-experimental one-group pre-test-post-test design across three Grade X vocational school classes. Data were analyzed using N-Gain. The results indicate that the developed e-book flipbook demonstrates high feasibility and effectively improves students' scientific literacy at moderate to high levels, with N-Gain values ranging from 0.63 to 0.77. These findings confirm the effectiveness of integrating local cultural contexts into vocational science learning.

Abstrak: Literasi ilmiah merupakan kompetensi esensial dalam pendidikan abad ke-21, khususnya di sekolah kejuruan yang menuntut kemampuan peserta didik dalam mengaplikasikan pengetahuan sains secara kontekstual. Penelitian ini bertujuan mengembangkan modul e-book interaktif untuk meningkatkan literasi ilmiah siswa pada materi Makhluk Hidup dan Lingkungan melalui integrasi batik ecoprint sebagai konteks pembelajaran. Inovasi penelitian ini terletak pada pemanfaatan batik ecoprint tidak hanya sebagai keterampilan praktik, tetapi sebagai konteks ilmiah sistematis dalam pembelajaran digital vokasional. Penelitian menggunakan pendekatan Research and Development dengan model 4-D yang meliputi tahap define, design, develop, dan disseminate. Produk dikembangkan dalam bentuk modul e-book flipbook dan divalidasi oleh ahli materi, media, bahasa, dan desain pembelajaran menggunakan Content Validity Index (CVI). Uji efektivitas dilakukan melalui desain quasi-eksperimental one-group pretest-posttest yang melibatkan tiga kelas SMK kelas X. Data dianalisis menggunakan N-Gain. Hasil penelitian menunjukkan bahwa e-book flipbook memiliki tingkat kelayakan tinggi dan mampu meningkatkan literasi ilmiah siswa secara moderat hingga tinggi dengan nilai N-Gain antara 0,63-0,77. Temuan ini menegaskan efektivitas integrasi konteks budaya lokal dalam pembelajaran sains kejuruan.

A. Introduction

Science literacy is one of the essential competencies of the 21st century, requiring not only an understanding of scientific concepts but also the ability to critically apply that knowledge in real-life contexts, including in decision-making related to the environment and sustainability (Fuadi et al., 2020). Low science literacy remains a global problem, including in Indonesia, as reflected in international assessments that show science literacy achievements are below the OECD average (OECD, 2023).

Vocational education at vocational high schools requires students not only to master technical skills but also to have a strong foundation in scientific knowledge (Alfiah et al., 2024). This statement underscores the importance of SMK students gaining direct experience in the learning process, being trained to discover actively, for themselves, the various concepts studied thoroughly, meaningfully, and authentically, and to develop critical and creative thinking skills to solve problems related to phenomena in everyday life. Science literacy enables students to understand and use modern technology and keep up with developments in science relevant to their vocational fields (Winarsi & Ningsih, 2025).

Previous studies show that vocational high school students tend to have difficulty understanding scientific concepts in depth and in context, especially in science and technology subjects that require integrating natural and social knowledge (Maharani et al., 2025). The Nature and Social Science (NSS) subject on the theme of Living Things and the Environment has great potential to develop science literacy by linking concepts in biology, chemistry, and the environment to real phenomena around us. However, NSS learning in vocational schools is still often presented theoretically and teacher-centered, so it has not been able to encourage students to actively construct scientific knowledge (Maharani et al., 2025).

One relevant and contextual sub-topic within the theme of Living Things and the Environment is ecoprint batik. This fabric-dyeing technique uses natural plant pigments via a color-transfer process that involves principles of physics, chemistry, and biology (Syahri et al., 2024). Ecoprint batik contains rich scientific concepts, such as plant tissue structure, the properties of natural dyes, fixation reactions, and the ecological impact of using environmentally friendly materials compared to synthetic dyes (Lubis et al., 2024). The integration of ecoprint batik into science learning is expected to increase the material's relevance while instilling environmental awareness (Damayanti et al., 2024). However, the study's results show that ecoprint batik learning in vocational schools is still primarily focused on practical skills and does not explicitly aim to develop science literacy (Syahri et al., 2024). Previous research has found that traditional teaching materials tend to be passive and do not provide meaningful learning experiences, making it difficult to understand concepts comprehensively (Rismayani et al., 2024). In addition, several studies report that the teaching materials used in many educational units are still conventional printed materials that have not been optimally integrated with digital technology, limiting interactivity and the learning context (Kaamilah et al., 2023).

Along with the development of educational technology, flipbook-based e-modules have become an alternative form of digital teaching materials that can present material in an interactive, visual, and flexible manner, in line with their characteristics (Humairah et al., 2024). Yunita (2025) states that flipbook e-modules enable the integration of text, images, animations, and reflective activities, thereby increasing learning engagement and conceptual understanding. Several empirical studies have shown that flipbook-based e-modules significantly improve science literacy by encouraging students to interpret information, analyze phenomena, and relate scientific concepts to real-world contexts (Prihatiningtyas et al., 2025).

The development of e-modules that integrate local contexts into learning materials has been proven to provide a more meaningful learning experience for students and improve their understanding of scientific concepts, as the relevance of the material to the surrounding environment and culture makes it easier for students to connect scientific concepts with real phenomena (Lestari et al., 2024). The use of local contexts, such as ecoprint batik practices, in science learning can be an effective bridge between abstract scientific concepts and students' real experiences, helping them relate learning materials to everyday life and strengthening their contextual understanding of these concepts (Putra & Wahyuni, 2025).

Based on the existing literature, three major gaps can be identified. First, the development of flipbook-based e-modules in science education has rarely been oriented explicitly toward scientific literacy, particularly in vocational education settings. Second, the integration of local cultural and environmental contexts, such as ecoprint batik, into digital science learning materials remains limited and often lacks systematic alignment with scientific literacy indicators. Third, existing instructional materials tend to separate vocational practices from scientific reasoning, resulting in fragmented learning experiences that do not optimally support students' ability to explain scientific phenomena, interpret data, and evaluate environmental impacts. These gaps indicate the absence of digital learning resources that integrate local contextual practices into science instruction through a scientific literacy framework in vocational education.

The novelty of this research lies in the development of a flipbook-based e-module that specifically integrates ecoprint batik material as a context for learning science and environmental studies to improve the science literacy of 10th-grade vocational high school students. Unlike previous studies, which generally focused on the development of flipbook e-modules on general science materials or at the junior high and high school levels (Humairah et al., 2024), this study links the local and cultural potential of ecoprint batik with the concepts of living things and the environment within the framework of vocational education. Furthermore, most previous studies still place ecoprint batik as a practical activity or skill reinforcement, without explicitly directing it towards the development of science literacy dimensions, such as the ability to explain scientific phenomena, interpret data, and evaluate environmental impacts (Syahri et al., 2024). Therefore, this study offers a new approach by positioning ecoprint batik not only as a context for learning but also as a

systematic medium for developing science literacy through interactive digital e-modules aligned with the characteristics of NSS learning in vocational schools.

Accordingly, this study seeks to answer the following research questions: (1) What are the characteristics of a flipbook-based e-module on Living Things and the Environment designed to enhance scientific literacy among 10th-grade vocational high school students?. (2) To what extent is the developed flipbook-based e-module feasible in terms of content, media, language, and instructional design?. (3) How effective is the flipbook-based e-module in improving students' scientific literacy?. The objectives of this study are to identify the characteristics of a scientific literacy-oriented flipbook-based e-module, to examine its feasibility through expert validation and student responses, and to evaluate its effectiveness in enhancing students' scientific literacy in the context of NSS learning. By clearly articulating the research gap, novelty, and objectives, this study is expected to contribute to the development of contextual digital learning resources that strengthen scientific literacy in vocational science education.

B. Method

This study uses a 4-D design model (Define, Design, Develop, Disseminate) for research and development (R&D). To ensure that the developed product meets learning needs and can be empirically tested for viability, instructional materials development research frequently employs the 4-D development model. This research was conducted at SMK Negeri Purwosari from January 2024 to December 2024. The subjects of this study were 108 tenth-grade students at a vocational high school. The population in this study was tenth-grade students in the 2024/2025 academic year. In addition, subject matter experts and learning media experts were involved to assess the product's feasibility during development. The development stages using the 4-D model are shown in Figure 1.



Figure 1. The Development Stages Using the 4-D Model

The first stage is the define stage, which consists of analysis activities to identify the basic problems faced by students and teachers. At this stage, learning needs are analyzed through curriculum studies, characteristics, learning tasks, and learning concepts. The define stage uses observation sheets and interview sheets as instruments. This analysis aims to define the module's content requirements and the learning objectives to be achieved.

The design stage includes preparing the initial design of the flipbook e-module, including content structure, learning scenarios, selection of supporting media, and visual format. The initial prototype of the product is prepared as a design to test feasibility. Teaching materials are selected based on the learning outcomes to be achieved, the results of student characteristic analysis and curriculum analysis, and problems identified during the define stage. The teaching media selected was the flipbook e-module, a learning medium

relevant to students' characteristics and learning issues, with the theme of living things and their environment in the ecoprint batik material. The flipbook e-module was selected to align with the analysis of student characteristics, concept analysis, task analysis, and learning objective analysis, which emphasized improving science literacy.

The third stage is the development stage, which aims to turn the design developed in the previous stage into a product ready for implementation. The development stage includes activities such as compiling content, selecting and developing teaching materials, conducting formative revisions, and trials. At this stage, Draft 1 of the flipbook e-module was validated by 8 experts: 2 media experts, 2 subject matter experts, 2 language experts, and 2 learning experts. The instrument used at this stage was a validation questionnaire. The results of the questionnaires filled out by the experts were then analyzed using CVI score analysis with the formula:

$$CVI = \left(\frac{\sum s}{n(c-1)} \right) \text{ where } s = r - l$$

Explanation:

r: respondent score

l: lowest respondent score

n: number of respondents

c: highest category

CVI: Content Validity Index

The NSS Project Teaching Material Draft 1 was deemed feasible if it had a high CVI (≥ 0.8) or moderate CVI ($0.4 \leq CVI < 0.8$). In addition to the quantitative assessment, the experts also provided qualitative feedback through comments and suggestions, which served as the basis for improving the NSS Project Module Draft 1 (Revision 1).

The fourth stage, dissemination, aims to help students achieve competence and ensure that, at the end of the learning process, students have the necessary competencies, attitudes, and abilities. The research design used was a quasi-experiment with a one-group pretest-posttest type. The data analysis technique used was quantitative analysis. Quantitative analysis was used to test the effectiveness of the flipbook E-Module in improving students' science literacy on living things and their environment. The quantitative analysis used was the N-Gain test.

C. Result

The final result of this development research is an e-module Flipbook on Living Things and the Environment. The e-module development research adopted the 4D development model, which involves four main stages that are interrelated and sequential, namely define, design, development, and disseminate.

1. Define Stage Result

The definition stage involves researchers identifying problems and needs in the learning process. The focus is on gaining a deep understanding of the problems to be solved and identifying the expected outcomes. In the definition stage, researchers identified problems and needs in the learning process. An initial needs analysis was conducted in the field using subject teacher observation sheets. The results of the initial observation of subject teachers are shown in Table 1.

Table 1. Initial Observation Results of Subject Teachers

Aspect Analyzed	Teacher 1	Teacher 2	Teacher 3
Implementation of NSS learning	Lectures, discussions, assignments; still teacher-centered	Predominantly lectures	Lectures and assignments
Use of instructional media	Used occasionally	Rarely used	Very rarely used
Teaching methods & models	Lectures, discussions, PjBL, and Discovery Learning	Lectures, discussions, Cooperative Learning	Lectures and discussions
Modules/textbooks used	Printed textbooks and worksheets (LKPD)	Textbooks and online materials	Government-issued textbooks
Adequacy of modules/textbooks	Not yet adequate	Not yet adequate	Not yet adequate
Strengths of modules/textbooks	Aligned with the curriculum	Aligned with the curriculum	Easy to use
Weaknesses of modules/textbooks	Lack of interactivity	Limited visual elements	Less engaging
Printed vs digital modules	Digital modules are more effective	Digital modules are more effective	Digital modules are more effective
Experience with flipbook e-modules	No prior experience	No prior experience	No prior experience
Material development strategies	Contextualized to the environment	Environmental case studies	School surrounding environment
Challenges in NSS learning	Low scientific literacy	Abstract concepts are difficult to understand	Low learning motivation
Role of flipbook e-modules	Interactive learning media	Concept visualization	Increasing learning interest
Student engagement strategies	Independent tasks & discussions	E-module-based projects	Reading and summarizing tasks
Accessibility & sustainability	Online and offline access	Lightweight & easy to access	Requires device support
Suggestions for e-module development	Multimedia & HOTS-based	Simple language	Science literacy-based
Support for independent learning	Strongly supportive	Supportive	Supportive

The main challenges in NSS learning include low science literacy, difficulty in understanding abstract concepts, and low student motivation. Teachers believe that flipbook e-modules have the potential to help overcome these problems through visual, interactive, and contextual presentations of material, as well as by supporting independent and student-centered learning.

The next analysis in the define stage, namely student character analysis, is used to identify and determine the basic problems encountered in the learning process at the research site. Initial observations indicate that NSS learning resources in 10th-grade vocational schools are still predominantly printed textbooks, which are not being used optimally. Although most students have these books, limitations in flexibility, visual appeal, and ease of access mean that printed books do not fully support science learning, which requires visualizing concepts and their relevance to real-world contexts. On the other hand, the questionnaire results indicate that all students have smartphones, suggesting that the digital learning infrastructure is ready. However, the use of these devices as learning media remains low, marked by students' limited experience with e-modules and teachers' uneven implementation of digital teaching materials. These findings confirm the gap between the availability of technology and its utilization in the learning process.

Based on the results of the task analysis, it is known that NSS learning in grade X at SMK Negeri Purwosari has implemented the Merdeka Curriculum, so that the development of e-modules is compiled with reference to the learning outcomes and learning objectives of the NSS Project. Furthermore, a concept analysis was conducted to examine the structure and depth of the material in accordance with the learning outcomes of phase E, which emphasizes students' science literacy skills in understanding the concepts of living things and their environment through product creation activities. The sub-material of ecoprint batik was chosen as a relevant applied context to integrate an understanding of plant biology, problem-solving, and the development of scientific attitudes such as critical, creative, independent, and collaborative thinking.

The learning objective formulation stage was developed by synthesizing the results of the needs analysis, task analysis, and concept analysis to serve as the basis for designing a Project-Based Learning e-module product. The learning objectives are to master the concepts of living things and plant anatomy, identify plant parts as sources of natural dyes, and plan, implement, and communicate the practice of making ecoprint batik. Thus, the define stage provides a strong conceptual and empirical foundation for the development of contextual, applicable, and science literacy-oriented flipbook e-modules for vocational high school students.

2. Design Stage Result

At the design stage, researchers create detailed learning steps and develop an effective, efficient E-Module to improve students' science literacy. The initial draft of the E-Module was developed based on data collected at the define stage. The results of this design stage are as follows:

a. Test Instrument

The test was developed with the learning outcomes and objectives in mind. The test instrument developed was a formative test consisting of 15 essay questions. The test questions developed will be used in a limited-scale test to test the validity and reliability of the test instrument. The validity and reliability tests used content validity.

b. Teaching Materials

Teaching materials are selected based on the learning outcomes to be achieved, the results of student characteristic analysis and curriculum analysis, and problems identified during the definition stage.

c. Teaching Media

The selected teaching media are E-Modules, a learning medium that aligns with students' characteristics and learning needs, using material that suits their needs. E-Modules are selected to align with analyses of student characteristics, concept analysis, task analysis, and learning objective analysis that emphasize PjBL characteristics and science literacy skills. This helps students improve their science literacy.

d. Determination of Teaching Media Format

The sformat selection in development was carried out as an initial step to produce Draft 1, with the aim that the selected format would align with the learning material. The E-module used a flip book format so that both teachers and students could easily access it.

e. Initial Design

At the initial design stage of the E-Module, the supervising lecturer was consulted for guidance before the E-Module was used. This design is Draft 1 of the E-Module. The following steps were taken in the initial design stage:

i. E-module cover

The cover contains the title on the front of the E-Module, which describes PjBL-based learning in the NSS Project material inside. The E-module cover is shown in Figure 2.



Figure 2. E-Modul Cover

ii. E-Module usage instructions

The E-Module requires instructions to make it easier for readers to apply. The procedures for using the module are compiled for educators and students. The instructions for use are presented in Figure 3.



Figure 3. E-Module Usage Instructions

The e-module usage instructions are located at the beginning of the product/opening guide to help users use the product appropriately.

iii. E-Module Identity

The e-module identity is designed so that students know the e-module's identity in terms of its author, phase, allocation, learning outcomes, aspects, themes, objectives, and so on. The e-module identity design is presented in Figure 4.

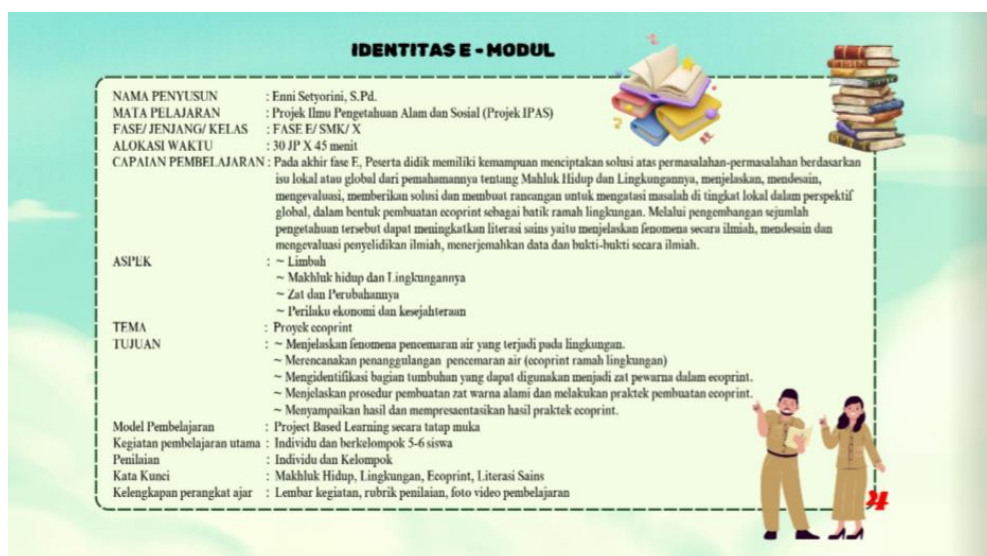


Figure 4. E-Module Identity

iv. Product Content

Product content creation is the process of compiling product content in accordance with the initial design. Product content includes materials, project assignments, and exercises. The product content display is shown sequentially in Figure 5.



Figure 5. Content Product

The e-module developed uses a PjBL learning model, so it must include PjBL learning syntax. The e-module content aligned with the PjBL-STEM learning model is found in project assignments, as shown in Figure 6.

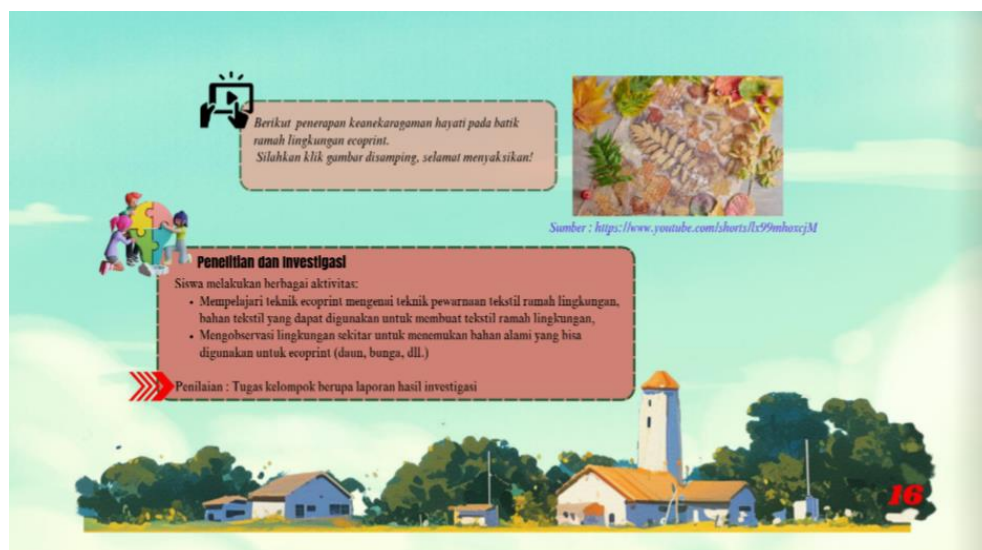


Figure 6. Project Assignment

The exercises in the e-module are designed to help test students' understanding and develop their learning skills. The exercises in the e-module are presented as multiple-choice questions. The appearance of the exercise questions is shown in Figure 7.



Figure 7. The Exercise Questions

3. Development Stage Result

During development, the product was validated and tested to assess the e-Module's practicality and feasibility.

a. Validation Results

i. E-Module Validation Results

Expert appraisal is a technique for validating or assessing the feasibility of a product design. Validators validated the results of the initial draft. The validators in this study included media, subject matter, language, and learning experts.

The results of the media expert validation are shown in Table 2.

Table 2. Media Expert Validation Results

Aspect	Average Score	Criteria
Presentation Techniques	0,958	High
Presentation Completeness	0,944	High
Module Size	0,833	High
Module Design	0,944	High
Module Content Design	0,907	High
Average CVI Score	0,918	High

The results of the material validation test are shown in Table 3.

Table 3. The Results of the Material Validation

Aspect	Average Score	Criteria
Completeness of Material	1	High
Breadth of Material	1	High
Depth of Material	0,667	Medium
Accuracy of Material	0,833	High
Up-to-date and contextual	0,875	High

Aspect	Average Score	Criteria
Compliance with laws and regulations	0,867	High
Average CVI Score	0,874	High

The results of the language validation test are shown in Table 4.

Table 4. The Results of the Language Validation Test

Aspect	Average Score	Criteria
General Appearance	0,889	High
Use of Language in the Module	0,833	High
Clarity of Language	0,917	High
Average CVI Score	0,880	High

The results of the learning validation test are shown in Table 5.

Table 5. The Results of the Learning Validation Test

Aspect	Average Score	Criteria
Learning Content	0,833	High
Learning Strategies	0,896	High
Learning Evaluation	0,778	Medium
Assessment	0,889	High
Average CVI Score	0,907	High

The results of a limited-scale test for students showed that out of 72 students, the average score was 83% in the excellent category. This score can be interpreted as a very practical category ($80\% \leq \text{SIP}$), as the average score was 81%. The results of the limited-scale test show that the e-module is very practical for learning, making it feasible for use in a large-scale test (dissemination stage).

4. Dissemination Stage Result

The dissemination stage consists of activities to apply the Flipbook e-module in NSS learning. This stage aims to determine the effectiveness of the Flipbook e-module in improving science literacy among 10th-grade students. The average pre-test and post-test scores for the experimental and control groups are shown in Table 6.

Table 6. The Effectiveness Test of the Flipbook E-Module in Improving Science Literacy Results

Class	Pre-test	Post-test	N-Gain	Criteria
1 st Experiment	45,00	79,79	0,63	Medium
2 nd Experiment	40,00	82,71	0,71	High
3 rd Experiment	38	86	0,77	High

Class	Pre-test	Post-test	N-Gain	Criteria
Average	41	82,83	0,70	High

The N-Gain calculation results showed that the three experimental classes had scores of 0,63 (moderate), 0,71 (high), and 0,77 (high), respectively.

The results of the analysis of improvements in science literacy for each indicator are shown in Table 7.

Table 7. The Results of the Analysis of Science Literacy Improvement for Each Indicator

Indicator	1 st Experimental		2 nd Experimental		3 rd Experimental	
	Class		Class		Class	
	N-Gain	Criteria	N-Gain	Criteria	N-Gain	Criteria
Identifying valid scientific arguments	0,765	High	0,855	High	0,885	High
Evaluating the validity of sources	0,691	Medium	0,750	High	0,810	High
Evaluating the use and misuse of scientific information	0,629	Medium	0,725	High	0,785	High
Understanding the elements of research design and how they influence scientific findings and conclusions	0,651	Medium	0,717	High	0,750	High
Creating graphs as representations of data.	0,742	High	0,742	High	0,775	High
Reading and interpreting graphically represented data correctly.	0,694	Medium	0,720	High	0,755	High
Solving problems using quantitative skills, including probability and statistics.	0,519	Medium	0,617	Medium	0,773	High
Understanding and interpreting basic statistics.	0,512	Medium	0,659	Medium	0,681	Medium
Justifying conclusions, predictions, and inferences based on quantitative data.	0,500	Medium	0,624	Medium	0,713	High
Average	0,634	Medium	0,712	High	0,770	High

The scores for each science literacy indicator in Table 8 indicate that each improved, meeting good and very good criteria.

The results of the analysis of student responses to the flipbook e-module are shown in Table 8.

Table 8. The Results of the Analysis of Student Responses

Assessment Aspects	Score	Category
Practicality of use	84%	Good
Readability and comprehensibility of content	83%	Good
Interest in the media	86%	Very Good
Relevance to learning	84%	Good
Effectiveness of learning	87%	Very Good
Average	85%	Good

The results of the analysis of student responses to the flipbook e-module show that overall, the assessment aspect scored above 80%, indicating a positive response from students. In detail, the media aspect scored highest at 86% with a rating of "Very Good," followed by learning effectiveness at 87% with a rating of "Very Good." Other aspects, such as practicality of use, readability and comprehension of content, and relevance to learning, each scored 84%, 83%, and 84% with a "Good" rating.

D. Discussion

The final result of this development research is an e-module Flipbook on Living Things and the Environment. The effectiveness of the flipbook e-module in improving science literacy is evident from the N-Gain value. Analysis of the research results shows that the application of the flipbook e-module in science learning, especially on the theme of Living Things and Their Environment with a Project-Based Learning (PjBL) approach, has varying effectiveness but generally falls in the moderate to high range in improving science literacy. The N-Gain calculation results for the three experimental classes showed scores of 0.63 (moderate), 0.71 (high), and 0.77 (high), respectively. The N-Gain values, which were consistently above 0,60, indicate that the flipbook e-modules used increased conceptual understanding, scientific thinking skills, and the ability to apply scientific knowledge contextually after the learning treatment.

The results of this study are in line with previous research findings, which state that the development of a digital flipbook-based science e-module has been proven effective in improving science literacy based on high N-Gain scores (0,84) after the implementation of this media in the context of science learning (Humairah et al., 2024). This study shows that interactive flipbooks can facilitate a more in-depth learning process and motivate active engagement in understanding scientific concepts holistically and authentically. Other studies have also shown that implementing STEM-based flipbooks improves students' science literacy, with a significant increase in scores from pre-test to post-test (Prihatiningtyas et al., 2025). That research reinforces the empirical evidence that flipbooks, as a digital learning medium, have great potential to support interactive, reflective, and skills-oriented 21st-century science learning.

From a learning model perspective, integrating Project-Based Learning (PjBL) with flipbook e-modules enhances learning by fostering exploration, investigation, collaboration,

and reflection. The PjBL model encourages students to formulate problems, design experiments, make direct observations, and construct scientific arguments based on evidence. This is consistent with findings from similar studies that the application of the PjBL model has been proven effective in improving science and digital literacy compared to conventional learning (Pratama et al., 2024).

The N-Gain values in the moderate (0,63) to high (0,71 and 0,77) categories in this study indicate that the flipbook e-module not only improves concept mastery but also develops scientific thinking skills and the application of scientific concepts in real-world contexts, especially when learning activities are directed toward ecoprint batik projects that are relevant to students' lives. Engagement in real-world project activities enhances opportunities to use science in social and environmental contexts, which is one of the main indicators of science literacy. This is also supported by other empirical evidence showing that combining project-based learning with digital media, such as flipbooks, significantly improves learning outcomes and critical thinking skills (Kharomah et al., 2024).

Overall, learning that combines Project-Based Learning and flipbook e-modules has been proven effective in improving science literacy, with N-Gain scores indicating positive development in each experimental class. The implementation of this learning strategy shows that structured digital learning media with an active approach not only improve learning outcomes but also support the formation of more comprehensive science literacy competencies.

The results of the analysis of science literacy improvement for the indicator "Evaluating the validity of sources and evaluating the use and misuse of scientific information" show a significant increase from the moderate to high category in Experiment classes 2 and 3. This improvement indicates that the flipbook e-module provides a relevant and authentic learning context, enabling students to distinguish credible sources of information and apply scientific information appropriately. These findings align with previous studies showing that STEM-designed flipbooks can effectively train a range of science literacy skills, including the ability to evaluate and use scientific information correctly (Assalimi & Indana, 2025).

The next indicator, understanding research design elements and their influence on scientific findings and conclusions, also showed an upward trend from moderate to high (classes 2 and 3). This illustrates that the combination of PjBL and flipbook e-modules can help students understand the methodological aspects of scientific inquiry. The empirical application of PjBL has been shown to improve science literacy through student involvement in investigation and experimental design activities, as reported in previous studies that found a significant effect of the PjBL model on science literacy using a quasi-experimental design (Winarsi & Ningsih, 2025).

Indicators of data representation skills, such as creating graphs and reading and interpreting graphical data, showed a consistent increase, indicating that flipbook e-modules can support the development of students' quantitative skills. Science literacy encompasses not only conceptual understanding, but also data reading and representation

skills – competencies that are increasingly important in the 21st century (Nurwidiyanti & Sari, 2022).

However, several indicators related to more complex quantitative skills, such as problem-solving using quantitative methods and understanding and interpreting basic statistics, showed more varied results. In experimental classes 1 and 2, these indicators remained in the moderate category, whereas in experimental class 3, they increased to the high category. This indicates that although the media and learning approach are quite effective, some students' numerical abilities may require additional instructional support to develop optimally. The integration of PjBL with numeracy-based, statistical learning can improve these skills more consistently when combined with explicit numeracy strategies in the context of science (Pratama et al., 2024).

The indicators confirm the conclusions, predictions, and inferences based on quantitative data and also show a significant upward trend, especially in experiment class 3, from moderate to high. The improvement in these indicators reflects students' ability to use quantitative evidence to make scientific inferences, which is one of the key aspects of science literacy measured in the PISA (Programme for International Student Assessment) study.

Overall, the N-Gain data per indicator shows that the flipbook e-module integrated with the PjBL model is effective in improving almost all aspects of science literacy, particularly scientific critical thinking, source evaluation, research design, and data interpretation. The average N-Gain scores in the high category for grades 2 and 3 indicate that this learning medium can have a stronger impact when used consistently and structurally in project-based learning processes. These results reinforce previous research findings that learning with the PjBL model and digital media, such as e-flipbook modules, can holistically improve students' science literacy, not only in knowledge but also in scientific skills applicable in real-world contexts.

The analysis of student response data toward the developed flipbook e-module revealed that all evaluated aspects achieved scores above 80%, indicating an overwhelmingly positive student perception. Specifically, the media attractiveness aspect scored 86% ("Very Good"), followed closely by learning effectiveness at 87% ("Very Good"). Other aspects, such as usability, readability, comprehension, and relevance to learning, scored 84%, 83%, and 84%, respectively, all of which were categorized as "Good." These results suggest that students not only accepted the flipbook e-module but also perceived it as engaging, practical, and pedagogically effective in supporting their science learning in Living Things and the Environment (Sari & Nisa, 2024; Sari et al., 2023).

High scores in usability indicate that students found the flipbook e-module easy to access and use, with few technical difficulties. This aligns with the literature, which indicates that digital e-modules provide flexible learning environments that facilitate autonomous learning by allowing students to interact with instructional materials at their own pace and in their own context (Humairah et al., 2024).

Regarding readability and comprehension, the positive scores indicate that the e-module's content structure and language were accessible and logically organized, thereby facilitating students' understanding of scientific concepts. Prior research has demonstrated that e-modules with clear instructional structure and age-appropriate language significantly enhance learners' conceptual grasp (Herlina & Abidin, 2024).

The notably high media attractiveness score confirms that the flipbook e-module's visual and interactive features significantly increased student engagement. Visual elements such as images, diagrams, and animations have been shown to enhance motivation and cognitive engagement in science learning, consistent with established findings in multimedia learning research. The aspect of relevance to learning also received a favorable score, indicating that the e-module content was well aligned with curricular objectives and contextually meaningful to students. The ability to connect scientific concepts with real-world phenomena is central to scientific literacy, as reported in recent educational studies (Kusumaningsih et al., 2025).

Importantly, the high rating for learning effectiveness suggests that students perceived the flipbook e-module as more effective than traditional learning materials in supporting their understanding of science concepts and increasing confidence in their learning. This finding resonates with empirical evidence indicating that flipbook-based e-modules can positively impact conceptual mastery and science literacy when designed with interactive features and aligned with instructional goals (Sari & Nisa, 2024; Sari et al., 2023).

Overall, the students' highly positive responses underscore the practical viability and pedagogical value of the developed flipbook e-module. The consistent scores across multiple instructional aspects provide empirical support for the module's effectiveness in enhancing scientific literacy among Grade X students. These findings substantiate the research hypothesis and reinforce the conclusion that the flipbook e-module is an effective digital instructional tool in the context of Living Things and the Environment.

E. Implication

The findings of this study provide significant theoretical and practical implications for the development of science education grounded in scientific literacy and digital learning media. From a theoretical perspective, the results reinforce the notion that scientific literacy is optimally developed through contextual, interactive, and learner-centered instructional approaches supported by well-designed digital media. The developed flipbook-based e-module functions not merely as an alternative learning resource but as an instructional tool that facilitates conceptual understanding, scientific reasoning skills, and the ability to relate scientific knowledge to real-life contexts. Consequently, this study extends the existing body of literature by positioning flipbook-based e-modules as pedagogically meaningful digital learning media that directly enhance students' scientific literacy, particularly in the topic of Living Things and the Environment.

From a practical standpoint, the high levels of usability, readability, media attractiveness, content relevance, and learning effectiveness reported by students indicate

that the flipbook-based e-module is feasible for classroom implementation in vocational secondary schools. The e-module can support teachers in promoting active student engagement, fostering independent learning, and facilitating project-based and contextual learning in alignment with the Merdeka Curriculum. Furthermore, the utilization of students' digital devices as learning tools highlights the potential of flipbook-based e-modules to optimize technology integration in schools without requiring substantial additional infrastructure.

At the policy level, the findings offer empirical evidence to support the development and dissemination of digital teaching materials that integrate local contexts and scientific literacy in vocational education. The integration of contextual content within the flipbook-based e-module demonstrates that enhancing scientific literacy can be aligned with character education, local wisdom, and workforce readiness. Therefore, this study may inform educational policymakers in formulating strategies for the sustainable and innovative development of digital learning resources.

F. Limitation and Suggestion for Further Research

Despite its positive findings, this study has several limitations that should be considered. First, the quasi-experimental design without a control group limits the ability to directly compare the effectiveness of the flipbook-based e-module with other instructional media or learning models. Second, the study was conducted in a single vocational school, which may restrict the generalizability of the results to other educational contexts with different student characteristics and learning facilities. Third, the assessment of scientific literacy was conducted within a relatively short timeframe, preventing a comprehensive evaluation of the long-term effects of flipbook-based e-module implementation on students' conceptual retention and sustained scientific literacy development.

G. Conclusion

Based on research on the development of flipbook e-modules to improve students' science literacy, it can be concluded that the flipbook e-modules developed have characteristics as digital teaching materials that are interactive, contextual, and oriented towards strengthening science literacy. The material is systematically arranged according to learning outcomes and science literacy indicators and presented as scientific texts, visual illustrations, supporting videos, project activities, and integrated evaluation questions. Based on feasibility assessments by subject matter experts, media experts, and learning practitioners, the developed flipbook e-module was deemed feasible for use in 10th-grade science instruction. The feasibility of the e-module was reviewed in terms of the suitability of the material with the curriculum, the accuracy of scientific concepts, the clarity of language, the quality of visual display, and ease of use. Based on the effectiveness test results, the flipbook e-module was proven effective in improving science literacy in grade X. This was demonstrated by the average N-Gain scores in the three experimental classes:

0,634 in the moderate category, 0,712 in the high category, and 0,770 in the very high category.













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