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Development of Problem-Based Learning (PBL)-Based Flipbook E-Modules on Ecology Materials to Improve Students' Learning Outcomes

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Abstract: The development of Problem-Based Learning (PBL)-based flipbook e-modules on ecology is essential for meaningful learning experiences connected to real-world environmental issues. This research aims to develop a Problem-Based Learning (PBL)-based Flipbook E-Module on Ecology material for grade VII students and determine its validity, practicality, and effectiveness in science learning. This research uses the Research and Development (R&D) method with a 4-D development model consisting of define, design, develop, and disseminate stages. Data was collected through expert validation sheets, practical questionnaires, and learning outcome tests. The data were analyzed using percentage analysis to determine validity and practicality, the Shapiro-Wilk test to test normality, the Paired Sample t-test to determine the difference in learning outcomes, and the N-Gain to determine the improvement of learning outcomes. The validation results showed that 87% of material experts, 94.7% of media experts, and 89.5% of learning design experts, with an average of 90.4%, were categorized as very valid. The results showed 92% based on teacher assessment, 94% on individual tests, 93% on small-group tests, and 95% on large-group tests, with a very practical category. The effectiveness results showed an increase in the average learning outcome from the pretest (59.56) to the posttest (88.38), with an N-Gain of 0.73, placing it in the high category. The Paired Sample t-test showed a significant difference ($p < 0.05$). The product is developed and evaluated through expert validation and a phased practicality test before effectiveness testing. Thus, PBL-based Flipbook E-Modules meet valid and practical criteria and show a high increase in learning outcomes, so that they can be an alternative to digital teaching materials that support interactive, contextual, and student-centered science learning in the digital era.

Keywords: Ecology; Flipbook E-Module; Learning Outcomes; Problem-Based Learning (PBL).

Introduction

The Independent Curriculum is an educational policy designed to realize student-centered learning and encourage the creation of a more active, independent, and meaningful learning process. The implementation of the curriculum requires educators to be able to utilize technological developments as part of the learning process to improve the quality of learning and learning outcomes of students. In line with the development of information technology in the digital era, the use of technology-based learning media is necessary to support an effective and engaging learning process [1]. The challenges of 21st-century learning also require teachers to have the ability to utilize technology and adapt learning to the development of science and technology [2]. The use of technology in learning not only functions as a means of delivering information, but can also support the creation of more interactive and student-centered learning.

Technological developments in education provide educators with opportunities to create more innovative teaching materials and learning media. However, the use of digital media for learning remains suboptimal in many schools. Based on interviews with teachers of Natural Sciences (IPA) subjects, learning is still dominated by the use of package books and Student Worksheets (LKS). The learning process tends to be teacher-centered through verbal delivery of material, followed by assignments to students. Supporting facilities, such as computers and internet networks, are available, but their use for learning is not optimal. This condition causes students to be less actively involved in the learning process and shows the need for teaching materials that are able to utilize technological facilities while supporting more interactive and independent learning.

One of the science materials that students consider difficult is ecology. Ecological materials study the relationships between living things and their environment, including biotic and abiotic components, food chains, food webs, and ecosystem balance [3]. The material's characteristics, which involve interrelated components and processes, make it difficult for students to understand concepts, especially when learning relies solely on textbooks and conventional methods. Limited classroom time can also reduce students' opportunities to explore ecological concepts more deeply. This condition highlights the need for teaching materials that present concepts visually, interactively, and contextually, enabling students to connect the material to everyday phenomena.

The results of the needs analysis show that the use of science learning media is still dominated by package books, at 95.5%. As many as 81.8% of students stated that the learning media used today are not interesting. On the other hand, 68.2% of students already have a, but only 63.6% of them use it for learning activities. As many as 90.9% of students stated that it is easier to understand material through media containing images, videos, and animations, while

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86.4% of students prefer learning that involves contextual problem-solving. The findings show a gap between the available learning media and students' learning needs. This gap reinforces the need for digital teaching materials that can integrate visual, multimedia, and problem-based learning activities.

This condition affects students' learning outcomes. Data on the learning outcomes of ecological materials for the 2024/2025 school year show that students' classical completeness is only 46.87%, while the school's completeness criteria are 75%. The low learning outcomes indicate the need to develop teaching materials that not only present content digitally but also provide opportunities for students to understand concepts, explore information, solve problems, and evaluate their learning. The achievement of learning outcomes is related to learning planning, learning strategies, and the suitability of learning materials and methods with the characteristics of the material and students [4].

One alternative to address these problems is to develop a flipbook e-module based on Problem-Based Learning (PBL). E-modules are digital teaching materials that are systematically compiled to support students' independent learning [5]. E-modules can be presented in various electronic formats and can integrate text, images, audio, video, animations, and interactive links to provide a more engaging and active learning experience [6]. E-modules can also be accessed on various electronic devices, such as computers, laptops, tablets, and smartphones, providing students with flexibility in accessing learning materials.

An effective e-module needs to have characteristics that support self-paced learning and ease of use. E-modules have the characteristics of self-instruction, self-contained, stand-alone, adaptive, and user-friendly [7]. These characteristics allow students to learn the material independently, obtain the material in its entirety in a single teaching resource, use modules without dependence on other teaching materials, adapt them to technological developments, and operate them easily. E-modules also offer advantages in accessibility, multimedia integration, evaluation features, and integration with visual sources [8]. These advantages support the presentation of more flexible and interactive materials. However, the implementation of e-modules can still face obstacles such as limited teacher competence, limited school facilities and infrastructure, and limited availability of student devices [5]. Therefore, the development of e-modules needs to take into account user characteristics and learning conditions to ensure optimal use.

One form of e-module presentation that can support these needs is flipbooks. Flipbooks are digital learning media that can transform text-based materials into more interactive formats through animations, videos, audio, images, and *hyperlinks* [9]. These characteristics allow learning materials to be presented in the same way as books with the support of various multimedia elements. Heyzine Flipbook can be used to develop digital teaching materials that are easily accessible and support interactive presentation [10]. The use of Heyzine Flipbook in the development of e-modules allows ecological materials to be presented through a combination of text, images, videos, links, and learning activities so that it is more in line with the needs of students for visual and interactive learning media.

The presentation of teaching materials in an interactive manner should be supported by a learning model that guides students to actively engage with the material. One relevant model is Problem-Based Learning (PBL). PBL places real problems as a basis for students to acquire knowledge and skills [11]. PBL also encourages students to collaborate in groups in solving complex problems [12]. These characteristics are relevant to ecological materials because various concepts within them relate to environmental problems encountered in daily life.

The application of PBL provides students with opportunities to gain learning experience through problem-solving. PBL can help students develop problem-solving skills, improve independence and learning outcomes, and apply knowledge to new situations [11]. PBL has characteristics in the form of the use of real and relevant problems, student-centered learning, collaborative activities, and opportunities to develop and organize knowledge [13]. The implementation of PBL consists of five stages, namely student orientation to problems, organizing students to learn, individual and group investigations, development and presentation of works, and analysis and evaluation of problem-solving processes [14]. The integration of these stages into the flipbook e-module allows teaching materials to serve not only as a presentation of information but also as a guide for students' learning and problem-solving in ecology.

A number of previous studies have shown the potential of PBL-based flipbook e-modules to support learning processes and outcomes. The development of flipbook-based e-modules with the PBL model on colloidal materials achieved a validity level above 91%, excellent practicality, and an N-gain value of 0.85 [15]. These results show that integrating flipbooks with PBL can produce valid, practical, and effective teaching materials. However, the research was conducted on colloidal materials at the high school level, so it has not yet described the application of PBL-based e-modules to the characteristics of ecological materials at the junior high school level. Another study on PBL-based digital flipbooks to improve learning outcomes of grade V students reported an N-gain value of 0.71 [16]. These results show that PBL-based flipbooks have the potential to support improvements in student learning outcomes, but the research was conducted at the elementary school level and has not been specifically developed for grade VII junior high school ecology materials. The development of PBL-based e-modules using Kvisoft Flipbook Maker also demonstrates that the products are valid, practical, and effective for use in learning [17]. The study shows the feasibility of PBL-based e-modules as teaching materials, but uses the Kvisoft Flipbook Maker platform and is applied to mathematics materials, so that the use of Heyzine Flipbook in science learning, especially ecology materials, has not been studied. Research on the science-based Heyzine Flipbook interactive e-module on water cycle materials for grade V elementary school students shows that the Heyzine Flipbook has the potential to serve as an interactive digital teaching material [18]. However, the study has not integrated Heyzine Flipbook with PBL syntax and has not been applied to junior high school ecology materials.

Based on the previous research, there are still limitations in the development of teaching materials that

specifically combine Heyzine Flipbook, PBL syntax, interactive multimedia, and contextual problems in ecology materials in grade VII junior high school. The differences in materials, education levels, platforms, and learning approaches underscore the need to develop teaching materials tailored to the characteristics of science learning and the needs of grade VII junior high school students.

The novelty of this research lies in the development of a PBL-based flipbook e-module on ecology materials in grade VII junior high school by utilizing the Heyzine Flipbook and integrating text, images, videos, hyperlinks, contextual problems, investigation activities, discussions, solution preparation, presentation of results, and evaluation in one digital teaching material. Thus, the products developed not only combine digital technology and PBL models but also adjust the content, activities, and presentation of teaching materials to the characteristics of ecological materials and the needs of junior high school students.

This research makes a theoretical and practical contribution to the development of digital teaching materials. Theoretically, this study extends the use of e-modules and flipbooks by integrating PBL syntax into electronic teaching materials in ecology. The integration is realized through the presentation of contextual problems, investigation activities, discussions, solution preparation, presentation of results, and analysis and evaluation in accordance with the stages of PBL. In practice, the e-modules developed integrate text, images, videos, hyperlinks, problem-solving activities, and evaluations into a single digital teaching resource accessible on electronic devices. The product can be an alternative teaching material for teachers in supporting science learning that is more interactive, contextual, and student-centered and helps students learn more independently.

This research also has different product testing characteristics at the practicality and effectiveness stages. Practicality tests are carried out in stages through individual, small-group, and large-group trials. After the product is deemed practical at the trial stage, the effectiveness test is conducted across different classes. Using separate classes for the practicality and effectiveness tests allows the practicality assessment to be conducted in stages before the product is used to measure its effectiveness on learning outcomes. These test characteristics are among the aspects that distinguish this research during the development and testing of PBL-based flipbook e-modules.

Based on this, the study aims to develop a flipbook e-module on ecological materials using Problem-Based Learning (PBL) that meets the criteria of validity, practicality, and effectiveness. This study specifically analyzes the level of product validity based on the assessment of material experts, media experts, and learning design experts, the level of practicality based on user responses, and the effectiveness of the product in improving student learning outcomes on ecological materials.

Research Methods

This research and development (R&D) project aims to produce a flipbook e-module based on Problem-Based Learning (PBL) for grade VII junior high school students on ecology. The development model used is the 4-D model developed by Thiagarajan, which consists of the define, design, develop, *and* disseminate stages [19]. The definition stage includes initial analysis, student analysis, task analysis, concept analysis, and formulation of learning objectives. The design stage includes preparing criteria reference tests, selecting media and formats, and developing initial product design. The development stage includes expert validation and development trials, while the dissemination stage includes validation testing, packaging, and product dissemination.

The research was conducted at SMP Muhammadiyah 1 Medan during the 2025/2026 school year. The research subjects consisted of three lecturers from the FMIPA Department of Biology as product validators, one science teacher as practicality assessors, students of class VII T2 as subjects of development trials, and 34 students of class VII T3 as subjects of effectiveness tests. The product validator consists of three lecturers who are purposively selected for their expertise in the aspect of the product being assessed. Learning design expert validators have key expertise in science learning strategies, models, and innovations, and assess aspects such as logical flow, ease of understanding, relevance of learning objectives, content suitability, and alignment of e-modules with Problem-Based Learning syntax. Media expert validators have qualifications in science learning media and assess the appearance, ease of use, usefulness, and graphics of e-modules. Material expert validators have qualifications and expertise in ecology and assess the feasibility and suitability of ecological materials for learning objectives. The development trial consisted of individual trials for 3 students, small-group trials for 9 students, and large-group trials for 21 students, based on students' ability levels. The subjects of the effectiveness test consisted of 34 students in class VII T3, purposively selected based on research considerations.

Data collection was carried out through observation, interviews, questionnaires, documentation studies, and learning outcome tests. Observations and interviews are used to collect data on learning needs. A questionnaire is a data collection instrument that uses a series of questions or written statements to elicit responses from respondents. In this study, a questionnaire was used to obtain data on the validity and practicality of e-modules. Documentation studies are a data collection technique that uses documents related to the research object as sources of supporting information. In this study, documentation studies were used as supporting data for needs analysis, research implementation, and analysis of research results [19]. Learning outcome tests are a series of questions administered to students to assess achievement of specific learning outcomes or competencies. In this study, the learning outcome test was used to measure students' initial abilities and learning outcomes through pretest and posttest [20].

The research instruments include material expert validation sheets, media expert validation sheets, learning design expert validation sheets, teacher practicality questionnaires, student practicality questionnaires, and learning outcome tests. Validation sheets are used to assess the product's feasibility in terms of content, media, and learning design. The practicality questionnaire was used to gather feedback from teachers and students on the product's ease of use, time efficiency, benefits, and technical aspects. The learning outcome test is in multiple-choice format and is

compiled based on learning indicators and the cognitive domain.

The quality of the learning outcome test instruments is assessed before they are used to collect research data. Test quality tests include item validity, difficulty, differentiation, and reliability. The validity of the item is analyzed to determine the item that meets the criteria, while the level of difficulty and differentiating power are used to evaluate the characteristics of each item. The reliability of the instrument was analyzed using Cronbach's Alpha coefficient to determine the internal consistency of the instrument. The results of the analysis are used to determine the question items for the pretest and posttest. The expert validation sheet and the practicality questionnaire are validated by one lecturer before being used in data collection to assess the suitability of the instrument item with the aspect being measured.

Validity data were obtained from assessments of material experts, media experts, and learning design experts using a five-point Likert scale. The validity percentage is calculated using a comparison of the score obtained with the maximum score, with the formula:

$$V1 = \frac{\text{skor yang diperoleh}}{\text{jumlah tertinggi}} \text{x } 100\%$$

[21]

The results of the validity calculation are then interpreted based on the criteria in Table 1.

Table 1. Validity Criteria

Percentage (%)	Criteria
81 – 100	Very valid
61 – 80	Valid
41 – 60	Quite valid
21 – 40	Invalid
0 – 20	Invalid

[21]

Practicality data were obtained from teacher and student response questionnaires. The practicality percentage is calculated using a formula.

$$P\ (s) = \frac{f}{N} \text{ x } 100\%$$

Description :
P(s) = Sub-variable percentage
f = score obtained
N = maximum score

The results of the practicality calculation are interpreted based on the criteria in Table 2.

Table 2. Practicality Criteria

Percentage (%)	Criteria
80 – 100	Very practical
60 - 79,99	Practical
40 - 59,99	Quite practical
20 - 39,99	Less practical
0- 19,99	Impractical

[19]

The effectiveness of the e-module was analyzed using the One Group Pretest-Posttest design, chosen to determine changes in students' learning outcomes before and after the use of the Problem Based Learning flipbook e-module. The pretest is administered before learning, and the posttest after learning using an e-module. The data on learning outcomes were analyzed using IBM SPSS Statistics 27 through descriptive statistics, the Shapiro-Wilk normality test, and the paired-samples t-test. Descriptive statistics were used to describe pretest and posttest scores. The Shapiro-Wilk test was used to assess the normality of the data as a prerequisite for parametric analysis, with a significance level of 0.05. The paired-samples t-test was used to determine the difference in learning outcome scores before and after the use of e-modules. The improvement in learning outcomes was then analyzed using N-Gain based on pretest and posttest scores, with the formula:

$$\text{N} - \text{Gain} = \frac{\text{skor posttest} - \text{skor pretest}}{\text{skor ideal} - \text{skor pretes}}$$

The results of the N-Gain calculation are then interpreted based on the criteria in Table 3.

Table 3. N-Gain Criteria

N-Gain	Notes
N-Gain ≥ 0.7	Height
0,30 - 0,69	Medium
0,00 - 0,29	Low

[22]

The One Group Pretest-Posttest design does not involve a control group or a comparison group. Therefore, the improvement in pretest and posttest scores is used as an indicator of changes in learning outcomes after the implementation of the product, but is not interpreted as causal evidence that the increase is entirely due to the use of e-modules. Other factors that may affect changes in learning outcomes, such as teachers' learning processes, previous learning experiences, and the effects of repetitive measurements, cannot be fully controlled in this design.

The research was carried out after obtaining permission from SMP Muhammadiyah 1 Medan. Before data collection, the researcher explained the objectives, procedures, and research activities to the school, teachers, and students. The research was implemented after obtaining approval from the school and students' consent to participate in research activities.

Results and Discussion

The development of a flipbook e-module based on Problem-Based Learning (PBL) for Ecology material was carried out using the 4-D model, consisting of the define, design, develop, and disseminate stages. The four stages are carried out systematically to produce e-modules that undergo validation, practicality tests, and effectiveness tests.

At the definition stage, initial analysis, student analysis, task analysis, concept analysis, and formulation of learning objectives are carried out. The results of the initial analysis show that science learning is still dominated by the use of package books by 95.5%, while the use of technology-based learning media is not optimal. In addition, 81.8% of students stated that less interesting learning media was one

of the obstacles in learning, and 90.9% of students stated that it was easier to understand material through pictures, videos, or animations. The completeness of learning outcomes in the Ecology material showed that 53.13% of students had not achieved the KKTP. The analysis of tasks and concepts produces material that includes ecosystem units, biotic and abiotic components, interactions between organisms, energy flow, and biogeochemical cycles which subsequently become the basis for the formulation of learning objectives and the preparation of e-module content.

The design stage is carried out based on the results of the analysis at the define stage through the preparation of benchmark reference tests, media selection, format selection, and initial product design. The e-modules are developed using Canva, Wordwall, Educaplay, and Heyzine Flipbook. Canva is used for designing the look and layout, while Wordwall and Educaplay are used to provide interactive activities. Furthermore, Heyzine is used to package e-modules as digital flipbooks.

The e-module is designed to include a cover, instructions for use, learning outcomes and objectives, concept maps, Ecology materials, learning activities based on the Problem-Based Learning syntax, summaries, reflections, glossaries, and a bibliography. Pretest and posttest instruments are also organised by learning objectives, material indicators, and cognitive domains. The initial design of the developed e-module is presented in Table 1.

The development of flipbook e-modules based on Problem-Based Learning (PBL) is grounded in students' needs and school learning conditions. The results of the initial analysis showed that most students already had smartphones and tended to exhibit visual learning characteristics. This condition underscores the need for teaching materials that present information in an interesting, interactive, and easily accessible manner. E-modules are an appropriate alternative teaching material because they allow learning materials to be accessed flexibly and support students' independent learning. This is in line with [22] which states that e-modules as digital teaching materials can support independent learning and increase student involvement in the learning process.

The choice of the flipbook format for the e-module is based on its ability to integrate various forms of information into a single learning medium. The developed e-modules not only present text but also include images, videos, concept maps, and interactive activities. This integration provides a more diverse learning experience than conventional presentation of material. This finding is in line with [23] which states that flipbooks as a digital learning medium have interactive and interesting characteristics so that they can support student involvement in learning.

Theoretically, the use of various forms of representation in e-modules can be attributed to the Cognitive Theory of Multimedia Learning. [24] explains that information is processed through verbal and visual channels that allow learners to organize and integrate new information with existing knowledge. In the context of this study, the use of text, images, videos, and animations in Ecology materials provides conceptual representations of various forms so that they can help students understand materials that are abstract and that require visualization. Thus, the multimedia function in the e-module is not solely to beautify the display but also to support the processing and understanding of information.

However, the existence of various multimedia elements does not automatically guarantee an increase in students' understanding. The multimedia presentation needs to be adjusted to the needs of the material and the ability of students so that the information received is not excessive. [25] explained that the development of multimedia learning needs to pay attention to cognitive load so that the presentation of information does not cause cognitive overload. Therefore, the multimedia element in this research e-module serves to support the learning materials and activities, not merely as a decorative element. This is reinforced by [26], which shows that applying multimedia design principles is an important aspect of digital learning development. Thus, the benefits of multimedia are determined more by its relevance and alignment with the learning objectives than by its many features.

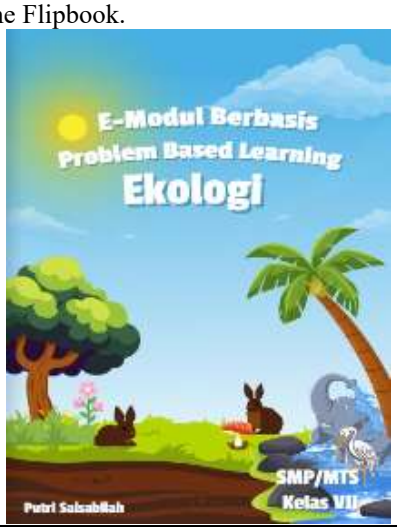
The interactivity of the e-module is also strengthened through the use of Wordwall and Educaplay, which are integrated into practice activities and learning evaluations. Both platforms provide students with the opportunity to interact directly with the material through quizzes and educational games. This condition shifts evaluation activities from simply receiving information to requiring students to respond to problems or questions. The results of this study are in line with [27], which shows that the use of Wordwall can positively impact students' learning outcomes. Similarly, [28] reports that Educaplay can support learning through interactive activities. However, this study has not been able to determine the separate contributions of Wordwall and Educaplay to improving learning outcomes because both platforms are used simultaneously with multimedia and PBL models.

In addition to the multimedia aspect, the application of PBL is an important component in the e-module learning structure. PBL not only serves as a method for presenting material but also provides a framework for students to build knowledge through real-life problems. At the problem orientation stage, students are directed to identify and understand ecological problems. Furthermore, investigative activities encourage students to search for and process information, while discussion activities provide space to test understanding and develop alternative problem-solving. At the stage of presenting the results, students communicate their problem-solving outcomes, then evaluate and reflect on the process carried out. The process allows learners not only to accept concepts but also to use them in inquiry and problem-solving.

The implementation of PBL aligns with the constructivist perspective, which views learning as an active process of building knowledge through experience and interaction with the environment. [29] shows that PBL aligns with a constructivist approach, as learners are actively involved in problem-solving and knowledge development. In this study, these characteristics are seen in the activities of students who not only read the material but also identify problems, conduct investigations, discuss, present results, and reflect. Thus, PBL provides a learning mechanism that enables multimedia in e-modules to be used more meaningfully, as students are directed to use the information available during problem-solving.

The learning outcome test instrument is tested before being used at the *validation testing stage*. The instrument quality test includes item validity, difficulty, differentiation, and reliability. Of the 50 questions tested, 36 items were declared valid and 14 items were invalid. Furthermore, 36 valid items were analyzed based on the level of difficulty and differentiating power and were used for reliability testing. The results of the difficulty-level analysis showed that 5 items were in the easy category, 25 in the medium category, and 6 in the difficult category. The differentiating power analysis showed that 9 items were in the sufficient category, 25 in the good category, and 2 in the excellent category. The reliability test on 36 valid grains yielded a Cronbach's Alpha coefficient of 0.922 which is in the very high category.

Table 1. Initial Design of the E-Module

No	Visual	No	Visual
1	Flipbook e-module covers based on Problem Based Learning (PBL) on ecological materials using Heyzine Flipbook. 	2	The title of the orientation of the first problem for learning activities. 
3	Learning activities organize students, investigate, present and present results, analyze and evaluate students. 		

The development stage is a stage to realize the initial design into a Problem Based Learning (PBL)-based flipbook e-module that is ready to be tested. At this stage, validation is conducted by material, media, and learning design experts, followed by product revisions based on the validators' input and practicality tests by teachers and students. The results at the development stage include the e-module's validity, revisions, and practicality.

The results of instrument validation by one lecturer showed 80% and were classified as feasible. These results show that expert validation sheets and practicality questionnaires can be used to collect research data.

Expert Appraisal

Validation by materials experts is conducted to assess the feasibility and suitability of Ecology materials for the Problem-Based Learning (PBL)-based flipbook e-module. The aspects assessed include content digestibility, coverage accuracy, and language**.** The assessment is carried out by lecturers with qualifications in Ecology. The results of the subject matter experts' assessment are presented in Figure 1.

Based on Figure 1, the validation results from the subject matter experts showed 87.0%, placing them in the very valid category**.** The validator provides suggestions to correct some writing errors in the e-module. The suggestion

is then used as the basis for product revision before development trials are conducted. Media expert validation was conducted to assess the appearance, ease of use, usefulness, and graphics of the Problem-Based Learning (PBL) flipbook e-module. The assessment is carried out by lecturers with qualifications in science learning media. The results of the media expert's assessment are presented in Figure 2. Based on Figure 2, the validation results from media experts showed 94.7%, placing them in the very valid category**.** The validator stated that the developed e-module **is** good and feasible to use**.**

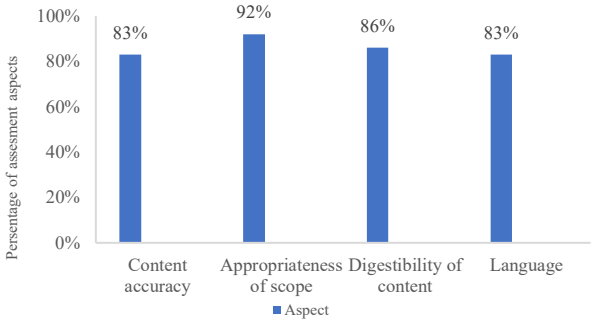


Figure 1. Material Expert Validation Results

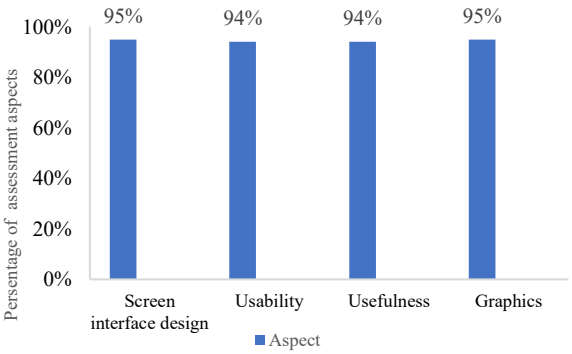


Figure 2. Media Expert Validation Results

Validation by learning design experts was conducted to assess the quality of the learning design in the Problem-Based Learning (PBL)- based flipbook e-module. The aspects assessed include logical flow, ease of understanding, relevance of objectives, content suitability, and suitability of each stage of PBL syntax**.** The assessment is conducted by lecturers with expertise in science learning strategies, models, and innovations. The assessment results for each indicator are presented in Figure 3.

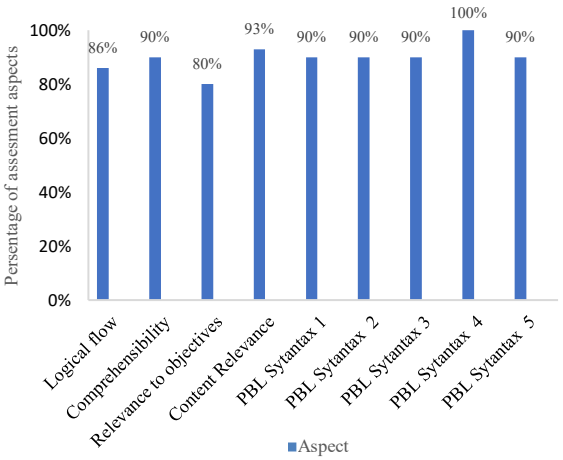


Figure 3. Learning Design Expert Validation Results

Based on Figure 3, the validation results from learning design experts showed 89.5%, placing them in the very valid category**.** The validator provided several suggestions for improvement, including adjusting the flow of learning objectives with learning objectives in each chapter, including clear sources in examples and visualizations, adjusting videos with learning materials, improving sentences and writing in group activities, and adding tests or questions to the reflection section of learning outcomes.

In terms of product quality, the validation results showed that the e-module received 87% from material experts, 94.7% from media experts, and 89.5% from learning design experts, all of whom rated it very valid. These results show that the e-module has met the feasibility aspects of materials, media, and learning design. These findings support [30] that the validity of learning products is related to the suitability of content, presentation, and learning objectives. In addition, [31] explained that the quality of e-modules is also related to the suitability of materials, language, and media display. Thus, the validation results provide evidence that the product used in the trial stage has been assessed across various relevant aspects.

Product revisions are carried out based on input from material, media, and learning design experts. Improvements include several aspects of the content and presentation of the e-module, namely correcting writing errors, adjusting the flow of learning objectives with the objectives of each chapter, including sources in examples and visualizations, adjusting videos with materials, improving writing in group activities, and adding questions to the reflection section of learning outcomes. The results of the product revision are presented in Table 2.

Table 2. Results of E-Module Revision Based on Validator Input

After Revision
The flow of learning objectives and objectives of each chapter has been aligned with the learning objectives in the initial section.





Visual examples used have been added to the source



The video was replaced with a Lake Toba context, accompanied by improved writing and instructions for group activities.



Reflections on each chapter added



Developmental Testing

The teacher's practicality test was conducted to assess the ease of use of e-modules for learning. The assessment covers aspects of content, presentation, language, and ease of use. The results of the teacher's assessment are presented in Figure 4.

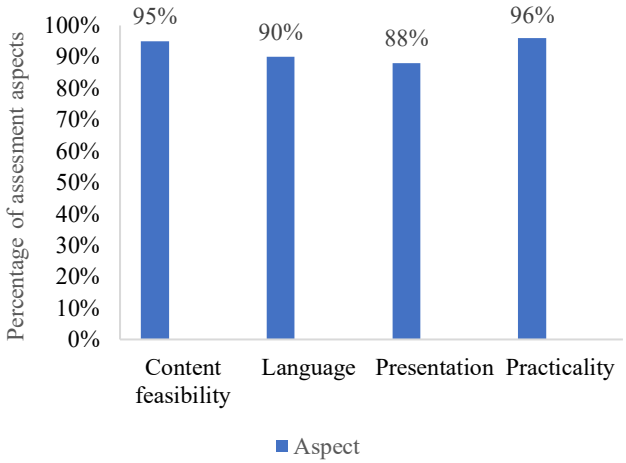


Figure 4. Results of the Teacher's Practicality Test

Based on Figure 4, the teacher's assessment results showed a practicality percentage of 92%, classified as very practical**.** The practical test for students was conducted through individual trials for 3 students, small groups of 9 students, and large groups of 21 students. The assessment covers aspects of media, time efficiency, and benefits. The results of the students' practicality test are presented in Figure 5.

Based on Figure 5, the percentage of practicality in the individual trial was 94%, the small group was 93%, and the large group was 95%. So the results obtained are in the very practical category**.** The results of the practicality test also showed that the e-module was in the very practical category, as assessed by teachers and students. Practicality concerns ease of use, clarity of instructions, display, and the accessibility of e-modules on smartphones. [32] states that the practicality of learning media is related to its ease of use and benefits in supporting the learning process. The findings

show that e-modules not only meet the feasibility criterion theoretically, as assessed by experts, but can also be used in actual learning conditions.

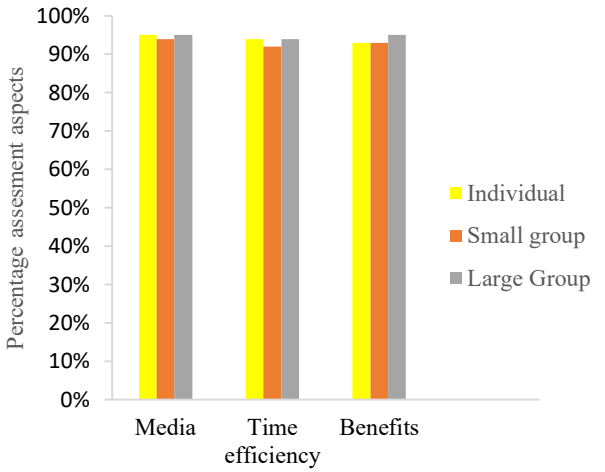


Figure 5. Results of the Students' Practical Test

The dissemination stage is the final stage of development, carried out through validation testing, packaging, and limited product distribution. In this study, e-modules were used with students in grade VII T3 at SMP Muhammadiyah 1 Medan to obtain learning outcome data through pretests and posttests. After testing, the e-module was packaged as a digital flipbook using Heyzine and then disseminated on a limited basis to teachers and students at SMP Muhammadiyah 1 Medan as teaching materials to support Ecology learning.

Validation Testing

Validation testing was carried out to determine changes in student learning outcomes after the implementation of Problem-Based Learning (PBL)- based flipbook e-modules. The test involved 34 students in class VII T3 at SMP Muhammadiyah 1 Medan and used the One Group Pretest-Posttest design. Students are given *a pretest* before learning and *a* posttest after learning using e-modules. The results of descriptive statistics are presented in Table 3.

Table 3. Results of Descriptive Statistical Analysis of Pretest and Posttest Scores

Variable	Quantity (N)	Average (Mean)	Standard Deviation
Pretest	34	59.56	14.64
Posttest	34	88.38	7.56

Based on Table 3, the average pretest score was 59.56 with a standard deviation of 14.64, while the average posttest score was 88.38 with a standard deviation of 7.56. A comparison of the average scores and standard deviations for the pretest and posttest is presented in Figure 6. The normality test was performed using the Shapiro-Wilk test with a significance level of 0.05. The decision-making criterion is that the data is declared to be normally distributed if the significance value (p-value) is ≥ 0.05, while the *p-value* < 0.05 indicates that the data is not normally distributed. The results of the normality test are presented in Table 6.

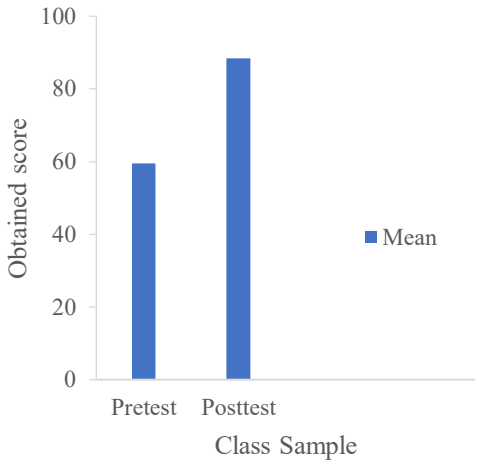


Figure 6. Comparison of Average and Standard Deviation of Pretest and Posttest Scores

Table 6. Normality Test Results (Shapiro-Wilk)

Variable	Shapiro-Wilk	Sig.	Remarks
Pre-test	0.951	0.133	Normal distribution
Post-test	0.964	0.314	Normal distribution

Based on Table 6, the significance value of the pretest is 0.133, and the posttest is 0.314, both of which are greater than 0.05. Thus, the pretest and posttest data are normally distributed, and the analysis is continued with a paired-samples t-test. The paired-samples t-test was conducted to determine the difference in students' learning outcomes before and after using the Problem-Based Learning (PBL)-based flipbook e-module. The decision-making criterion is that if the significance value (p-value) < 0.05, then there is a significant difference between the pretest and posttest scores, while if the p-value ≥ 0.05, then there is no significant difference. The test results are presented in Table 7.

Table 7. Paired Sample t-test results

Variable	Mean Difference	t-Count	df	Sig. (2-tailed)
Pre-test and Post-test	28.824	17.474	33	<0.00

Based on Table 7, a *t* value of 17.474 with df = 33 and a significance value of p < 0.001. Because the p-value < 0.05, there is a significant difference between the *students'* pretest and posttest scores after the implementation of the e-module.

N-Gain analysis was conducted to assess the extent of improvement in learning outcomes using pretest and posttest *scores*. The analysis showed an average N-Gain of 0.73 with a standard deviation of 0.14, which fell in the high category**.** The results of the N-Gain analysis are presented in Table 8.

Table 8. N-Gain Analysis Results

Number of Students	N-Gain	Standard Deviation	Categories
34	0.73	0.14	Height

At the packaging stage, the e-module is created in Heyzine as a digital flipbook accessible online via a link.

Furthermore, at the diffusion and adoption stage, products that have undergone validation, revision, practicality testing, and effectiveness testing are disseminated on a limited basis to teachers and students at SMP Muhammadiyah 1 Medan as teaching materials to support Ecology learning.

Furthermore, the analysis of learning outcomes showed an increase after the implementation of the e-module. The average score of students increased from 59.56 in the pretest to 88.38 in the posttest. The decrease in the standard deviation from 14.64 to 7.56 indicates that the spread of grades after learning is smaller than before. The results of the normality test indicated that the pretest and posttest data were normally distributed. Furthermore, the results of the paired-samples t-test showed a t-value of 17.474 (df = 33) and a p-value < 0.001. Thus, there is a significant difference between students' learning outcomes before and after the implementation of e-modules. The N-Gain value of 0.73 in the high category also indicates that the improvement in learning outcomes is substantial.

The increase can be attributed to the integration of several learning components within the e-module. Multimedia provides representations of material in the form of text, visuals, and videos, while Wordwall and Educaplay provide interactive activities. At the same time, PBL syntax directs learners to use the information in the process of investigation and problem-solving. The integration provides a learning environment that is not only oriented to the reception of information but also to students' cognitive activities. These findings are consistent with [33], which suggests that interactive digital learning can positively impact learning outcomes. These results are also consistent with [34], which reports that PBL-based flipbook modules are effective in improving science learning outcomes.

However, the improvement in learning outcomes observed in this study needs to be interpreted with caution. The paired-samples t-test results showed a significant difference between pretest and posttest scores, but the study design used was a one-group pretest-posttest without a control group. Therefore, the increase cannot be fully attributed to the e-module, as other factors may also affect learning outcomes. In addition, this study was conducted in only one school with a total of 34 students, so generalization of results to the wider population is still limited. This study has also not measured long-term retention, so it is not known whether the improvement in learning outcomes can be maintained after learning is completed.

Another limitation is that an analysis of each component's contribution to the e-module has not been conducted. Multimedia, Wordwall, Educaplay, and PBL are used in an integrated manner, so this study has been unable to determine which components contribute most to improving learning outcomes. Thus, the claim of effectiveness in this study is better understood as the overall effectiveness of e-module use**,** not the effectiveness of each feature individually. Further research could use experimental designs with control groups, involving a larger and more diverse sample, and conduct retention measurements to obtain stronger evidence of effectiveness. Advanced research can also compare the use of e-modules with and without certain features to identify the contribution of each component to learning outcomes.

In the broader educational context, PBL-based flipbook e-modules have the potential to serve as teaching materials that support learning in Ecology by integrating digital technology with problem-oriented learning. Multimedia integration can help provide a diverse representation of the material [26], while PBL provides a learning experience that encourages learners to engage in investigation and problem-solving [25]. However, the product's broader implementation still needs to consider teachers' readiness, the availability of devices and internet access, and students' characteristics. Therefore, the use of e-modules depends not only on the quality of the product but also on the learning environment's readiness to support its optimal use.

Thus, the main contribution of this research lies not only in the development of e-modules in the form of flipbooks but also in the integration of multimedia, interactive activities, and PBL syntax into a single digital teaching material for Ecology learning. The validation results, practical use, and improved learning outcomes provide early evidence that the product has the potential to support learning. However, the limitations of the study design and sample coverage suggest that the findings on effectiveness still need to be confirmed through studies with stronger designs and wider scope.

Conclusion

This research successfully developed a Flipbook E-Module based on Problem-Based Learning (PBL) on Ecology materials for grade VII junior high school students using the 4-D development model. The results indicate that the product meets the criteria of validity, practicality, and effectiveness, as evidenced by its high validity, practical nature, and improved student learning outcomes. Theoretically, this research contributes to technology-based science learning by integrating multimedia and problem-solving activities across all stages of PBL into a single digital teaching material, enabling students to access information while engaging in investigation, discussion, solution development, presentation, and reflection. Practically, the product supports teachers in providing interactive, contextual, and systematic teaching materials while encouraging students to learn more actively and independently through digital devices. The novelty lies in the development of a PBL-based Flipbook E-Module for Ecology using Heyzine Flipbook, integrating multimedia, interactive activities, contextual ecological problems, and complete PBL stages, and in conducting practical testing progressively through individual, small-group, and large-group trials before effectiveness testing. However, the effectiveness test was conducted in only one class using a one-group pretest-posttest design without a control group, so the improvement in learning outcomes cannot be fully attributed to the e-module and may be influenced by other factors. The study was also limited to one school and did not examine long-term learning retention. Future research is recommended to employ experimental designs with control or comparison groups and involve larger, more diverse samples across different schools and learning contexts.

Authors's Contribution

P. Salsabilah: Initiated the research idea, designed the study, developed the Flipbook E-Module based on Problem-Based Learning (PBL), collected and analyzed the data, and

prepared and revised the manuscript. S. D. Pohan Contributed to the research design, supervised the research, validated the research instruments, interpreted the data, and reviewed the manuscript.

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