Inovasi Kurikulum *- p-ISSN 1829-6750 & e-ISSN 2798-1363*
Volume 22 No 3 (2025) 1811-1824

Inovasi Kurikulum
https://ejournal-hipkin.or.id/index.php/jik

Development of Nepenthes diversity module at Mount Sibuatan for Biology learning

Arif Fadila[1], Miza Nina Adlini[2]
[1,2]Universitas Islam Negeri Sumatera Utara, Kota Medan, Indonesia
ariffadila@uinsu.ac.id[1], mizaninaadlini@uinsu.ac.id[2]

ABSTRACT

The biodiversity of pitcher plants *(Nepenthes sp.)* on Mount Sibuatan faces serious threats due to pollution and human activities. However, specific teaching materials related to this endemic species are still minimal in high school biology education. This study developed a local-potential-based learning module on *Nepenthes* diversity on Mount Sibuatan to improve student understanding and conservation awareness. Using the Research and Development method using the ADDIE model, data were collected through field exploration on the Naga Lingga trail, analysis of the Merdeka curriculum, expert validation, and practicality and effectiveness tests at MAN Batubara. The study identified four *Nepenthes* species: *N. tobaica, N. spectabilis, N. rhombicaulis,* and one other species. The module obtained very good validity from media and material experts. Implementation showed high effectiveness, with significant improvement from pretest to posttest. This module proved effective in increasing conceptual understanding and creating protection enlightenment, while developing student character based on Pancasila values, critical thinking, and environmental awareness through the integration of local knowledge in biology learning.

ARTICLE INFO

Article History:
Received: 14 Apr 2025
Revised: 27 Jul 2025
Accepted: 29 Jul 2025
Available online: 14 Aug 2025
Publish: 29 Aug 2025

Keywords:
Learning Module; Mount Sibuatan; Nepenthes

Open access
Inovasi Kurikulum is a peer-reviewed open-access journal.

ABSTRAK

Keanekaragaman hayati tumbuhan kantong semar (Nepenthes sp.) di Gunung Sibuatan menghadapi ancaman serius akibat pencemaran dan kegiatan manusia. tetapi, bahan ajar khusus terkait spesies endemik ini masih minim pada pendidikan hayati Sekolah Menengan Atas. Penelitian ini mengembangkan modul pembelajaran berbasis potensi lokal tentang keragaman Nepenthes di Gunung Sibuatan untuk meningkatkan pemahaman peserta didik dan kesadaran konservasi. menggunakan metode Research and Development menggunakan model ADDIE, data dikumpulkan melalui eksplorasi lapangan di jalur Naga Lingga, analisis kurikulum Merdeka, validasi ahli, serta uji kepraktisan dan efektivitas pada MAN Batubara. Penelitian mengidentifikasi empat spesies Nepenthes: N. tobaica, N. spectabilis, N. rhombicaulis, serta satu spesies lainnya. Modul memperoleh validitas sangat baik dari ahli media dan materi. Implementasi menunjukkan efektivitas tinggi, menggunakan peningkatan signifikan dari pretest ke posttest. Modul ini terbukti efektif dalam menaikkan pemahaman konseptual serta menciptakan pencerahan perlindungan, sekaligus menghasilkan karakter peserta didik berlandaskan nilai-nilai Pancasila, pemikiran kritis, dan kepedulian lingkungan melalui integrasi pengetahuan lokal pada pembelajaran hayati.

Kata Kunci: *Gunung Sibuatan; kanotng semar; modul pembelajaran; Nepenthes*

How to cite (APA 7)
Fadila, A. & Adlini, M. N. (2025). Development of Nepenthes diversity module at Mount Sibuatan for Biology learning. *Inovasi Kurikulum, 22*(3), 1811-1824.

Peer review
This article has been peer-reviewed through the journal's standard double-blind peer review, where both the reviewers and authors are anonymised during review.

https://doi.org/10.64014/jik.v22i3.108

INTRODUCTION

In Indonesia, Mount Sibuatan is one of the natural tourist icons located in Karo Regency, North Sumatra Province, which houses natural wealth in the form of flora and fauna with unique characteristics, including various species of pitcher plants (*Nepenthes*) that grow naturally in this area. The flora and fauna found on Mount Sibuatan, particularly the pitcher plant population, remain in their natural state to this day. This mountain has an elevation of 2,457 meters above sea level, providing ideal conditions for the growth of highland pitcher plants (Tarigan & Ritonga, 2021). The Mount Sibuatan area is a highland tropical rainforest with a collection of flora and fauna, particularly various types of pitcher plants that can be used as a source for botanical education and research.

Mount Sibuatan, famous for its biodiversity, especially pitcher plants (*Nepenthes*), faces several serious problems. The *Nepenthes* population in this area has experienced a decline in species variation due to environmental pollution from visitor and climber waste (Rizqiani et al., 2018). The waste polluting the soil in the natural habitat of pitcher plants prevents some species from growing properly, leaving only those more resistant to pollution able to survive. This has resulted in a significant decline in the genetic diversity of *Nepenthes* on Mount Sibuatan compared to previous years. Another issue faced by *Nepenthes* is the threat of habitat destruction, which endangers their existence (Rizqiani et al., 2018). While climate, soil type, and natural species dispersal processes play a crucial role in shaping the diversity and distribution of *Nepenthes*, human-caused factors such as environmental pollution have disrupted their ecosystem balance (Wong et al., 2020). While some species like *Nepenthes gracilis* can survive in low pH and high organic matter conditions in specific ecosystems, many other species on Mount Sibuatan lack the same adaptive capacity to environmental changes caused by pollution. *Nepenthes* populations have declined in recent years (Rawi & Shahrudin, 2021). The leading causes are residential construction activities, the conversion of natural land into plantations by the community, deforestation for oil palm plantations, illegal forest burning, and exploitation by the community for business purposes (Setiawan, 2025; Yudaputra et al., 2023).

Given the importance of biodiversity conservation, learning is key to educating the younger generation, where learning serves as a process of behavioral change towards self-maturity through interaction with the environment (Hong et al., 2022; Straka et al., 2025). Biodiversity must be integrated into biology education because many students lack an understanding of the importance of preserving the environment, particularly endangered species such as the pitcher plant. Through well-planned education, students can develop an awareness of species conservation in their surroundings. Research shows that biodiversity challenges in Conservation Biology studies increase student participation, enrich knowledge, and make them aware of knowledge gaps in the discipline (Oikonomou et al., 2025; Oliveira et al., 2025; Hidayat, 2024). While integrating biodiversity into biology education has been proven to enhance students' understanding and awareness of environmental conservation by bringing together various community groups to discuss issues related to sustainability.

Given the various challenges in biodiversity education, the development of locally-based learning modules can be an effective solution to enhance students' understanding and awareness. Modules are teaching materials designed following the applicable curriculum and aimed at achieving established competency standards, thereby helping students learn independently and purposefully about the importance of preserving biodiversity, particularly pitcher plants on Mount Sibuatan (Pary et al., 2025; Putri & Manalu, 2024). This is supported by the fact that teaching modules often become a topic of discussion among teachers at all levels of education due to their effectiveness in the learning process. Furthermore, research has proven the effectiveness of independent curriculum teaching modules based on local wisdom in improving learning outcomes in Indonesia, indicating that the use of modules can be an appropriate

https://doi.org/10.64014/jik.v22i3.108

strategy to address students' low understanding and concern for the preservation of biodiversity in their surrounding environment (Aprianti et al., 2024).

Although numerous studies on *Nepenthes* have been conducted, none have directly addressed the development of *Nepenthes* learning modules. Previous research focused on plant diversity in high schools but did not include specific content on *Nepenthes* and its conservation value (Hasmiati et al., 2023). Furthermore, other research developed a local wisdom-based learning module for medicinal plants, but did not address the importance of *Nepenthes* as an endangered endemic species (Khuzaimah et al., 2025). At the secondary school level, biodiversity education still faces various challenges, including low student understanding of the impacts of environmental damage and minimal concern for local endemic species. This situation is increasingly alarming due to the drastic decline in pitcher plant diversity in the Sibuatan Mountain area as a result of increasing environmental pollution and uncontrolled human activities. Despite the critical nature of this situation, there are currently no comprehensive and specific learning modules available that discuss the diversity of pitcher plants in the area, even though such modules are urgently needed as part of a conservation strategy through formal education. The absence of relevant learning modules results in a lack of knowledge transfer and awareness among the younger generation about the importance of preserving pitcher plant species, which are a unique biological asset of the region.

This study aims to develop a locally-based biology learning module on the diversity of pitcher plants *(Nepenthes sp.)* in Mount Sibuatan. The development of this module is designed to increase high school students' understanding and awareness of biodiversity conservation, particularly pitcher plants, which are endemic carnivorous plants whose existence is threatened. Through this module, it is hoped that students will not only gain theoretical knowledge but also develop an awareness of the importance of preserving various plant species in their surrounding environment.

LITERATURE REVIEW

Diversity of Nepenthes in Indonesia

Nepenthes is the largest genus of carnivorous plants. There are 39 species of *Nepenthes* recorded in Sumatra, 34 of which are endemic, making Sumatra the region with the highest diversity of *Nepenthes* species after Kalimantan (Mansur et al., 2023). This high diversity makes *Nepenthes* an interesting subject of study in the context of conservation and biological education. Previous research identified the types of *Nepenthes* found on Mount Sibuatan, particularly in Karo Regency, North Sumatra Province, through exploration methods (Tarigan & Ritonga, 2021). The results of this study provide important basic data on the diversity of *Nepenthes* species on Mount Sibuatan and serve as an initial reference for studies on the biodiversity of carnivorous plants in this region. *Nepenthes* has a wide geographic distribution and can adapt to various environmental conditions from lowlands to altitudes of 3,000 meters above sea level, including in tropical mountain ecosystems such as Mount Sibuatan (Gilbert et al., 2020). Biodiversity is the variation of life on Earth, including species, genetics, and ecosystems, thus making *Nepenthes* a clear example of adaptive evolution in complex ecological systems (Hong et al., 2022). Based on the researcher's review of these three references, it can be concluded that *Nepenthes* biodiversity research is not only important for taxonomic identification but also for supporting education and conservation based on local potential. The integration of field exploration data and biodiversity theory provides a more comprehensive understanding of the importance of preserving endemic species in the context of environmental change and the development of local teaching materials.

https://doi.org/10.64014/jik.v22i3.108

Ecology and Habitat of *Nepenthes*

Nepenthes are carnivorous plants with unique ecological characteristics and special adaptations to their habitats. As part of tropical rainforest ecosystems, *Nepenthes* typically grow in areas with nutrient-poor soils, such as peat, silica sand, or acidic sandy soils, necessitating alternative nutritional strategies through insect traps. *Nepenthes* have complex interactions with various arthropod species, both as a nutrient source and as part of a symbiotic relationship (Mansur et al., 2023). *Nepenthes* pitcher traps also provide microhabitats for specific organisms, including mosquitoes, spiders, and other insects, in some cases exhibiting mutualistic relationships. Previous research also revealed that *Nepenthes* species exhibit a wide range of environmental tolerances, found from lowlands to mountainous areas with elevations reaching 3,000 meters above sea level (Gilbert et al., 2020). This species thrives in areas with high humidity, moderate to high light levels, and relatively stable temperatures.

The results of an exploratory survey on Mount Sibuatan, particularly along the hiking trail at an altitude of 1,500 to 2,500 meters, indicate high floral diversity, including significant potential for the presence of various *Nepenthes* species (Tarigan & Ritonga, 2021). This area is an ideal habitat for *Nepenthes* due to a combination of topographic factors, microclimate, and soil conditions that support the growth of this endemic species. 3 Thus, a deep understanding of the ecology and habitat of *Nepenthes* is not only important for conservation aspects but also as a basis for developing locally-based teaching materials relevant to biology education at the secondary level.

Development of Biology Learning Modules

The development of biology learning modules in Indonesia has experienced rapid growth in the last five years. Research on the development of guided inquiry-based biology learning modules shows the importance of determining module characteristics, module feasibility, and responses from teachers and students (Prihatin et al., 2017). Analysis of trends in e-module development research in Indonesian biology education journals shows that Indonesia has produced extensive e-module educational resources (Almaas et al., 2025). The Merdeka Curriculum implemented in Indonesian schools allows teachers to create, select, and modify learning modules according to the context and needs of students (JPPI, 2024). This provides a great opportunity to develop learning modules that integrate local wisdom, such as the diversity of *Nepenthes*.

Local Potential-Based Learning

The development of biology learning modules that explore the potential of local biodiversity has shown good effectiveness. Research on the development of biology learning modules that explore the potential of plant diversity in South Kalimantan using the STEM-Project Based Learning model syntax has shown positive results (Nurtamara et al., 2023). A similar approach can be applied to develop modules on the diversity of *Nepenthes* in Mount Sibuatan. The development of a sustainable learning model based on Indonesian case studies shows the importance of integrating local contexts into learning (Simbolon, 2021). This supports the relevance of developing learning modules based on the diversity of *Nepenthes* as Indonesia's local biological wealth.

METHODS

The research method used in this study was the Research and Development (R&D) method with the ADDIE *(Analysis, Design, Development, Implementation, Evaluation)* development model. Data collection

https://doi.org/10.64014/jik.v22i3.108

was carried out in two main stages, namely exploration in Mount Sibuatan to classify *Nepenthes sp.* And the development of learning modules to be implemented at MAN Batubara at the high school level.

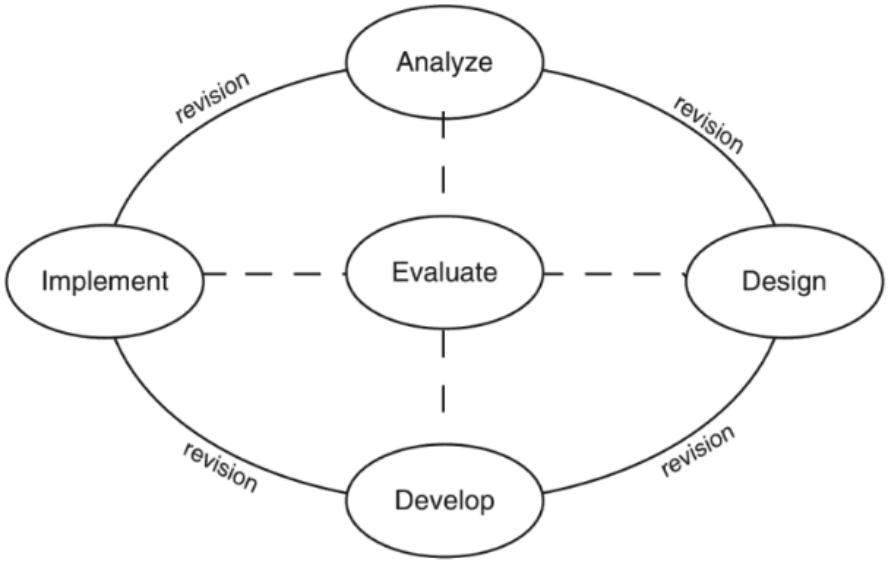

Figure 1. ADDIE Concept
Sumber: Branch in the book entitled "*Instructional design: The ADDIE approach*"

A description of each stage can be seen as follows.

1. **The analysis** stage, a needs analysis was conducted by identifying the diversity of pitcher plants on Mount Sibuatan and analyzing the curriculum and learning needs for Biology at the high school level. Field data collection was conducted using the exploration method to observe and document various *Nepenthes* species found along the Naga Lingga trail.
2. **The design** stage involves designing the framework for the learning module based on the field data that has been collected. At this stage, researchers design the systematic presentation of the material, determine the components of the module, and prepare the layout design that will be used in the printed module.
3. **The development** stage, two main tests are conducted. First, a validity test is conducted by subject matter experts and learning media experts using a validation sheet instrument. This validation sheet covers aspects of content feasibility, language, presentation, and graphics. Second, a practicality test is conducted using a 1-4 Likert scale questionnaire given to teachers and students in a limited trial. This questionnaire assesses aspects of ease of use, learning time efficiency, and module benefits.
4. **The implementation** stage focuses on testing the effectiveness of the learning module by administering learning outcome tests to students. The instruments used are pretest and posttest questions to measure students' understanding of the *Nepenthes* diversity material. Learning outcomes are evaluated by analyzing pretest and posttest scores to determine the improvement in student learning outcomes after using the module.
5. **The evaluation** stage is the final stage to assess the overall effectiveness of the developed learning module. At this stage, researchers analyze all data collected from the previous stages to determine the final quality of the product and its impact on learning.

The data collection instruments in this study included expert validation sheets, response questionnaires, and 10 multiple-choice test questions to measure learning outcomes. Data analysis was performed using descriptive quantitative techniques.

https://doi.org/10.64014/jik.v22i3.108

The results of the calculations from the validity and practicality tests were categorized according to the criteria listed in **Table 1**, which were used to ensure the quality of the instrument and ease of implementation in authentic contexts.

Table 1. Validity/Practicality Criteria

Score Range	Category	Description
25-40	Not Valid/Practical	Should not be used
41-55	Less Valid/Practical	Should not be used
56.00-70.00	Fairly Valid/Practical	May be used after major revision
71.00-85.00	Valid/Practical	May be used with minor revision
86.00-100.00	Very Valid/Practical	Very good to use

Source: Research 2025

The practicality data from the Likert scale questionnaire was analyzed by calculating the average score of the respondents' answers. The results of the calculation were then converted into practicality categories according to the criteria in **Table 1**.

The effectiveness data of the module was analyzed by comparing the pretest and posttest results using a normalized gain score (N-Gain) test to measure the improvement in student learning outcomes after using the learning module. The results of the N-Gain test are categorized based on the criteria in **Table 2** to measure the level of effectiveness of the module in improving student learning outcomes.

Table 2. Interpretation of the Gain Index

Coefficient Interval	Criteria
N-gain < 0.3	Low
0.3 ≤ N-gain < 0.7	Medium
N-gain ≥ 0.7	High

Source: Research 2025

RESULTS AND DISCUSSION

Analysis Stage

The analysis stage in this study was conducted through two main approaches, namely curriculum analysis and field diversity analysis (Ryan & Rashid, 2023). Exploratory methods were used to identify and document *Nepenthes* species along the Naga Lingga trail of Mount Sibuatan, resulting in the discovery of four different species with distinctive morphological characteristics. At the same time, curriculum analysis was conducted by reviewing the Merdeka Curriculum for high school biology, particularly the elements of biodiversity and ecosystems in phase E, to identify learning outcomes relevant to the material on endemic plant diversity, so that field findings could be integrated as a local learning context that supports students' understanding of taxonomy, adaptation, and conservation of Indonesia's biodiversity.

Curriculum analysis was conducted by reviewing the structure of the Merdeka Curriculum for high school biology, specifically the element “Biodiversity and Ecosystems” in phase E (grade 10), to identify learning outcomes that could be linked to findings on *Nepenthes* diversity. This analysis included mapping basic competencies on the classification of living things, genetic and species diversity, morphological and physiological adaptation, and biodiversity conservation issues, which are then adapted to the local context of North Sumatra through the integration of empirical data on endemic *Nepenthes* species as authentic

https://doi.org/10.64014/jik.v22i3.108

learning materials that support the Pancasila learner profile, particularly in the dimensions of critical thinking and environmental awareness.

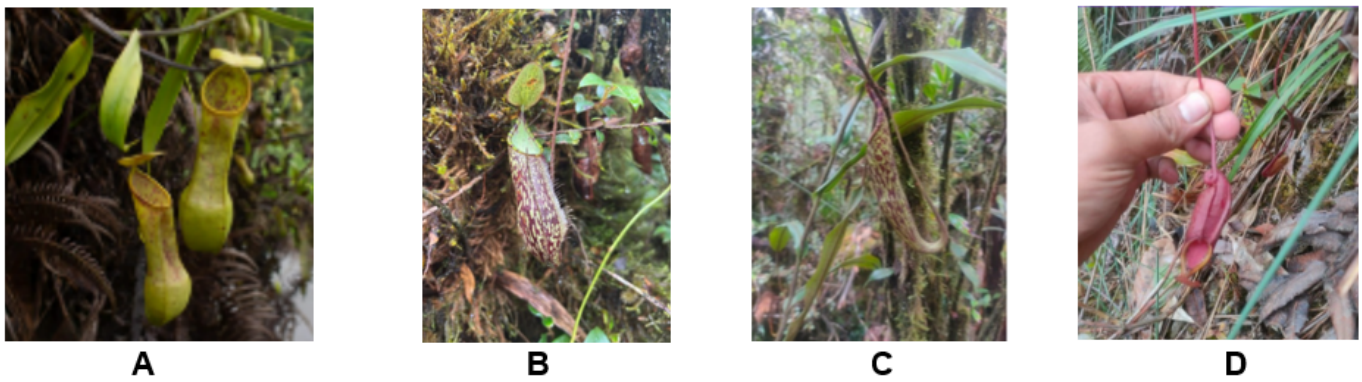

Figure 2. *Nepenthes* species found on Mount Sibuatan
(A*) Nepenthes tobaica* (B*) Nepenthes spectabilis* lower pitcher (C) *Nepenthes spectabilis* upper pitcher (D) *Nepenthes rhombicaulis*
Source: Author's documentation 2025

The analysis stage produced documentation of four species of *Nepenthes* identified on Mount Sibuatan, namely *Nepenthes* tobaica (A), which has cylindrical pouches with a yellowish-green color and rounded lids; *Nepenthes* spectabilis lower pouch (B), which has pink striped pouches and a rounder shape; *Nepenthes* spectabilis upper pitcher (C) with a slimmer shape and smooth surface, and *Nepenthes rhombicaulis* (D), characterized by reddish-colored pitchers and relatively small size. This morphological diversity reflects the specific adaptations of each species to the varying microclimatic conditions and elevations along the study route.

Design Stage

The design stage in this study was carried out by designing a learning module framework based on the findings of *Nepenthes* diversity on Mount Sibuatan using the Canva application in A4 paper format, which allows flexibility in layout design and integration of attractive visual elements (Irianti & Mahrudin, 2024). The design process involved determining the systematic presentation of materials, starting from the basic concepts of biodiversity, the morphological characteristics of *Nepenthes*, ecological adaptations, and conservation aspects, while integrating field documentation photos as authentic learning media. The module components are systematically designed to include a cover page with the module identity, an introductory page containing learning objectives and competencies to be achieved, main content presented with a layout combining informative text and high-quality images, and interactive learning activities that encourage students to analyze the morphological characteristics and phylogenetic relationships between *Nepenthes* species found.

https://doi.org/10.64014/jik.v22i3.108

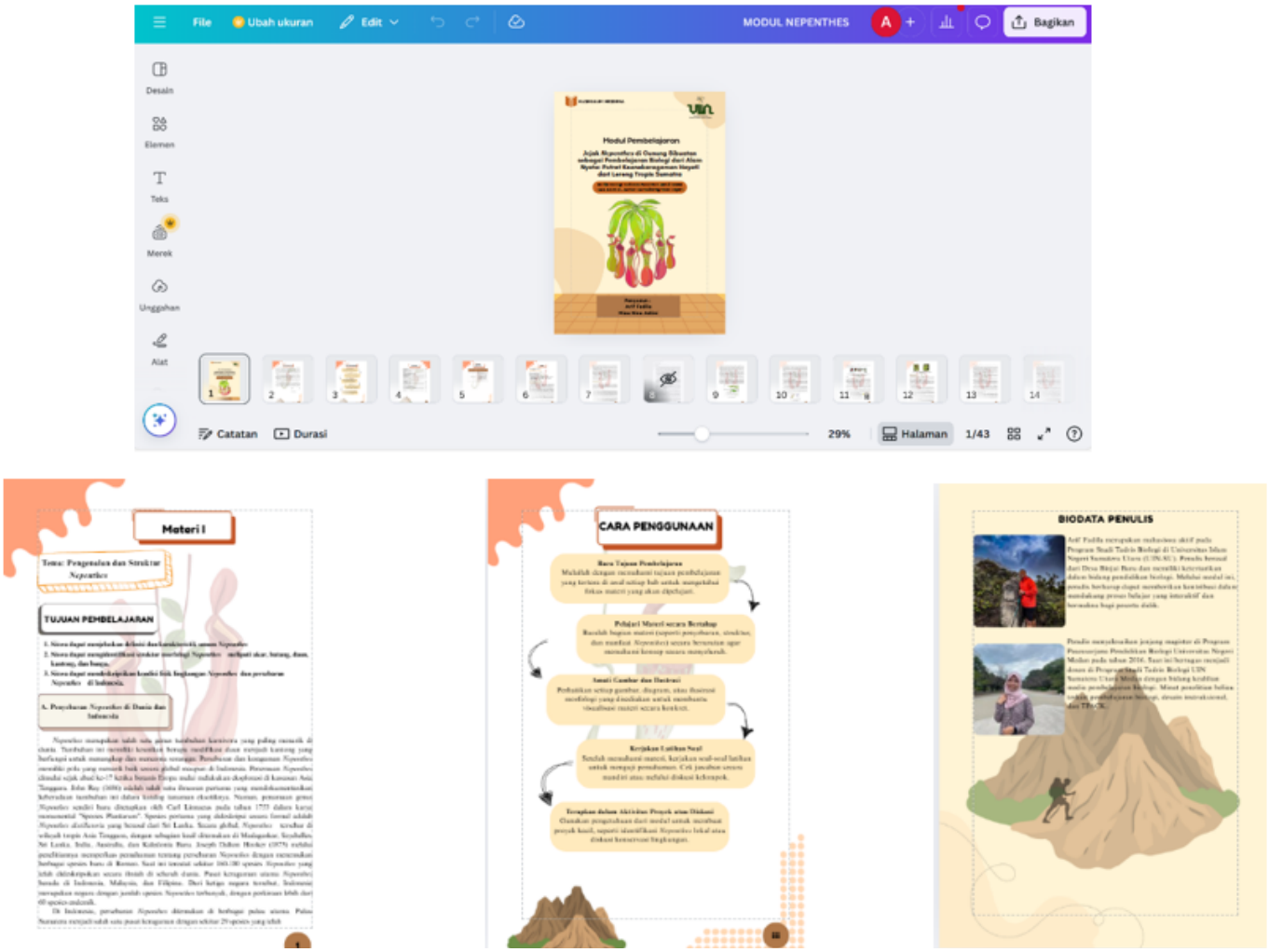

Figure 3. Module Display and Content in the Application
Source: Author's documentation 2025

Figure 3 shows the Canva application interface used in the learning module design process, which displays a workspace with various templates and design elements available for creating educational content. The Canva interface displays a toolbar on the left side containing various element options such as text, images, and graphics, while the main work area displays a preview of the module being developed with an A4 format layout that displays a combination of text and visuals about *Nepenthes*. Three preview panels at the bottom show different pages of the designed module, including an attractive cover page, a content page with detailed information about the *Nepenthes* species, and a page containing images and morphological descriptions, all of which are designed with consistent colors and typography that support the readability and visual appeal of the learning module.

Development Stage

The development stage is a crucial phase in the development of the *Nepenthes* learning module, involving a series of validations and tests to ensure product quality before implementation (Kadir et al., 2024). During this phase, three main evaluation processes are conducted: media expert validation, subject matter expert validation, and practical testing involving teachers and students as end-users. Each process provides constructive feedback for module improvements, resulting in a learning product that meets academic and practical standards for use in Biology education at the high school level.

https://doi.org/10.64014/jik.v22i3.108

Table 3. Comments and Suggestions from Validators

Validator	Validator Comments	Before Revision	After Revision
Media	Adjust the cover to match the content		
Material	Revise the material content		

Source: 2025 Research

Table 3 shows constructive input from both validators who provided specific directions for improving the learning module, where the media validator suggested adjusting the cover design to be more in line with the module content to create better visual cohesion. In contrast, the material validator recommended revisions to the substance of the learning material to be more comprehensive and in line with the expected learning outcomes. As seen in this table, which displays detailed “before” and “after” revision images, this feedback serves as the basis for improvements made by the researcher to enhance the quality of the module before conducting practical testing with end users.

Table 4. Results of Content and Media Expert Validation

Validator	Assessment Aspect	Statement Items	Score	Max Score	Validity Score (%)	Criteria
Media	Media Display	7	26	28	**94%**	**High**
	Programming Techniques	6	22	24		
	Usage Practicality	5	20	20		
	Total Score	**-**	**68**	**72**		
Material	Curriculum Compatibility (Merdeka)	5	20	20	**99%**	**High**
	Content Feasibility	7	27	28		
	Presentation Feasibility	5	20	20		
	Conceptual	6	24	24		
	Total Score	**-**	**91**	**92**		

Source: 2025 Research

https://doi.org/10.64014/jik.v22i3.108

Table 4 shows the highly satisfactory validation results from both experts with a high validity percentage, where the media expert gave a total score of 68 out of 72 (94%) with a “High” rating in the media display aspect (26/28), programming technical aspects (22/24), and practicality of use (20/20), indicating that the visual design and functionality of the module have met the expected quality standards. The subject matter expert validation yielded an even higher score of 91 out of 92 (99%) with a “High” category rating across all evaluation aspects, including alignment with the Merdeka Curriculum (20/20), content appropriateness (27/28), presentation appropriateness (20/20), and conceptual aspects (24/24), indicating that the module content is in line with the academic and pedagogical standards required to support learning based on local biodiversity.

Implementation Stage

The implementation phase is the phase of applying the *Nepenthes* learning module in a real-life learning context (Putir et al., 2022). This phase is carried out through three systematic stages to measure the effectiveness of the developed product. The first stage begins with a 10-question pretest administered to students to gauge their initial understanding of the material on *Nepenthes* diversity and related biodiversity concepts. This is followed by the distribution of the learning module to all participants for independent study. The second stage, conducted the following day, provides students with dedicated time to read and study the module's content in depth, enabling them to understand the morphological characteristics of various *Nepenthes* species, their ecological adaptations, and the taxonomic concepts presented through a local wisdom-based learning approach. The third stage, on the third day, involves administering a questionnaire to teachers and students to evaluate their perceptions of the module's effectiveness, ease of use, and impact on conceptual understanding. This provides comprehensive data on the product's implementability and usefulness in supporting the achievement of Biology learning objectives following the Independent Curriculum.

Evaluation Stage

The evaluation phase is a comprehensive assessment of the effectiveness and quality of the implemented *Nepenthes* learning module, using formative and summative evaluation approaches to analyze the learning impact achieved (Rahmawati et al., 2024). The evaluation was conducted through quantitative data analysis in the form of pretest and posttest results, as well as qualitative data from student and teacher questionnaire responses, to measure the product's success in achieving the established learning objectives.

Table 5. N-gain Results

Assessment	Average Score	Max Score	N-Gain Score (%)	Criteria
Pretest	49.4	100	71%	High/Effective
Posttest	85.2	100		

Source: 2025 Research

Based on the evaluation results shown in Table 5, the N-gain analysis revealed that the *Nepenthes* learning module achieved a very satisfactory level of effectiveness, with an N-gain score of 71%, which falls into the "High/Effective" category. The significant increase from an average pretest score of 49.4 to a posttest score of 85.2 demonstrates that the *Nepenthes* diversity-based learning approach successfully enhanced students' understanding of the concepts of taxonomy, morphology, and ecological adaptation of carnivorous plants with an optimal level of success.

https://doi.org/10.64014/jik.v22i3.108

These evaluation results confirm that the integration of local wisdom in the form of *Nepenthes* diversity on Mount Sibuatan into the learning module design not only effectively improved student academic achievement but also facilitated meaningful learning that fostered student awareness of the importance of conserving Indonesia's biodiversity. The high N-gain value indicates that the developed module met the criteria for good learning product quality and aligns with the Merdeka Curriculum standards in creating contextual, relevant learning experiences that positively impact the development of Pancasila students who are critical thinkers and environmentally conscious. This evaluation also indicates that the *Nepenthes* learning module product is worthy of wider implementation as an alternative learning resource to support the achievement of Biology learning competencies at the senior high school level.

Discussion

The needs analysis in this study revealed a pressing issue related to the decline in the diversity of pitcher plants *(Nepenthes sp.)* on Mount Sibuatan due to environmental pollution and uncontrolled human activities. Furthermore, there are no teaching materials specifically addressing the diversity of these endemic species to support biology learning at the high school level. This situation aligns with findings that more than 76% of *Nepenthes* species in Sumatra are endemic and face serious threats from illegal activities and deforestation (Mansur et al., 2023). Furthermore, it was confirmed that Indonesia is the global distribution center of *Nepenthes* with 79 species, or 43% of the total species worldwide, yet this potential has not been optimized in the context of formal education (Mansur et al., 2023). The discovery of four *Nepenthes* species identified along the Naga Lingga trail *(N. tobaica, N. spectabilis, and N. rhombicaulis)* highlights the region's significant potential as a natural laboratory for biodiversity education. However, the lack of knowledge transfer to younger generations through formal education remains a significant obstacle to sustainable conservation efforts.

The development of this local wisdom-based learning module successfully met very high validity criteria based on assessments by media experts (94%) and material experts (99%), indicating that integrating empirical field data with a systematic pedagogical approach can produce high-quality teaching materials aligned with the Merdeka Curriculum standards. These results align with research developing biodiversity modules with high levels of validity, as well as research emphasizing the importance of ethnobiology-based e-modules in achieving sustainable biodiversity conservation (Bariroh et al., 2024; Pary et al., 2025). The module design using the Canva application in A4 format allows for the presentation of comprehensive information on the morphological characteristics, ecological adaptations, and taxonomic aspects of various *Nepenthes* species through a combination of informative text and authentic visual documentation from field exploration results, thus providing a contextual and meaningful learning experience for high school students. This approach is supported by findings that developed character education-based biology learning media with high validity results on the immune system material, proving the effectiveness of integrating local content with modern learning methodologies (Damayanti, 2024). The success of this validation indicates that the development of teaching materials that integrate local biodiversity richness with the national curriculum framework can be an innovative model for improving the quality of science education in Indonesia.

The module implementation showed significant effectiveness with an N-gain value of 71% (high/effective criteria), where the increase in the average score from the pretest of 49.4 to the posttest of 85.2 indicates that the local biodiversity-based learning approach was able to improve students' conceptual understanding of Indonesian biodiversity substantially. This finding is consistent with previous research on the development of a STEM-PjBL-based module on exotic fruit biodiversity in South Kalimantan which showed high effectiveness in improving students' understanding of local biodiversity, as well as research that proved the potential of *Nepenthes* as an effective learning object with an optimal humidity level of 67-90% (Nainggolan et al., 2020; Nurtamara et al., 2023).

https://doi.org/10.64014/jik.v22i3.108

This success demonstrates that the utilization of local wisdom in the form of endemic *Nepenthes* species not only supports the achievement of academic competencies in line with the learning outcomes of the Independent Curriculum, but also contributes to developing the profile of Pancasila students who think critically and care about the environment, while also serving as an effective strategy to raise awareness of the younger generation towards conservation efforts for the unique biodiversity of North Sumatra which is threatened with extinction, as confirmed by recent research on the conservation status of *Nepenthes* in West Sumatra (Mansur et al., 2024). The positive implications of the results of this study underscore the importance of integrating local natural resources in educational curriculum design to create meaningful and sustainable learning.

CONCLUSION

Based on the research objective to develop a local wisdom-based biology learning module on the diversity of *Nepenthes* on Mount Sibuatan, the results obtained indicate that the module developed using the ADDIE model can effectively improve students' conceptual understanding of biodiversity through the integration of four endemic species *(N. tobaica, N. spectabilis, and N. rhombicaulis)* successfully identified on the Naga Lingga trail. This module has undergone a comprehensive validation process by media and material experts with a very feasible category, proving that the learning design based on empirical field data with a systematic pedagogical approach can produce high-quality teaching materials that are in accordance with the Merdeka Curriculum standards. Its implementation shows a significant increase in student learning outcomes with a high/effective N-gain category, confirming that contextual learning through the exploration of local biodiversity has a substantial positive impact on the achievement of academic competencies. These findings indicate that a local potential-based learning approach not only enriches teaching materials and increases the relevance of learning, but also fosters deep conservation awareness and shapes the profile of Pancasila students who are critical thinkers and care about the environment. It also proves that integrating local knowledge in the form of endemic *Nepenthes* species into the curriculum is a relevant, innovative, and impactful strategy in biodiversity education and efforts to preserve Indonesia's natural wealth through formal education. Based on the results of this study, there are several recommendations for further research that need to be considered. Future research should explore the diversity of *Nepenthes* in other geographic locations to enrich the database of endemic flora. Longitudinal research is needed to measure the long-term impact on students' conservation awareness. The development of an AR/VR-based digital platform is recommended to enhance the immersive learning experience. Comparative research on the effectiveness of local wisdom-based modules with conventional modules is needed. Integration of modules with interdisciplinary STEM learning is recommended for a holistic approach.

AUTHOR'S NOTE

The authors declare that there are no conflicts of interest related to the publication of this article. The authors confirm that the data and content of this article are free from plagiarism. We would like to express our deepest gratitude to all those who contributed to this research.

REFERENCES

Almaas, A. F., Paidi, P., Mualimin, M., & Prakarsa, T. B. P. (2025). Research trends e-module development in SINTA indexed Indonesian journal of Biology education 2: A literature review. *JPBI (Jurnal Pendidikan Biologi Indonesia), 11*(1), 326-335.

https://doi.org/10.64014/jik.v22i3.108

Aprianti, N., Arsyad, M., & Palloan, P. (2024). Development of independent curriculum teaching modules based on local wisdom to improve students'critical thinking skills. *Spektra: Jurnal Kajian Pendidikan Sains, 10*(2), 318-325.

Bariroh, G., Riandi, R., & Solihat, R. (2024). The potential of the Malabot Tumpe ethnobiology-containing e-module in realizing sustainable biodiversity conservation. *Bio-Inoved: Jurnal Biologi-Inovasi Pendidikan, 6*(2), 154-163.

Damayanti, A. (2024). Development of biology smart card learning media based on character education in immune system material. *Bio-Inoved: Jurnal Biologi-Inovasi Pendidikan, 6*(2), 179-190.

Gilbert, K. J., Bittleston, L. S., Naive, M. A. K., Kiszewski, A. E., Buenavente, P. A. C., Lohman, D. J., & Pierce, N. E. (2020). Investigation of an elevational gradient reveals strong differences between bacterial and eukaryotic communities coinhabiting Nepenthes phytotelmata. *Microbial Ecology, 80*(2), 334-349.

Hasmiati, H., Rukmana, M., Watung, F. A., & Agustina, T. P. (2023). Pengembangan modul Biologi berbasis potensi lokal Kabupaten Enrekang pada materi Plantae untuk siswa kelas X SMA. *Jurnal Biotek, 11*(1), 1-13.

Hidayat, T. (2024). Numerical taxonomy in school: Sustainability in biodiversity learning. *KnE Social Sciences, 2024*(1), 111-119.

Hong, P., Schmid, B., De Laender, F., Eisenhauer, N., Zhang, X., Chen, H., ... & Wang, S. (2022). Biodiversity promotes ecosystem functioning despite environmental change. *Ecology Letters, 25*(2), 555-569.

Irianti, R., & Mahrudin, M. (2024). Development of the popular scientific book of Nepenthes diversity in Tanta District forest areas, Tabalong regency: Validity and practicality. *Bio-Inoved: Jurnal Biologi-Inovasi Pendidikan, 6*(1), 105-111.

Kadir, N. A. H., Herinda, M., Ani, M. H., Dewi, W. K. B., Elya, N., Marini, S. H., & Ilyas, H. H. (2024). Pengembangan e-modul biologi berbasis Problem Based Learning (PBL) berbantuan aplikasi Canva pada materi perubahan lingkungan kelas x di SMA Negeri 1 Telaga Biru. *Jurnal Biogenerasi, 10*(1), 203-211.

Khuzaimah, S., Istiqomah, T., Hafizhah, M., & Elliza, S. (2025). Penerapan konsep ekoeduwisata berbasis sumber daya lokal sebagai inovasi pendidikan lingkungan di Taman Wisata Alam (TWA) Gunung Kelam Sintang Kalimantan Barat. *Edumedia: Jurnal Keguruan dan Ilmu Pendidikan, 9*(1), 31-43.

Mansur, M., Salamah, A., Mirmanto, E., & Brearley, F. Q. (2023). Diversity, ecology and conservation status of Nepenthes in West Sumatra Province, Indonesia. *Biotropia, 30*(2), 220-231.

Mansur, M., Salamah, A., Mirmanto, E., & Brearley, F. Q. (2024). Ecology of Nepenthes on Mount Talang, West Sumatra, Indonesia. *Tropical Ecology, 65*(3), 460-469.

Nainggolan, L., Gultom, T., & Silitonga, M. (2020). Inventory of pitcher plant (Nepenthes sp.) and its existence in North Sumatra Indonesia. *Journal of Physics: Conference Series, 1485*(1), 1-8.

Nurtamara, L., Noorhidayati, N., & Amintarti, S. (2023). The development of teaching module Biodiversity of exotic fruits plants of South Kalimantan based on STEM-PJBL for phase e students in senior high school. *Jurnal Penelitian Pendidikan IPA, 9*(2), 1346-1353.

Oikonomou, A., Stasinakis, P. K., Mavrikaki, E., & Pafilis, P. (2025). Greek Biology students' knowledge and perceptions of Natura 2000 protected areas. *Mediterranean Marine Science, 26*(1), 30-39.

https://doi.org/10.64014/jik.v22i3.108

Oliveira, A. P., Paramés, A., Bajanca, A., & Martinez-Perez, C. (2025). Higher education students' biodiversity knowledge. *Education Sciences, 15*(4), 1-16.

Pary, C., Keliata, F., Renngiwur, J., & Kurnia, T. S. (2025). Science module development problem-based learning for biodiversity in junior high school. *Jurnal Penelitian Pendidikan IPA, 11*(1), 545-550.

Prihatin, P., Prayitno, B. A., & Rinanto, Y. (2017). Pengembangan modul berbasis inkuiri terbimbing pada materi jamur untuk meningkatkan kemampuan berpikir kritis siswa kelas X SMA Negeri 1 Cepogo Boyolali. *Inkuiri: Jurnal Pendidikan IPA, 6*(1), 75-90.

Putir, P. E., Firdara, E. K., Nuwa, N., & JFS, A. (2022). Keanekaragaman jenis kantong semar (Nepenthes spp) di KHDTK Hutan Pendidikan Hampangen Universitas Palangka Raya. *Daun: Jurnal Ilmiah Pertanian dan Kehutanan, 9*(2), 177-187.

Putri, A., & Manalu, K. (2024). Development of a module based on Problem Based Learning (pbl) model and local potential as supporting biodiversity materials in senior high school of SMA Negeri 1 Natal. *Jurnal Pembelajaran dan Biologi Nukleus, 10*(2), 414-430.

Tarigan, M. R. I. M. A., & Ritonga, Y. E. (2021). Nepenthes di Gunung Sibuatan, Provinsi Sumatera Utara, Indonesia. *BioWallacea: Jurnal Penelitian Biologi (Journal of Biological Research), 8*(2), 123-133.

Rahmawati, S., Nurhikmah, H., & Muin, A. (2024). Development of web-based digital Mathematics modules grade VII SMPN 1 Watansoppeng. *Inovasi Kurikulum, 21*(2), 647-660.

Rawi, N. H. Z., & Shahrudin, R. (2021). Species richness and soil properties in Nepenthes habitat at Bris ecosystem in Setiu, Terengganu. *Universiti Malaysia Terengganu Journal of Undergraduate Research, 3*(4), 67-72.

Rizqiani, S., Ariyanti, N. S., & Sulistijorini. (2018). Diversity of lowland Nepenthes (pitcher plants) in Bangka Belitung Islands. *IOP Conference Series: Earth and Environmental Science, 197*(1), 1-8.

Ryan, S., & Rashid, M. (2023). Systematic review of diversity and curriculum improvement case studies: Lessons for inclusion and research instruction in library and information science programs. *In Proceedings of the ALISE Annual Conference, 1*(1), 1-19.

Setiawan, R. B. (2025). IBA-induced rooting in Nepenthes reinwardtiana Miq. cuttings for germplasm conservation. *Jurnal Agronomi Indonesia (Indonesian Journal of Agronomy), 53*(1), 72-79.

Simbolon, A. M. (2021). Education for sustainable development in Indonesia: Developing online sustainable development learning model based on Indonesian typical case studies. *Proceedings of the International Conference on Educational Sciences and Teacher Profession (ICETeP 2020), 532*(1), 43-49.

Straka, T. M., Glahe, C., Dietrich, U., Bui, M., & Kowarik, I. (2025). From nature experience to pro-conservation action: How generational amnesia and declining nature-relatedness shape behaviour intentions of adolescents and adults. *Ambio, 54*(7), 1165-1184.

Wong, C., Ling, Y. S., Wee, J. L. S., Mujahid, A., & Müller, M. (2020). A comparative UHPLC-Q/TOF-MS-based eco-metabolomics approach reveals temperature adaptation of four Nepenthes species. *Scientific Reports, 10*(1), 1-13.

Yudaputra, A., Astuti, I. P., Handayani, T., Siregar, H., Robiansyah, I., Wahyuni, S., ... & Cropper Jr, W. P. (2023). Comprehensive approaches for assessing extinction risk of endangered tropical pitcher plant Nepenthes talangensis. *Plos One, 18*(8), 1-21.

https://doi.org/10.64014/jik.v22i3.108