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Development Local Potential-Based Exploration Modules for Learning About Terrestrial Insect Diversity in High Schools

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ABSTRACT

This study aimed to analyze terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, and to develop a local potential–based learning module aligned with Phase E of the Merdeka Curriculum for Grade X biology. The research employed a research and development (R&D) design consisting of biodiversity data collection, module planning and design, expert validation, practitioner validation, and limited user testing. Empirical data on species composition, abundance, and ecological indices were transformed into structured learning materials integrating exploration activities, guided inquiry tasks, and reflective components. The module was validated by six subject-matter experts, six instructional design experts, two biology teachers, and Grade X students. The validation results indicated very high feasibility, with expert scores exceeding 87% and positive evaluations from teachers and students in terms of clarity, relevance, readability, and usability. These findings demonstrate that the module possesses strong content validity, instructional quality, and practical applicability in high school biology learning. In conclusion, integrating authentic local biodiversity data into contextual learning modules provides meaningful and pedagogically sound instructional materials, with potential for adaptation in other regions through local biodiversity-based contextualization.

Pengembangan Modul Eksplorasi Berbasis Potensi Lokal untuk Pembelajaran Keanekaragaman Serangga Darat di Sekolah Menengah Atas

ABSTRAK: *Penelitian ini bertujuan untuk menganalisis keragaman serangga darat di Laboratorium Pertanian Terpadu Jagan, Sukoharjo, dan mengembangkan modul pembelajaran berbasis potensi lokal yang selaras dengan Fase E Kurikulum Merdeka untuk mata pelajaran Biologi kelas X. Penelitian ini menggunakan desain penelitian dan pengembangan (R&D) yang meliputi pengumpulan data keanekaragaman hayati, perencanaan dan desain modul, validasi oleh ahli, validasi oleh praktisi, dan pengujian pengguna terbatas. Data empiris tentang komposisi spesies, kelimpahan, dan indeks ekologi diubah menjadi bahan pembelajaran terstruktur yang mengintegrasikan aktivitas eksplorasi, tugas penyelidikan terarah, dan komponen reflektif. Modul ini divalidasi oleh enam ahli materi pelajaran,* *enam ahli desain instruksional, dua guru biologi, dan siswa Kelas X. Hasil validasi menunjukkan kelayakan yang sangat tinggi, dengan skor ahli melebihi 87% dan evaluasi positif dari guru dan siswa terkait kejelasan, relevansi, keterbacaan, dan kegunaan. Temuan ini menunjukkan bahwa modul memiliki validitas konten yang kuat, kualitas instruksional, dan keterapan praktis dalam pembelajaran biologi di sekolah menengah atas. Kesimpulannya, integrasi data keanekaragaman hayati lokal yang autentik ke dalam modul pembelajaran kontekstual menyediakan bahan pembelajaran yang bermakna dan secara pedagogis sound, dengan potensi adaptasi di wilayah lain melalui kontekstualisasi berbasis keanekaragaman hayati lokal.*

INTRODUCTION

Terrestrial insects play a fundamental role in maintaining global ecosystem stability through their functions as pollinators, decomposers, components of food webs, and biological indicators of environmental change. These organisms contribute significantly to ecosystem services that support biodiversity, agricultural productivity, and ecological resilience (Abbasi, 2025; Barragán-fonseca et al., 2025). However, terrestrial insect diversity is currently facing unprecedented threats driven by habitat loss, land-use change, rapid urbanization, and climate change, which have led to declining insect populations across many regions worldwide (Farooq et al., 2025; Vaz et al., 2023). The ongoing reduction in insect diversity not only disrupts ecological balance but also underscores the urgent need to enhance biodiversity literacy through formal education, particularly at the secondary school level, where students begin to develop scientific understanding and environmental awareness (Efe & Efe, 2022; Fajri et al., 2025).

High school biology, in particular, represents a strategic educational level at which students begin to develop scientific reasoning, ecological understanding, and attitudes toward environmental sustainability (Al-barakat et al., 2025; Jackson et al., 2023). However, biodiversity instruction at the secondary school level often remains abstract and detached from students' immediate environments, limiting their ability to connect ecological concepts with real-world biological phenomena (Lestari et al., 2025; Murti et al., 2024). Strengthening biodiversity literacy through context-based and experiential biology learning is therefore essential to equip students with the knowledge, skills, and values needed to understand and respond to contemporary biodiversity challenges.

Despite the recognized importance of biodiversity literacy, the teaching of insect diversity in high school biology remains largely dominated by textbook-based instruction that emphasizes classification and theoretical descriptions rather than direct engagement with living organisms Such abstract approaches often limit students' opportunities to observe, investigate, and interpret insect diversity within their surrounding environments, resulting in superficial understanding and reduced interest in ecological topics (Audrin & Audrin, 2023; Christ et al., 2022; White et al., 2025). Consequently, students may struggle to develop essential scientific skills, such as observation, identification, and data interpretation, which are fundamental to biological inquiry. These limitations highlight the need for instructional strategies that move beyond conventional classroom-based learning toward more concrete and experiential approaches in teaching insect biodiversity (Lampert et al., 2025; Siregar et al., 2025).

The limited opportunities for students to directly observe and identify insects in natural environments further constrain the effectiveness of biodiversity learning in high school biology (Brown & White, 2024;

Klopčič & Torkar, 2025). Without hands-on experiences, students tend to perceive insect diversity as a set of disconnected facts rather than as dynamic components of living ecosystems. This lack of authentic engagement restricts the development of conceptual understanding and hinders the acquisition of essential science process skills, such as systematic observation, classification, and evidence-based reasoning, which are central to biological inquiry (Hamidah et al., 2024; Siregar et al., 2025). Moreover, insufficient exposure to real-world biodiversity contexts may weaken students' environmental awareness and sense of responsibility toward ecological conservation. When learning experiences fail to connect biological concepts with students' immediate surroundings, the relevance of biodiversity education becomes diminished, reducing students' motivation and ecological concern (Fajri et al., 2025; Id Babou et al., 2023; Nursidin et al., 2022).

Within the Indonesian educational context, the implementation of the Merdeka Curriculum emphasizes deep learning approaches that promote meaningful understanding, student autonomy, and contextual learning experiences, particularly in high school biology at Phase E, where biodiversity topics are introduced. However, preliminary observations conducted in a public high school in Sukoharjo indicate that classroom practices have not yet fully reflected these principles. Biology learning activities were found to be predominantly teacher-centered, with limited opportunities for student discussion, environmental exploration, or direct observation of local biological resources. Learning was largely focused on content delivery, with minimal integration of practical work or field-based activities, resulting in less meaningful learning experiences. Moreover, the instructional materials used were mainly standard Grade X biology textbooks and commercially published supplementary books that present biodiversity, ecosystem, and classification topics in a generalized and theoretical manner. Locally relevant biological data, such as information on terrestrial insect diversity and other region-specific organisms in Sukoharjo, as well as findings from local research, were rarely incorporated, highlighting a gap between curriculum expectations and the actual implementation of contextual and exploration-based biology learning. These challenges underscore the need for biology learning approaches that are contextual, authentic, and exploration-based, enabling students to actively engage with local biological resources and construct meaningful understanding through direct interaction with terrestrial insect diversity.

Previous studies in biology education consistently report that field-based learning and inquiry-based approaches are effective in improving students' understanding of biological concepts, particularly in biodiversity-related topics. Research has shown that learning experiences involving direct exploration of natural environments enable students to actively construct knowledge through observation, data collection, and scientific investigation. Moreover, inquiry-based learning supports the development of higher-order thinking and scientific reasoning skills by engaging students in questioning and evidence-based explanation, thereby reinforcing the pedagogical value of exploration-oriented approaches in secondary biology education.

In addition to experiential approaches, the integration of local potential or local biodiversity as a learning resource has gained attention in recent educational research. Learning activities that draw on students' immediate environments have been shown to increase the relevance and meaningfulness of biology instruction, as students are able to relate abstract concepts to observable biological phenomena. Within this context, learning modules function as effective instructional tools by providing structured guidance for exploration-based activities, supporting independent learning,

and ensuring alignment with learning objectives in secondary school biology.

Although prior research has demonstrated positive outcomes, existing studies still reveal notable limitations. Many learning modules remain generic and are not explicitly aligned with particular local ecosystems, limiting their potential to leverage local biodiversity as a learning resource. Moreover, relatively few studies have focused on terrestrial insects as primary objects of exploration, even though insects represent one of the most diverse and ecologically significant groups of organisms. This gap indicates a need for context-specific, exploration-based learning modules that systematically incorporate local terrestrial insect diversity into high school biology instruction.

Despite the documented effectiveness of field-based and local potential–based learning approaches, significant gaps remain in the development of biology learning modules that systematically integrate local terrestrial insect biodiversity into structured field exploration activities. In the Indonesian context, where the country is recognized as a global megabiodiversity hotspot, local biological resources are still underutilized in high school biology instruction. Learning environments such as the Integrated Agricultural Laboratory of Jagan, Sukoharjo, offer rich terrestrial insect diversity with strong potential as contextual learning resources; however, few existing modules are explicitly designed to leverage such local ecosystems while ensuring content validity, practical usability, and alignment with biology learning outcomes. This gap highlights the need for context-specific, empirically grounded exploration modules that connect biodiversity-rich local environments with meaningful and structured biology learning experiences.

To address these gaps, the present study offers a novel contribution through the development of a local potential-based exploration module that utilizes terrestrial insect diversity from the Jagan Sukoharjo area as a contextual learning resource for high school biology. The novelty of this study lies in the systematic integration of structured field exploration, insect identification activities, and inquiry-based reflective tasks within a single learning module designed to support meaningful and authentic learning experiences. Theoretically, this study enriches the framework for developing biology learning materials grounded in local biodiversity, while practically providing a contextual and adaptable module that can be replicated in other regions by aligning learning activities with locally available biological resources.

Accordingly, this study aims to 1) How is the terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, characterized as core content for the development of a local potential–based learning module? 2) design a local potential-based exploration module for learning about terrestrial insect diversity in high school biology, 3) evaluate the feasibility of the developed module through expert validation involving biology education specialists, as well as practical assessments by high school biology teachers and students. The findings of this study are expected to contribute to biology education by providing empirically validated, context-based instructional materials that enhance biodiversity learning, while also fostering awareness of local biological resources and supporting conservation-oriented education through formal schooling.

METHOD

This study employed a Research and Development (R&D) design to develop and evaluate a local potential–based exploration module on terrestrial insect diversity for high school biology. The development procedure was adapted from the Borg and Gall model (Borg & Gall, 1983) and modified into seven stages following (Nugroho, 2017; Safitri & Nugroho, 2025): (1) Research and information collecting: literature review and

a field study. The literature review examined relevant theories and curriculum requirements, while the field study identified the local potential of terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, which served as the empirical basis for the module content. (2) Planning: planning the learning objectives, determining the main topics and instructional content, designing the structure and components of the learning module, and selecting validators, including subject-matter experts, educational practitioners (biology teachers), and student users for product evaluation. (3) Develop preliminary form of product: developing the initial draft of a local potential-based terrestrial insect diversity learning module. (4) Preliminary field testing: content feasibility was evaluated through expert validation involving subject-matter experts and module design experts. (5) Main product revision: the module was revised based on feedback from expert validators. (6) Main field testing: practical validation was conducted by biology teachers and Grade X high school students. and (7) Operational product revision: The module was revised based on the results of practitioner and user evaluations. The modification was undertaken to enhance feasibility within the scope and timeframe of the study, as the original stages of dissemination and large-scale implementation require extended resources and were beyond the primary objective of this research, which focused on product development and feasibility evaluation at a limited scale. Despite this adjustment, the essential principles of R&D methodology were maintained. The study was conducted from March to August 2025. The detailed stages of the module development process are illustrated in Figure 1.

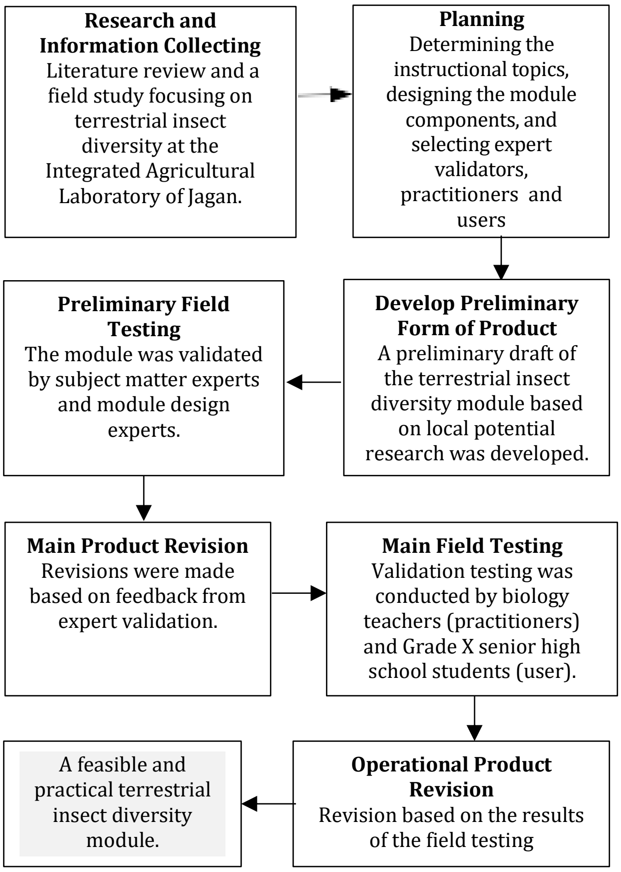

Figure 1. Research Procedure.

This study employed two data analysis techniques. First, qualitative descriptive analysis was used to interpret feedback obtained from the material experts, module design experts, biology teachers, and students during the initial product validation and limited field testing stages. The qualitative data consisted of comments, suggestions, critiques, and recommendations provided in the validation instruments, which were categorized and analyzed to inform product revision. Second, descriptive percentage analysis was applied to analyze quantitative data derived from the validation instruments (Rita T. Marpaung et al., 2025; Setiawan et al., 2024; Villamin et al., 2025; Zipser et al., 2025).

The module was evaluated by six validators, comprising subject-matter experts and module design experts holding master's degrees, as well as two professional biology teachers with a minimum of five years of teaching experience in insect-related biology topics. In addition, user validation

was conducted involving 25 Grade X high school students in Sukoharjo. The quantitative scores provided by the experts and practitioners were analyzed to determine the level of feasibility of the module by calculating the percentage of achievement across the assessed aspects. The feasibility criteria were determined using the formula adapted from Safitri & Nugroho (2025):

$N=\frac{k}{Nk} \times 100\%$

Where:

N = percentage score for each assessed aspect;

k = total score obtained;

Nk = maximum possible score.

The feasibility criteria of the module are presented in Table 1.

Table 1. Module Feasibility Criteria

Score Range (%)	Feasibility Criteria
0-20	Very Infeasible
21-40	Infeasible
41-60	Moderately Feasible
61-80	Feasible
81-100	Very Feasible

RESULTS AND DISCUSSION

This study began with a research and information-gathering phase that included a literature review and field observations. The field study conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, recorded a total of 641 terrestrial insect individuals representing various taxa. Several groups, including mosquitoes, grasshoppers, crickets, and ants, showed relatively high abundances, indicating their adaptability to the local environment, while other taxa were represented by fewer individuals, reflecting variation in species distribution within the habitat. Overall, the calculated ecological indices indicated a moderate level of species diversity and richness, with uneven species distribution but no single taxon exhibiting strong dominance, suggesting a relatively stable and heterogeneous terrestrial insect community.

The use of locally generated biodiversity data offers greater educational value than generic instructional materials because it provides epistemically authentic and contextually meaningful learning experiences (Niemiller et al., 2021; Prasetyo et al., 2025; Yli-Panula et al., 2018). By engaging with real ecological data from their immediate environment, students are able to connect abstract biodiversity concepts such as species diversity, population structure, and ecological balance with observable phenomena, thereby strengthening conceptual understanding and environmental awareness (Mason et al., 2025; Oliveira et al., 2025). This contextual integration aligns with deep learning principles, which emphasize higher-order thinking, inquiry, and reflective reasoning, and ensures that biodiversity learning is not limited to memorization but grounded in analysis and interpretation of real ecological patterns (Saputri et al., 2026; Wafa Taqiyya et al., 2025).

In this study, these empirical findings were utilized as core content in the development of a local potential–based terrestrial insect diversity learning module. Information on species composition, abundance, and ecological indices was systematically transformed into instructional materials aligned with the principles of the Merdeka Curriculum, particularly the deep learning approach implemented in Phase E (Grade X) biodiversity topics. The module incorporates authentic local research data into structured learning activities such as insect identification, ecological index analysis, data interpretation, and guided inquiry tasks encouraging students to construct conceptual understanding through observation, investigation, and reflection. By explicitly connecting biodiversity concepts with real ecological conditions in their immediate environment, the module promotes meaningful learning, strengthens scientific reasoning and higher-order thinking skills, and fosters environmental awareness consistent with the learning

outcomes of Phase E biology. (Azmi et al., 2023; Lema & Dewi, 2023).

After obtaining content materials derived from local potential–based terrestrial insect diversity data at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, the study proceeded to the planning stage (Islamiati et al., 2024; Salmia et al., 2024). This stage involved defining the learning outcomes and instructional objectives to be addressed in the module, designing the structure and key components of the learning module, and selecting expert validators to participate in the validation process. The local potential–based terrestrial insect module was developed for Grade X high school students and aligned with the biology learning outcomes of Phase E in the Merdeka Curriculum. Accordingly, the learning indicators embedded in the module were formulated to support deep learning through exploration-based activities, data analysis, and reflective tasks grounded in local biodiversity contexts. This terrestrial insect diversity module uses the following success indicators: 10.1 Analyze various levels of insect diversity and their role in the surrounding environment, along with threats and conservation, 10.2 Conduct observational research on various levels of insect diversity and their role in the surrounding environment by comparing insect diversity data from various regions in Indonesia from relevant sources, 10.3 Identify terrestrial insect species, analyze research data, calculate various ecological indices (Shannon-Wiener, Dominance Index, Evenness Index), and draw conclusions. 10.3 Identifying terrestrial insect species, analyzing research data, calculating various ecological indices (Shannon-Wiener, Dominance Index, Evenness Index), and drawing conclusions about ecosystem conditions based on insect diversity analysis results.

The module structure was designed in a systematic and comprehensive manner, encompassing an introductory section, core instructional content, presentation of identified local potential, student worksheets, observation activities, evaluation instruments, a concluding section, and references. Each component was developed to integrate conceptual knowledge with empirical research data, thereby supporting exploratory and contextual learning experiences. In the final stage of the planning process, validators were selected to assess the feasibility of the module, consisting of six subject-matter experts, six instructional media or module design experts, two biology teacher practitioners, and 25 Grade X high school students as users in a limited-scale trial. The involvement of these diverse stakeholders aimed to ensure that the developed module met content validity, presentation quality, readability, and instructional effectiveness criteria for high school biology learning (Homillano, 2023; Ula et al., 2025). Following the completion of the planning stage, the study proceeded to the development of the initial module prototype as the basis for subsequent validation and revision.

The design of the terrestrial insect module based on local potential at the Jagan Integrated Agricultural Laboratory, Sukoharjo, was developed with reference to the principles of systematic, contextual teaching material development that is in line with the characteristics of the students. This approach is in line with the findings of research on the development of modules based on local potential, which have been reported to have a high level of validity and effectiveness in supporting biology learning (Azmi et al., 2023; Wahyuni et al., 2025). The developed module draft was subsequently organized and formatted into a structured and user-friendly learning module to facilitate its implementation in instructional activities, as illustrated in Figure 2-7.

Figure 2. Cover

Figure 3. Instructions for use

Figure 4. Lesson Plan

Figure 5. Material

Figure 6. Worksheet Based on Local Potential

Figure 7. Evaluation

Based on Figures 2–7, the developed module demonstrates a systematic and comprehensive structure, incorporating key instructional components such as usage guidelines, lesson planning, local potential–based content, student worksheets, and evaluation activities. The integration of empirical findings on terrestrial insect diversity from the Integrated Agricultural Laboratory of Jagan, Sukoharjo into the instructional materials reflects the implementation of authentic and exploration-based contextual learning. This module structure supports deep learning through inquiry, data analysis, and reflective activities, thereby enhancing students' conceptual understanding, science process skills, and environmental awareness in high school biology learning (Mettis & Väljataga, 2022; Sudarmi et al., 2024). Subsequently, the developed module was validated by six expert validators to assess the feasibility of the content and instructional design aspects, prior to practitioner (teachers) and user (students) validation. The content evaluation aspects included the quality of learning components, the adequacy of the instructional content, and the presentation and design of the module. The results of the

content validation conducted by subject-matter experts are presented in Table 2.

Table 2. Results of the evaluation of material validity

Validator	Percentage Score (%)	Criteria
1	94,17	Very Feasible
2	96,67	Very Feasible
3	95,00	Very Feasible
4	90,83	Very Feasible
5	87,50	Very Feasible
6	96,67	Very Feasible
Average	93,47	Very Feasible

The results of the material validation conducted by six experts indicate that the developed module demonstrates a very high level of feasibility. The percentage scores ranged from 87.50% to 96.67%, with all validators categorizing the module as very feasible. The highest score of 96.67% was awarded by the second and sixth validators, while the lowest score of 87.50% still fell within the very feasible category. These findings suggest that the module content is scientifically accurate, conceptually appropriate, and aligned with the learning objectives of high school biology. Furthermore, the relevance of the material to instructional needs and the clarity of its presentation indicate that the module meets content feasibility standards.

The terrestrial insect module based on local potential was subsequently validated by experts in biology instructional design to evaluate the quality of its structure and presentation. The validation process encompassed several aspects, including objectives and integration, module content, module presentation, learning and implementation, ethics, safety, and field context. The results of the module validity evaluation are presented in Table 3.

Table 3. Results of the evaluation of learning module validity

Validator	Percentage Score (%)	Criteria
1	93,18	Very Feasible
2	96,59	Very Feasible
3	94,32	Very Feasible
4	93,18	Very Feasible
5	87,50	Very Feasible
6	90,91	Very Feasible
Average	92,61	Very Feasible

The results presented in Table 3 demonstrate that the learning module achieved a very high level of validity based on evaluations by six expert validators. All validators assigned percentage scores above 87%, ranging from 87.50% to 96.59%, which consistently fall within the very feasible category. This classification aligns with the criteria proposed by Safitri & Nugroho (2025), who categorize scores within the range of 81–100 as indicating very high feasibility. The consistently high scores reflect strong agreement among experts regarding the quality of the module's instructional design, content organization, visual presentation, and adherence to ethical and copyright standards. These findings further indicate that the module meets established instructional quality criteria and possesses adequate content quality and pedagogical design to support effective implementation in high school biology learning, consistent with previous studies (Husna et al., 2021; Suwandi et al., 2024).

Overall, the results of the subject-matter expert and instructional module expert validations indicate that the validation process contributed substantially to improving the quality and strengthening the validity of the module for instructional use in biology learning. Throughout the expert validation process, constructive feedback and recommendations were provided to refine the local potential-based terrestrial insect module. Systematic revisions were subsequently implemented by incorporating suggestions from both content and module design experts prior to practitioner (teacher) and user (student) validation. Details of the revisions and adjustments made based on the subject-matter experts' feedback are presented in Table 4.

Table 6. Suggestions and Improvements from Subject Matter Experts and Modules

Suggestions	Improvements
Subject Matter Experts	
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.
Only corrections to the typing, there are some words with incorrect letters (typos) and inaccuracies.	Correct typos and inaccuracies. For example, "di bawah" on page 18 should be "di bawah," 'jagan' on page 29 should be "Jagan," etc.
Images should be of good resolution so that they are not unclear, broken, or blurred.	Improve images with good resolution so that they appear clear. Refer to pages 23-27.
It would be good to add illustrations of insects to the material, then check again whether the evaluation measures all learning objectives.	Add illustrations of insects to the material referring to pages 6-7 and 30-36.
Modules Experts	
Clearer instructions for use are needed.	Correct the module usage instructions on page 7.
Implementation for learning does not yet exist.	Add implementation for learning to the module on page 36.
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.

The suggestions provided by subject-matter experts and module design experts, as summarized in Table 6, indicate that the revisions primarily focused on enhancing scientific accuracy, instructional clarity, and visual quality of the module. Recommendations such as the inclusion of Latin names for each insect species, correction of typographical errors, and improvement of image resolution were essential for strengthening content accuracy and scientific rigor. These revisions ensure that the module meets academic standards in biology learning and supports precise conceptual understanding (Fahmi et al., 2025; Foster et al., 2014).

In addition, feedback from module design experts emphasized the need for clearer usage instructions and the inclusion of explicit learning implementation guidance. The incorporation of these suggestions improved the module's usability and instructional coherence, thereby enhancing its practicality for classroom application. Overall, the revisions addressed both content and design aspects, reinforcing the validity and feasibility of the module and ensuring its readiness for subsequent validation by practitioners and users.

After undergoing expert validation, the terrestrial insect diversity module was subsequently evaluated through practitioner validation involving two biology teachers, as well as user validation conducted with tenth-grade senior high school students who had previously studied insect diversity material. This validation aimed to obtain both qualitative and quantitative evaluations of the main product, namely the local potential-based terrestrial insect diversity module. The results of the validity assessment conducted by the biology teachers are presented in Table 7.

Table 7. Results of Validity Testing by practitioner validity

Practitioners	Percentage Score (%)		Criteria
	Module	Content	
1	89,77	93,30	Very Feasible
2	85,23	81,67	Very Feasible
Average	87,50	87,50	Very Feasible

The results of the practitioner validation presented in Table 7 indicate that the terrestrial insect diversity module achieved a high level of feasibility. Both biology teachers assigned percentage scores above 85% for the module and content aspects, with average scores of 87.50% for

each, placing the module in the very feasible category. These findings suggest that, from the practitioners' perspective, the module is pedagogically appropriate, systematically organized, and contextually relevant for classroom implementation in high school biology learning (Indah et al., 2022; Ravista et al., 2021; Solfitri et al., 2024). The strong ratings across both instructional design and content dimensions demonstrate that the module not only meets theoretical feasibility standards but also possesses practical value in real classroom settings. Specifically, the clarity of learning objectives, coherence of content structure, integration of local potential, and alignment with curriculum demands contribute to its ease of use and instructional effectiveness.

These results are consistent with previous module development studies reporting that well-structured, context-based instructional materials tend to be perceived by teachers as practical, efficient, and supportive of classroom management (Faizal et al., 2023; Janssen et al., 2014). The high level of agreement among practitioners therefore reinforces the module's practicality and confirms its readiness for broader implementation. Based on this strong practitioner endorsement, the module was subsequently considered appropriate for further evaluation through user validation involving Grade X high school students. This stage aimed to examine its readability, usability, and capacity to foster student engagement during learning activities, with the results of the student validation presented in Table 8.

Table 8. Results of Validity Testing by Student

Students	Percentage Score (%)	Criteria
1	87,66	Very Feasible
2	96,06	Very Feasible
3	89,32	Very Feasible
4	92,01	Very Feasible
5	97,35	Very Feasible
6	92,69	Very Feasible
7	90,72	Very Feasible
8	89,02	Very Feasible
9	96,52	Very Feasible
10	94,51	Very Feasible
11	97,35	Very Feasible
12	92,88	Very Feasible
13	93,83	Very Feasible
14	98,03	Very Feasible
15	100,00	Very Feasible
16	94,55	Very Feasible
17	94,81	Very Feasible
18	92,96	Very Feasible
19	98,34	Very Feasible
20	96,21	Very Feasible
21	96,37	Very Feasible
22	97,05	Very Feasible
23	96,06	Very Feasible
24	98,60	Very Feasible
25	98,18	Very Feasible
Average	94,96	Very Feasible

The user validation results presented in Table 8 demonstrate that the terrestrial insect diversity module achieved a very high level of feasibility from the students' perspective. All 25 Grade X students assigned scores exceeding 87%, with an average score of 94.96%, consistently categorizing the module as very feasible**.** These findings indicate that the module is highly readable, user-friendly, and engaging, effectively supporting students' understanding of insect diversity concepts through exploration-based learning activities. These results are consistent with previous studies which report that instructional modules grounded in contextual and locally relevant content enhance students' conceptual understanding, motivation, and learning engagement, particularly in biology education settings (Montgomery et al., 2024).

The consistently high validation scores suggest that the module successfully facilitates student engagement, comprehension, and independent learning. Nevertheless, both practitioner and user validations also generated constructive suggestions aimed at further improving

clarity, presentation, and learning activities. Accordingly, the module was revised by incorporating feedback from biology teachers and students to enhance its overall quality and instructional effectiveness prior to finalization. The suggestions and revisions provided by the teachers and students are presented in Table 9.

Table 9. Suggestions and Improvements from teachers and Studenst

Suggestions	Improvements
Teachers	
Only corrections to the typing, there are some words with incorrect letters (typos) and do not yet comply with the rules of writing.	Correcting misspelled words (typos) and correcting them according to writing rules. For example, pitfall trap becomes pitfall trap, Density becomes Density.
Improve images with poor resolution/ blurring.	Improve the image with good resolution so that the image appears clear on pages 23-27.
Add the latest scientific references on insect diversity.	Add the latest scientific references regarding insect diversity to Chapter I.
Include a section for assessing student observation results.	Include a section for assessing student observation results.
Students	
More interesting illustrations are needed. The image quality needs to be improved to make it clearer.	Adding more interesting illustrations and improving image quality for greater clarity.

The suggestions and improvements summarized in Table 9 indicate that feedback from both teachers and students primarily focused on enhancing the technical accuracy, visual quality, and instructional completeness of the module. Recommendations related to correcting typographical errors, improving image resolution, updating scientific references, and adding sections for assessing student observation assessment contributed to strengthening the module's clarity, scientific rigor, and pedagogical coherence. Feedback from students further emphasized the importance of engaging and high-quality visual elements to support comprehension and learning interest. These findings are consistent with research by Ita (2024) and Shiyamsyah et al. (2024) , which emphasizes that iterative formative evaluation involving experts, practitioners, and users plays a crucial role in improving the quality, practicality, and validity of educational products. Their studies demonstrate that systematic revisions based on stakeholder feedback significantly enhance instructional effectiveness and usability.

Accordingly, the revisions were systematically incorporated to refine the final version of the local potential–based terrestrial insect diversity module. Following this stage of revision based on practitioner and user feedback, the research was concluded, as the study was limited to the development and feasibility evaluation phases and did not proceed to large-scale implementation or effectiveness testing. The final module is characterized by its integration of authentic local biodiversity data, structured exploration activities, guided inquiry tasks, and reflective learning components that support conceptual understanding and scientific reasoning. These characteristics strongly support contextual learning, as students engage directly with ecological data derived from their immediate environment, a strategy widely recognized for enhancing meaningful learning and biodiversity literacy (Lampert et al., 2025; Montgomery et al., 2024).

Compared to conventional biology textbooks that often present decontextualized and generalized content, this module offers greater relevance, learner engagement, and instructional clarity by linking abstract concepts to observable ecological phenomena, consistent with findings from prior module development studies (Bermudez & Krell, 2025; Diduck et al., 2020). Furthermore, although grounded

in the local context of the Jagan Integrated Agricultural Laboratory, the modular design and development framework allow the instructional structure to be replicated in other regions through adaptation to locally available biodiversity resources, as recommended in design-based research and local potential–based learning studies (Ijatuyi et al., 2025; Purwasih et al., 2025; Zidny et al., 2020).

The implications of this study indicate that integrating locally generated ecological research into high school biology modules can serve as a strategic model for strengthening biodiversity education and bridging the gap between scientific inquiry and classroom instruction. Such an approach aligns with research emphasizing the importance of place-based and context-responsive education in fostering environmental literacy, critical thinking, and student engagement (Ardoin et al., 2020; Rosyidah et al., 2025). Nevertheless, several limitations must be acknowledged. The study was restricted to the development and feasibility evaluation stages and did not include experimental testing to measure the module's effectiveness in improving learning outcomes, higher-order thinking skills, or long-term retention. In addition, the implementation was conducted within a single institutional and ecological context, which may limit broad generalization without contextual adaptation. Therefore, future research should involve quasi-experimental or experimental designs to examine comparative effectiveness against conventional textbooks, as well as longitudinal studies to evaluate impacts on biodiversity literacy and environmental attitudes. Replication studies across different ecological regions are also recommended to further test the scalability and adaptability of the local potential–based module development framework, consistent with recommendations in design-based research literature (McKenney & Is, 2019; Plomp & Nieveen, 2013).

CONCLUSIONS AND SUGGESTION

This study successfully characterized terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo and utilized the empirical findings as core content for developing a local potential–based exploration module for high school biology. The developed module demonstrated very high feasibility based on expert validation, practitioner evaluation, and user responses, indicating strong content quality, instructional design, practicality, and readability. These results confirm that integrating authentic local biodiversity data into structured, inquiry-oriented learning materials supports contextual and meaningful biology learning at the senior high school level. The findings imply that local potential–based modules can serve as effective alternatives to conventional textbooks by enhancing relevance, student engagement, and scientific reasoning. Future research is recommended to examine the effectiveness of the module through experimental implementation and to replicate the development framework in other ecological contexts to further test its scalability and impact on biodiversity literacy.

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anwari adi nugroho <anwaribio@gmail.com>

Your submission has been sent for review

1 pesan

Eka Wulandari <ejournal@radenintan.ac.id> 26 April 2026 pukul 08.21
Kepada: Anwari Adi Nugroho <anwaribio@gmail.com>

Dear Anwari Adi Nugroho,

I am pleased to inform you that an editor has reviewed your submission, Development Local Potential-Based Exploration Modules for Learning About Terrestrial Insect Diversity in High Schools, and has decided to send it for peer review. An editor will identify qualified reviewers who will provide feedback on your submission.

This journal conducts double-anonymous peer review. The reviewers will not see any identifying information about you or your co-authors. Similarly, you will not know who reviewed your submission, and you will not hear from the reviewers directly. You will hear from us with feedback from the reviewers and information about the next steps.

Please note that sending the submission to peer review does not guarantee that it will be published. We will consider the reviewers' recommendations before deciding to accept the submission for publication. You may be asked to make revisions and respond to the reviewers' comments before a final decision is made.

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12-05-2026 07:44

Dear Anwari Adi Nugroho,

Your submission Development Local Potential-Based Exploration Modules for Learning About Terrestrial Insect Diversity in High Schools has been reviewed and we would like to encourage you to submit revisions that address the reviewers' comments. An editor will review these revisions and if they address the concerns adequately, your submission may be accepted for publication.

The reviewers' comments are included at the bottom of this email. Please respond to each point in the reviewers' comments and identify what changes you have made. If you find any of the reviewer's comments to be unjustified or inappropriate, please explain your perspective.

When you have completed your revisions, you can upload revised documents along with your response to the reviewers' comments at your submission dashboard. If you have been logged out, you can login again with the username anwariadinugroho.

If you have any questions, please contact me from your submission dashboard.

We look forward to receiving your revised submission.

Kind regards,

Laila Puspita

The following comments were received from reviewers.

Reviewer 1:
Recommendation: Revisions Required

Reviewer 2:
Recommendation: Revisions Required

Gmail

anwari adi nugroho <anwaribio@gmail.com>

Your submission has been reviewed and we encourage you to submit revisions

1 pesan

Laila Puspita <ejournal@radenintan.ac.id> 12 Mei 2026 pukul 07.44
Kepada: Anwari Adi Nugroho <anwaribio@gmail.com>

Dear Anwari Adi Nugroho,

Your submission Development Local Potential-Based Exploration Modules for Learning About Terrestrial Insect Diversity in High Schools has been reviewed and we would like to encourage you to submit revisions that address the reviewers' comments. An editor will review these revisions and if they address the concerns adequately, your submission may be accepted for publication.

The reviewers' comments are included at the bottom of this email. Please respond to each point in the reviewers' comments and identify what changes you have made. If you find any of the reviewer's comments to be unjustified or inappropriate, please explain your perspective.

When you have completed your revisions, you can upload revised documents along with your response to the reviewers' comments at your submission dashboard. If you have been logged out, you can login again with the username anwariadinugroho.

If you have any questions, please contact me from your submission dashboard.

We look forward to receiving your revised submission.

Kind regards,

Laila Puspita

The following comments were received from reviewers.

Reviewer 1:
Recommendation: Revisions Required

Reviewer 2:
Recommendation: Revisions Required

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ABSTRACT

This study aimed to analyze terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, and to develop a local potential–based learning module aligned with Phase E of the Merdeka Curriculum for Grade X biology. The research employed a research and development (R&D) design consisting of biodiversity data collection, module planning and design, expert validation, practitioner validation, and limited user testing. Empirical data on species composition, abundance, and ecological indices were transformed into structured learning materials integrating exploration activities, guided inquiry tasks, and reflective components. The module was validated by six subject-matter experts, six instructional design experts, two biology teachers, and Grade X students. The validation results indicated very high feasibility, with expert scores exceeding 87% and positive evaluations from teachers and students in terms of clarity, relevance, readability, and usability. These findings demonstrate that the module possesses strong content validity, instructional quality, and practical applicability in high school biology learning. In conclusion, integrating authentic local biodiversity data into contextual learning modules provides meaningful and pedagogically sound instructional materials, with potential for adaptation in other regions through local biodiversity-based contextualization.

Pengembangan Modul Eksplorasi Berbasis Potensi Lokal untuk Pembelajaran Keanekaragaman Serangga Darat di Sekolah Menengah Atas

ABSTRAK: *Penelitian ini bertujuan untuk menganalisis keragaman serangga darat di Laboratorium Pertanian Terpadu Jagan, Sukoharjo, dan mengembangkan modul pembelajaran berbasis potensi lokal yang selaras dengan Fase E Kurikulum Merdeka untuk mata pelajaran Biologi kelas X. Penelitian ini menggunakan desain penelitian dan pengembangan (R&D) yang meliputi pengumpulan data keanekaragaman hayati, perencanaan dan desain modul, validasi oleh ahli, validasi oleh praktisi, dan pengujian pengguna terbatas. Data empiris tentang komposisi spesies, kelimpahan, dan indeks ekologi diubah menjadi bahan pembelajaran terstruktur yang mengintegrasikan aktivitas eksplorasi, tugas penyelidikan terarah, dan komponen reflektif. Modul ini divalidasi oleh enam ahli materi pelajaran, enam ahli desain instruksional, dua guru biologi, dan siswa Kelas X. Hasil validasi menunjukkan kelayakan yang sangat tinggi, dengan skor ahli melebihi 87% dan evaluasi positif dari guru dan siswa terkait kejelasan, relevansi, keterbacaan, dan kegunaan. Temuan ini menunjukkan bahwa* *modul memiliki validitas konten yang kuat, kualitas instruksional, dan keterapan praktis dalam pembelajaran biologi di sekolah menengah atas. Kesimpulannya, integrasi data keanekaragaman hayati lokal yang autentik ke dalam modul pembelajaran kontekstual menyediakan bahan pembelajaran yang bermakna dan secara pedagogis sound, dengan potensi adaptasi di wilayah lain melalui kontekstualisasi berbasis keanekaragaman hayati lokal.*

INTRODUCTION

Terrestrial insects play a fundamental role in maintaining global ecosystem stability through their functions as pollinators, decomposers, components of food webs, and biological indicators of environmental change. These organisms contribute significantly to ecosystem services that support biodiversity, agricultural productivity, and ecological resilience (Abbasi, 2025; Barragán-fonseca et al., 2025). However, terrestrial insect diversity is currently facing unprecedented threats driven by habitat loss, land-use change, rapid urbanization, and climate change, which have led to declining insect populations across many regions worldwide (Farooq et al., 2025; Vaz et al., 2023). The ongoing reduction in insect diversity not only disrupts ecological balance but also underscores the urgent need to enhance biodiversity literacy through formal education, particularly at the secondary school level, where students begin to develop scientific understanding and environmental awareness (Efe & Efe, 2022; Fajri et al., 2025).

High school biology, in particular, represents a strategic educational level at which students begin to develop scientific reasoning, ecological understanding, and attitudes toward environmental sustainability (Al-barakat et al., 2025; Jackson et al., 2023). However, biodiversity instruction at the secondary school level often remains abstract and detached from students' immediate environments, limiting their ability to connect ecological concepts with real-world biological phenomena (Lestari et al., 2025; Murti et al., 2024). Strengthening biodiversity literacy through context-based and experiential biology learning is therefore essential to equip students with the knowledge, skills, and values needed to understand and respond to contemporary biodiversity challenges.

Despite the recognized importance of biodiversity literacy, the teaching of insect diversity in high school biology remains largely dominated by textbook-based instruction that emphasizes classification and theoretical descriptions rather than direct engagement with living organisms Such abstract approaches often limit students' opportunities to observe, investigate, and interpret insect diversity within their surrounding environments, resulting in superficial understanding and reduced interest in ecological topics (Audrin & Audrin, 2023; Christ et al., 2022; White et al., 2025). Consequently, students may struggle to develop essential scientific skills, such as observation, identification, and data interpretation, which are fundamental to biological inquiry. These limitations highlight the need for instructional strategies that move beyond conventional classroom-based learning toward more concrete and experiential approaches in teaching insect biodiversity (Lampert et al., 2025; Siregar et al., 2025).

The limited opportunities for students to directly observe and identify insects in natural environments further constrain the effectiveness of biodiversity learning in high school biology (Brown & White, 2024;

Klopčič & Torkar, 2025). Without hands-on experiences, students tend to perceive insect diversity as a set of disconnected facts rather than as dynamic components of living ecosystems. This lack of authentic engagement restricts the development of conceptual understanding and hinders the acquisition of essential science process skills, such as systematic observation, classification, and evidence-based reasoning, which are central to biological inquiry (Hamidah et al., 2024; Siregar et al., 2025). Moreover, insufficient exposure to real-world biodiversity contexts may weaken students' environmental awareness and sense of responsibility toward ecological conservation. When learning experiences fail to connect biological concepts with students' immediate surroundings, the relevance of biodiversity education becomes diminished, reducing students' motivation and ecological concern (Fajri et al., 2025; Id Babou et al., 2023; Nursidin et al., 2022).

Within the Indonesian educational context, the implementation of the Merdeka Curriculum emphasizes deep learning approaches that promote meaningful understanding, student autonomy, and contextual learning experiences, particularly in high school biology at Phase E, where biodiversity topics are introduced. However, preliminary observations conducted in a public high school in Sukoharjo indicate that classroom practices have not yet fully reflected these principles. Biology learning activities were found to be predominantly teacher-centered, with limited opportunities for student discussion, environmental exploration, or direct observation of local biological resources. Learning was largely focused on content delivery, with minimal integration of practical work or field-based activities, resulting in less meaningful learning experiences. Moreover, the instructional materials used were mainly standard Grade X biology textbooks and commercially published supplementary books that present biodiversity, ecosystem, and classification topics in a generalized and theoretical manner. Locally relevant biological data, such as information on terrestrial insect diversity and other region-specific organisms in Sukoharjo, as well as findings from local research, were rarely incorporated, highlighting a gap between curriculum expectations and the actual implementation of contextual and exploration-based biology learning. These challenges underscore the need for biology learning approaches that are contextual, authentic, and exploration-based, enabling students to actively engage with local biological resources and construct meaningful understanding through direct interaction with terrestrial insect diversity.

Previous studies in biology education consistently report that field-based learning and inquiry-based approaches are effective in improving students' understanding of biological concepts, particularly in biodiversity-related topics. Research has shown that learning experiences involving direct exploration of natural environments enable students to actively construct knowledge through observation, data collection, and scientific investigation. Moreover, inquiry-based learning supports the development of higher-order thinking and scientific reasoning skills by engaging students in questioning and evidence-based explanation, thereby reinforcing the pedagogical value of exploration-oriented approaches in secondary biology education.

In addition to experiential approaches, the integration of local potential or local biodiversity as a learning resource has gained attention in recent educational research. Learning activities that draw on students' immediate environments have been shown to increase the relevance and meaningfulness of biology instruction, as students are able to relate abstract concepts to observable biological phenomena. Within this context, learning modules function as effective instructional tools by providing structured guidance for exploration-based activities, supporting independent learning,

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and ensuring alignment with learning objectives in secondary school biology.

Although prior research has demonstrated positive outcomes, existing studies still reveal notable limitations. Many learning modules remain generic and are not explicitly aligned with particular local ecosystems, limiting their potential to leverage local biodiversity as a learning resource. Moreover, relatively few studies have focused on terrestrial insects as primary objects of exploration, even though insects represent one of the most diverse and ecologically significant groups of organisms. This gap indicates a need for context-specific, exploration-based learning modules that systematically incorporate local terrestrial insect diversity into high school biology instruction.

Despite the documented effectiveness of field-based and local potential–based learning approaches, significant gaps remain in the development of biology learning modules that systematically integrate local terrestrial insect biodiversity into structured field exploration activities. In the Indonesian context, where the country is recognized as a global megabiodiversity hotspot, local biological resources are still underutilized in high school biology instruction. Learning environments such as the Integrated Agricultural Laboratory of Jagan, Sukoharjo, offer rich terrestrial insect diversity with strong potential as contextual learning resources; however, few existing modules are explicitly designed to leverage such local ecosystems while ensuring content validity, practical usability, and alignment with biology learning outcomes. This gap highlights the need for context-specific, empirically grounded exploration modules that connect biodiversity-rich local environments with meaningful and structured biology learning experiences.

To address these gaps, the present study offers a novel contribution through the development of a local potential-based exploration module that utilizes terrestrial insect diversity from the Jagan Sukoharjo area as a contextual learning resource for high school biology. The novelty of this study lies in the systematic integration of structured field exploration, insect identification activities, and inquiry-based reflective tasks within a single learning module designed to support meaningful and authentic learning experiences. Theoretically, this study enriches the framework for developing biology learning materials grounded in local biodiversity, while practically providing a contextual and adaptable module that can be replicated in other regions by aligning learning activities with locally available biological resources.

Accordingly, this study aims to 1) How is the terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, characterized as core content for the development of a local potential–based learning module? 2) design a local potential-based exploration module for learning about terrestrial insect diversity in high school biology, 3) evaluate the feasibility of the developed module through expert validation involving biology education specialists, as well as practical assessments by high school biology teachers and students. The findings of this study are expected to contribute to biology education by providing empirically validated, context-based instructional materials that enhance biodiversity learning, while also fostering awareness of local biological resources and supporting conservation-oriented education through formal schooling.

METHOD

This study employed a Research and Development (R&D) design to develop and evaluate a local potential–based exploration module on terrestrial insect diversity for high school biology. The development procedure was adapted from the Borg and Gall model (Borg & Gall, 1983) and modified into seven stages following (Nugroho, 2017; Safitri & Nugroho, 2025): (1) Research and information collecting: literature review and

a field study. The literature review examined relevant theories and curriculum requirements, while the field study identified the local potential of terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, which served as the empirical basis for the module content. (2) Planning: planning the learning objectives, determining the main topics and instructional content, designing the structure and components of the learning module, and selecting validators, including subject-matter experts, educational practitioners (biology teachers), and student users for product evaluation. (3) Develop preliminary form of product: developing the initial draft of a local potential-based terrestrial insect diversity learning module. (4) Preliminary field testing: content feasibility was evaluated through expert validation involving subject-matter experts and module design experts. (5) Main product revision: the module was revised based on feedback from expert validators. (6) Main field testing: practical validation was conducted by biology teachers and Grade X high school students. and (7) Operational product revision: The module was revised based on the results of practitioner and user evaluations. The modification was undertaken to enhance feasibility within the scope and timeframe of the study, as the original stages of dissemination and large-scale implementation require extended resources and were beyond the primary objective of this research, which focused on product development and feasibility evaluation at a limited scale. Despite this adjustment, the essential principles of R&D methodology were maintained. The study was conducted from March to August 2025. The detailed stages of the module development process are illustrated in Figure 1.

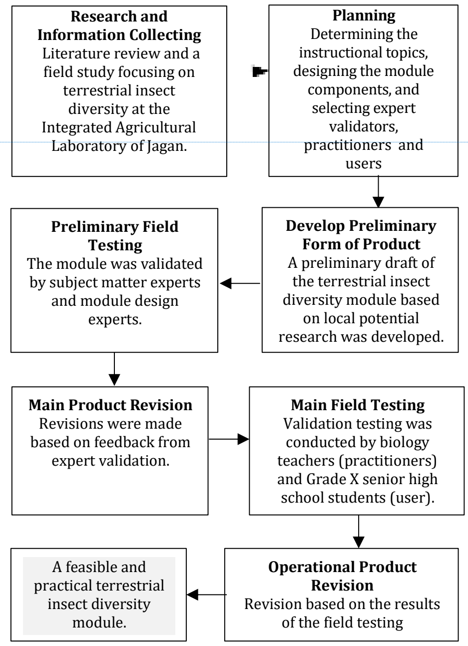

Figure 1. Research Procedure.

This study employed two data analysis techniques. First, qualitative descriptive analysis was used to interpret feedback obtained from the material experts, module design experts, biology teachers, and students during the initial product validation and limited field testing stages. The qualitative data consisted of comments, suggestions, critiques, and recommendations provided in the validation instruments, which were categorized and analyzed to inform product revision. Second, descriptive percentage analysis was applied to analyze quantitative data derived from the validation instruments (Rita T. Marpaung et al., 2025; Setiawan et al., 2024; Villamin et al., 2025; Zipser et al., 2025).

The module was evaluated by six validators, comprising subject-matter experts and module design experts holding master's degrees, as well as two professional biology teachers with a minimum of five years of teaching experience in insect-related biology topics. In addition, user validation

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was conducted involving 25 Grade X high school students in Sukoharjo. The quantitative scores provided by the experts and practitioners were analyzed to determine the level of feasibility of the module by calculating the percentage of achievement across the assessed aspects. The feasibility criteria were determined using the formula adapted from Safitri & Nugroho (2025):

$N=\frac{k}{Nk}$ x 100%

Where:
N = percentage score for each assessed aspect;
k = total score obtained;
Nk = maximum possible score.
The feasibility criteria of the module are presented in Table 1.

Table 1. Module Feasibility Criteria

Score Range (%)	Feasibility Criteria
0-20	Very Infeasible
21-40	Infeasible
41-60	Moderately Feasible
61-80	Feasible
81-100	Very Feasible

RESULTS AND DISCUSSION

This study began with a research and information-gathering phase that included a literature review and field observations. The field study conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, recorded a total of 641 terrestrial insect individuals representing various taxa. Several groups, including mosquitoes, grasshoppers, crickets, and ants, showed relatively high abundances, indicating their adaptability to the local environment, while other taxa were represented by fewer individuals, reflecting variation in species distribution within the habitat. Overall, the calculated ecological indices indicated a moderate level of species diversity and richness, with uneven species distribution but no single taxon exhibiting strong dominance, suggesting a relatively stable and heterogeneous terrestrial insect community.

The use of locally generated biodiversity data offers greater educational value than generic instructional materials because it provides epistemically authentic and contextually meaningful learning experiences (Niemiller et al., 2021; Prasetyo et al., 2025; Yli-Panula et al., 2018). By engaging with real ecological data from their immediate environment, students are able to connect abstract biodiversity concepts such as species diversity, population structure, and ecological balance with observable phenomena, thereby strengthening conceptual understanding and environmental awareness (Mason et al., 2025; Oliveira et al., 2025). This contextual integration aligns with deep learning principles, which emphasize higher-order thinking, inquiry, and reflective reasoning, and ensures that biodiversity learning is not limited to memorization but grounded in analysis and interpretation of real ecological patterns (Saputri et al., 2026; Wafa Taqiyya et al., 2025).

In this study, these empirical findings were utilized as core content in the development of a local potential–based terrestrial insect diversity learning module. Information on species composition, abundance, and ecological indices was systematically transformed into instructional materials aligned with the principles of the Merdeka Curriculum, particularly the deep learning approach implemented in Phase E (Grade X) biodiversity topics. The module incorporates authentic local research data into structured learning activities such as insect identification, ecological index analysis, data interpretation, and guided inquiry tasks encouraging students to construct conceptual understanding through observation, investigation, and reflection. By explicitly connecting biodiversity concepts with real ecological conditions in their immediate environment, the module promotes meaningful learning, strengthens scientific reasoning and higher-order thinking skills, and fosters environmental awareness consistent with the learning

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outcomes of Phase E biology. (Azmi et al., 2023; Lema & Dewi, 2023).

After obtaining content materials derived from local potential–based terrestrial insect diversity data at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, the study proceeded to the planning stage (Islamiati et al., 2024; Salmia et al., 2024). This stage involved defining the learning outcomes and instructional objectives to be addressed in the module, designing the structure and key components of the learning module, and selecting expert validators to participate in the validation process. The local potential–based terrestrial insect module was developed for Grade X high school students and aligned with the biology learning outcomes of Phase E in the Merdeka Curriculum. Accordingly, the learning indicators embedded in the module were formulated to support deep learning through exploration-based activities, data analysis, and reflective tasks grounded in local biodiversity contexts. This terrestrial insect diversity module uses the following success indicators: 10.1 Analyze various levels of insect diversity and their role in the surrounding environment, along with threats and conservation, 10.2 Conduct observational research on various levels of insect diversity and their role in the surrounding environment by comparing insect diversity data from various regions in Indonesia from relevant sources, 10.3 Identify terrestrial insect species, analyze research data, calculate various ecological indices (Shannon-Wiener, Dominance Index, Evenness Index), and draw conclusions. 10.3 Identifying terrestrial insect species, analyzing research data, calculating various ecological indices (Shannon-Wiener, Dominance Index, Evenness Index), and drawing conclusions about ecosystem conditions based on insect diversity analysis results.

The module structure was designed in a systematic and comprehensive manner, encompassing an introductory section, core instructional content, presentation of identified local potential, student worksheets, observation activities, evaluation instruments, a concluding section, and references. Each component was developed to integrate conceptual knowledge with empirical research data, thereby supporting exploratory and contextual learning experiences. In the final stage of the planning process, validators were selected to assess the feasibility of the module, consisting of six subject-matter experts, six instructional media or module design experts, two biology teacher practitioners, and 25 Grade X high school students as users in a limited-scale trial. The involvement of these diverse stakeholders aimed to ensure that the developed module met content validity, presentation quality, readability, and instructional effectiveness criteria for high school biology learning (Homillano, 2023; Ula et al., 2025). Following the completion of the planning stage, the study proceeded to the development of the initial module prototype as the basis for subsequent validation and revision.

The design of the terrestrial insect module based on local potential at the Jagan Integrated Agricultural Laboratory, Sukoharjo, was developed with reference to the principles of systematic, contextual teaching material development that is in line with the characteristics of the students. This approach is in line with the findings of research on the development of modules based on local potential, which have been reported to have a high level of validity and effectiveness in supporting biology learning (Azmi et al., 2023; Wahyuni et al., 2025). The developed module draft was subsequently organized and formatted into a structured and user-friendly learning module to facilitate its implementation in instructional activities, as illustrated in Figure 2-7.

Figure 2. Cover

Figure 3. Instructions for use

Figure 4. Lesson Plan

Figure 5. Material

Figure 6. Worksheet Based on Local Potential

Figure 7. Evaluation

Based on Figures 2–7, the developed module demonstrates a systematic and comprehensive structure, incorporating key instructional components such as usage guidelines, lesson planning, local potential–based content, student worksheets, and evaluation activities. The integration of empirical findings on terrestrial insect diversity from the Integrated Agricultural Laboratory of Jagan, Sukoharjo into the instructional materials reflects the implementation of authentic and exploration-based contextual learning. This module structure supports deep learning through inquiry, data analysis, and reflective activities, thereby enhancing students' conceptual understanding, science process skills, and environmental awareness in high school biology learning (Mettis & Väljataga, 2022; Sudarmi et al., 2024). Subsequently, the developed module was validated by six expert validators to assess the feasibility of the content and instructional design aspects, prior to practitioner (teachers) and user (students) validation. The content evaluation aspects included the quality of learning components, the adequacy of the instructional content, and the presentation and design of the module. The results of the

content validation conducted by subject-matter experts are presented in Table 2.

Table 2. Results of the evaluation of material validity

Validator	Percentage Score (%)	Criteria
1	94,17	Very Feasible
2	96,67	Very Feasible
3	95,00	Very Feasible
4	90,83	Very Feasible
5	87,50	Very Feasible
6	96,67	Very Feasible
Average	93,47	Very Feasible

The results of the material validation conducted by six experts indicate that the developed module demonstrates a very high level of feasibility. The percentage scores ranged from 87.50% to 96.67%, with all validators categorizing the module as very feasible. The highest score of 96.67% was awarded by the second and sixth validators, while the lowest score of 87.50% still fell within the very feasible category. These findings suggest that the module content is scientifically accurate, conceptually appropriate, and aligned with the learning objectives of high school biology. Furthermore, the relevance of the material to instructional needs and the clarity of its presentation indicate that the module meets content feasibility standards.

The terrestrial insect module based on local potential was subsequently validated by experts in biology instructional design to evaluate the quality of its structure and presentation. The validation process encompassed several aspects, including objectives and integration, module content, module presentation, learning and implementation, ethics, safety, and field context. The results of the module validity evaluation are presented in Table 3.

Table 3. Results of the evaluation of learning module validity

Validator	Percentage Score (%)	Criteria
1	93,18	Very Feasible
2	96,59	Very Feasible
3	94,32	Very Feasible
4	93,18	Very Feasible
5	87,50	Very Feasible
6	90,91	Very Feasible
Average	92,61	Very Feasible

The results presented in Table 3 demonstrate that the learning module achieved a very high level of validity based on evaluations by six expert validators. All validators assigned percentage scores above 87%, ranging from 87.50% to 96.59%, which consistently fall within the very feasible category. This classification aligns with the criteria proposed by Safitri & Nugroho (2025), who categorize scores within the range of 81–100 as indicating very high feasibility. The consistently high scores reflect strong agreement among experts regarding the quality of the module's instructional design, content organization, visual presentation, and adherence to ethical and copyright standards. These findings further indicate that the module meets established instructional quality criteria and possesses adequate content quality and pedagogical design to support effective implementation in high school biology learning, consistent with previous studies (Husna et al., 2021; Suwandi et al., 2024).

Overall, the results of the subject-matter expert and instructional module expert validations indicate that the validation process contributed substantially to improving the quality and strengthening the validity of the module for instructional use in biology learning. Throughout the expert validation process, constructive feedback and recommendations were provided to refine the local potential-based terrestrial insect module. Systematic revisions were subsequently implemented by incorporating suggestions from both content and module design experts prior to practitioner (teacher) and user (student) validation. Details of the revisions and adjustments made based on the subject-matter experts' feedback are presented in Table 4.

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Commented [Le11]: The claim of "agreement" is not supported by statistical tests (e.g. inter-rater reliability).

Table 6. Suggestions and Improvements from Subject Matter Experts and Modules

Suggestions	Improvements
Subject Matter Experts	
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.
Only corrections to the typing, there are some words with incorrect letters (typos) and inaccuracies.	Correct typos and inaccuracies. For example, "di bawah" on page 18 should be "di bawah," 'jagan' on page 29 should be "Jagan," etc.
Images should be of good resolution so that they are not unclear, broken, or blurred.	Improve images with good resolution so that they appear clear. Refer to pages 23-27.
It would be good to add illustrations of insects to the material, then check again whether the evaluation measures all learning objectives.	Add illustrations of insects to the material referring to pages 6-7 and 30-36.
Modules Experts	
Clearer instructions for use are needed.	Correct the module usage instructions on page 7.
Implementation for learning does not yet exist.	Add implementation for learning to the module on page 36.
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.

The suggestions provided by subject-matter experts and module design experts, as summarized in Table 6, indicate that the revisions primarily focused on enhancing scientific accuracy, instructional clarity, and visual quality of the module. Recommendations such as the inclusion of Latin names for each insect species, correction of typographical errors, and improvement of image resolution were essential for strengthening content accuracy and scientific rigor. These revisions ensure that the module meets academic standards in biology learning and supports precise conceptual understanding (Fahmi et al., 2025; Foster et al., 2014).

In addition, feedback from module design experts emphasized the need for clearer usage instructions and the inclusion of explicit learning implementation guidance. The incorporation of these suggestions improved the module's usability and instructional coherence, thereby enhancing its practicality for classroom application. Overall, the revisions addressed both content and design aspects, reinforcing the validity and feasibility of the module and ensuring its readiness for subsequent validation by practitioners and users.

After undergoing expert validation, the terrestrial insect diversity module was subsequently evaluated through practitioner validation involving two biology teachers, as well as user validation conducted with tenth-grade senior high school students who had previously studied insect diversity material. This validation aimed to obtain both qualitative and quantitative evaluations of the main product, namely the local potential-based terrestrial insect diversity module. The results of the validity assessment conducted by the biology teachers are presented in Table 7.

Table 7. Results of Validity Testing by practitioner validity

Practitioners	Percentage Score (%)		Criteria
	Module	Content	
1	89,77	93,30	Very Feasible
2	85,23	81,67	Very Feasible
Average	87,50	87,50	Very Feasible

The results of the practitioner validation presented in Table 7 indicate that the terrestrial insect diversity module achieved a high level of feasibility. Both biology teachers assigned percentage scores above 85% for the module and content aspects, with average scores of 87.50% for

Commented [Le12]: It's good, but it hasn't shown the concrete impact of the revision on product quality.

Commented [Le13]: Redundant with previous terms ("very feasible"); need for consistency of terms

each, placing the module in the very feasible category. These findings suggest that, from the practitioners' perspective, the module is pedagogically appropriate, systematically organized, and contextually relevant for classroom implementation in high school biology learning (Indah et al., 2022; Ravista et al., 2021; Solfitri et al., 2024). The strong ratings across both instructional design and content dimensions demonstrate that the module not only meets theoretical feasibility standards but also possesses practical value in real classroom settings. Specifically, the clarity of learning objectives, coherence of content structure, integration of local potential, and alignment with curriculum demands contribute to its ease of use and instructional effectiveness.

These results are consistent with previous module development studies reporting that well-structured, context-based instructional materials tend to be perceived by teachers as practical, efficient, and supportive of classroom management (Faizal et al., 2023; Janssen et al., 2014). The high level of agreement among practitioners therefore reinforces the module's practicality and confirms its readiness for broader implementation. Based on this strong practitioner endorsement, the module was subsequently considered appropriate for further evaluation through user validation involving Grade X high school students. This stage aimed to examine its readability, usability, and capacity to foster student engagement during learning activities, with the results of the student validation presented in Table 8.

Table 8. Results of Validity Testing by Student

Students	Percentage Score (%)	Criteria
1	87,66	Very Feasible
2	96,06	Very Feasible
3	89,32	Very Feasible
4	92,01	Very Feasible
5	97,35	Very Feasible
6	92,69	Very Feasible
7	90,72	Very Feasible
8	89,02	Very Feasible
9	96,52	Very Feasible
10	94,51	Very Feasible
11	97,35	Very Feasible
12	92,88	Very Feasible
13	93,83	Very Feasible
14	98,03	Very Feasible
15	100,00	Very Feasible
16	94,55	Very Feasible
17	94,81	Very Feasible
18	92,96	Very Feasible
19	98,34	Very Feasible
20	96,21	Very Feasible
21	96,37	Very Feasible
22	97,05	Very Feasible
23	96,06	Very Feasible
24	98,60	Very Feasible
25	98,18	Very Feasible
Average	94,96	Very Feasible

The user validation results presented in Table 8 demonstrate that the terrestrial insect diversity module achieved a very high level of feasibility from the students' perspective. All 25 Grade X students assigned scores exceeding 87%, with an average score of 94.96%, consistently categorizing the module as very feasible. These findings indicate that the module is highly readable, user-friendly, and engaging, effectively supporting students' understanding of insect diversity concepts through exploration-based learning activities. These results are consistent with previous studies which report that instructional modules grounded in contextual and locally relevant content enhance students' conceptual understanding, motivation, and learning engagement, particularly in biology education settings (Montgomery et al., 2024).

Commented [Le14]: There is no analysis of data distribution (e.g. variation or tendency towards extreme scores).

The consistently high validation scores suggest that the module successfully facilitates student engagement, comprehension, and independent learning. Nevertheless, both practitioner and user validations also generated constructive suggestions aimed at further improving

clarity, presentation, and learning activities. Accordingly, the module was revised by incorporating feedback from biology teachers and students to enhance its overall quality and instructional effectiveness prior to finalization. The suggestions and revisions provided by the teachers and students are presented in Table 9.

Table 9. Suggestions and Improvements from teachers and Studenst

Suggestions	Improvements
Teachers	
Only corrections to the typing, there are some words with incorrect letters (typos) and do not yet comply with the rules of writing.	Correcting misspelled words (typos) and correcting them according to writing rules. For example, pitfall trap becomes pitfall trap, Density becomes Density.
Improve images with poor resolution/ blurring.	Improve the image with good resolution so that the image appears clear on pages 23-27.
Add the latest scientific references on insect diversity.	Add the latest scientific references regarding insect diversity to Chapter I.
Include a section for assessing student observation results.	Include a section for assessing student observation results.
Students	
More interesting illustrations are needed. The image quality needs to be improved to make it clearer.	Adding more interesting illustrations and improving image quality for greater clarity.

The suggestions and improvements summarized in Table 9 indicate that feedback from both teachers and students primarily focused on enhancing the technical accuracy, visual quality, and instructional completeness of the module. Recommendations related to correcting typographical errors, improving image resolution, updating scientific references, and adding sections for assessing student observation assessment contributed to strengthening the module's clarity, scientific rigor, and pedagogical coherence. Feedback from students further emphasized the importance of engaging and high-quality visual elements to support comprehension and learning interest. These findings are consistent with research by Ita (2024) and Shiyamsyah et al. (2024) , which emphasizes that iterative formative evaluation involving experts, practitioners, and users plays a crucial role in improving the quality, practicality, and validity of educational products. Their studies demonstrate that systematic revisions based on stakeholder feedback significantly enhance instructional effectiveness and usability.

Accordingly, the revisions were systematically incorporated to refine the final version of the local potential–based terrestrial insect diversity module. Following this stage of revision based on practitioner and user feedback, the research was concluded, as the study was limited to the development and feasibility evaluation phases and did not proceed to large-scale implementation or effectiveness testing. The final module is characterized by its integration of authentic local biodiversity data, structured exploration activities, guided inquiry tasks, and reflective learning components that support conceptual understanding and scientific reasoning. These characteristics strongly support contextual learning, as students engage directly with ecological data derived from their immediate environment, a strategy widely recognized for enhancing meaningful learning and biodiversity literacy (Lampert et al., 2025; Montgomery et al., 2024).

Compared to conventional biology textbooks that often present decontextualized and generalized content, this module offers greater relevance, learner engagement, and instructional clarity by linking abstract concepts to observable ecological phenomena, consistent with findings from prior module development studies (Bermudez & Krell, 2025; Diduck et al., 2020). Furthermore, although grounded

in the local context of the Jagan Integrated Agricultural Laboratory, the modular design and development framework allow the instructional structure to be replicated in other regions through adaptation to locally available biodiversity resources, as recommended in design-based research and local potential–based learning studies (Ijatuyi et al., 2025; Purwasih et al., 2025; Zidny et al., 2020).

The implications of this study indicate that integrating locally generated ecological research into high school biology modules can serve as a strategic model for strengthening biodiversity education and bridging the gap between scientific inquiry and classroom instruction. Such an approach aligns with research emphasizing the importance of place-based and context-responsive education in fostering environmental literacy, critical thinking, and student engagement (Ardoin et al., 2020; Rosyidah et al., 2025). Nevertheless, several limitations must be acknowledged. The study was restricted to the development and feasibility evaluation stages and did not include experimental testing to measure the module's effectiveness in improving learning outcomes, higher-order thinking skills, or long-term retention. In addition, the implementation was conducted within a single institutional and ecological context, which may limit broad generalization without contextual adaptation. Therefore, future research should involve quasi-experimental or experimental designs to examine comparative effectiveness against conventional textbooks, as well as longitudinal studies to evaluate impacts on biodiversity literacy and environmental attitudes. Replication studies across different ecological regions are also recommended to further test the scalability and adaptability of the local potential–based module development framework, consistent with recommendations in design-based research literature (McKenney & Is, 2019; Plomp & Nieveen, 2013).

CONCLUSIONS AND SUGGESTION

This study successfully characterized terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo and utilized the empirical findings as core content for developing a local potential–based exploration module for high school biology. The developed module demonstrated very high feasibility based on expert validation, practitioner evaluation, and user responses, indicating strong content quality, instructional design, practicality, and readability. These results confirm that integrating authentic local biodiversity data into structured, inquiry-oriented learning materials supports contextual and meaningful biology learning at the senior high school level. The findings imply that local potential–based modules can serve as effective alternatives to conventional textbooks by enhancing relevance, student engagement, and scientific reasoning. Future research is recommended to examine the effectiveness of the module through experimental implementation and to replicate the development framework in other ecological contexts to further test its scalability and impact on biodiversity literacy.

Commented [Le15]: It is necessary to clarify indicators of success

Commented [Le16]: It is necessary to mention key quantitative values (e.g. average percentage) to strengthen the claim of "very high feasibility".

Commented [Le17]: There is no direct data that measures engagement or reasoning; these need to be avoided or supported with data.

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Development Local Potential-Based Exploration Modules for Learning About Terrestrial Insect Diversity in High Schools

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ABSTRACT

This study aimed to analyze terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, and to develop a local potential–based learning module aligned with Phase E of the Merdeka Curriculum for Grade X biology. The research employed a research and development (R&D) design consisting of biodiversity data collection, module planning and design, expert validation, practitioner validation, and limited user testing. Empirical data on species composition, abundance, and ecological indices were transformed into structured learning materials integrating exploration activities, guided inquiry tasks, and reflective components. The module was validated by six subject-matter experts, six instructional design experts, two biology teachers, and Grade X students. The validation results indicated very high feasibility, with expert scores exceeding 87% and positive evaluations from teachers and students in terms of clarity, relevance, readability, and usability. These findings demonstrate that the module possesses strong content validity, instructional quality, and practical applicability in high school biology learning. In conclusion, integrating authentic local biodiversity data into contextual learning modules provides meaningful and pedagogically sound instructional materials, with potential for adaptation in other regions through local biodiversity-based contextualization.

Pengembangan Modul Eksplorasi Berbasis Potensi Lokal untuk Pembelajaran Keanekaragaman Serangga Darat di Sekolah Menengah Atas

ABSTRAK: *Penelitian ini bertujuan untuk menganalisis keragaman serangga darat di Laboratorium Pertanian Terpadu Jagan, Sukoharjo, dan mengembangkan modul pembelajaran berbasis potensi lokal yang selaras dengan Fase E Kurikulum Merdeka untuk mata pelajaran Biologi kelas X. Penelitian ini menggunakan desain penelitian dan pengembangan (R&D) yang meliputi pengumpulan data keanekaragaman hayati, perencanaan dan desain modul, validasi oleh ahli, validasi oleh praktisi, dan pengujian pengguna terbatas. Data empiris tentang komposisi spesies, kelimpahan, dan indeks ekologi diubah menjadi bahan pembelajaran terstruktur yang mengintegrasikan aktivitas eksplorasi, tugas penyelidikan terarah, dan komponen reflektif. Modul ini divalidasi oleh enam ahli materi pelajaran, enam ahli desain instruksional, dua guru biologi, dan siswa Kelas X. Hasil validasi menunjukkan kelayakan yang sangat tinggi, dengan skor ahli melebihi 87% dan evaluasi positif dari guru dan siswa terkait kejelasan, relevansi, keterbacaan, dan kegunaan. Temuan ini menunjukkan bahwa*

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Commented [Le2]: Redundant ("research employed a research…"). The sentence needs to be simplified and a brief explanation of the R&D model used (e.g., Borg & Gall) is needed to be more specific.

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modul memiliki validitas konten yang kuat, kualitas instruksional, dan keterapan praktis dalam pembelajaran biologi di sekolah menengah atas. Kesimpulannya, integrasi data keanekaragaman hayati lokal yang autentik ke dalam modul pembelajaran kontekstual menyediakan bahan pembelajaran yang bermakna dan secara pedagogis sound, dengan potensi adaptasi di wilayah lain melalui kontekstualisasi berbasis keanekaragaman hayati lokal.

INTRODUCTION

Terrestrial insects play a fundamental role in maintaining global ecosystem stability through their functions as pollinators, decomposers, components of food webs, and biological indicators of environmental change. These organisms contribute significantly to ecosystem services that support biodiversity, agricultural productivity, and ecological resilience (Abbasi, 2025; Barragán-fonseca et al., 2025). However, terrestrial insect diversity is currently facing unprecedented threats driven by habitat loss, land-use change, rapid urbanization, and climate change, which have led to declining insect populations across many regions worldwide (Farooq et al., 2025; Vaz et al., 2023). The ongoing reduction in insect diversity not only disrupts ecological balance but also underscores the urgent need to enhance biodiversity literacy through formal education, particularly at the secondary school level, where students begin to develop scientific understanding and environmental awareness (Efe & Efe, 2022; Fajri et al., 2025).

High school biology, in particular, represents a strategic educational level at which students begin to develop scientific reasoning, ecological understanding, and attitudes toward environmental sustainability (Al-barakat et al., 2025; Jackson et al., 2023). However, biodiversity instruction at the secondary school level often remains abstract and detached from students' immediate environments, limiting their ability to connect ecological concepts with real-world biological phenomena (Lestari et al., 2025; Murti et al., 2024). Strengthening biodiversity literacy through context-based and experiential biology learning is therefore essential to equip students with the knowledge, skills, and values needed to understand and respond to contemporary biodiversity challenges.

Despite the recognized importance of biodiversity literacy, the teaching of insect diversity in high school biology remains largely dominated by textbook-based instruction that emphasizes classification and theoretical descriptions rather than direct engagement with living organisms Such abstract approaches often limit students' opportunities to observe, investigate, and interpret insect diversity within their surrounding environments, resulting in superficial understanding and reduced interest in ecological topics (Audrin & Audrin, 2023; Christ et al., 2022; White et al., 2025). Consequently, students may struggle to develop essential scientific skills, such as observation, identification, and data interpretation, which are fundamental to biological inquiry. These limitations highlight the need for instructional strategies that move beyond conventional classroom-based learning toward more concrete and experiential approaches in teaching insect biodiversity (Lampert et al., 2025; Siregar et al., 2025).

The limited opportunities for students to directly observe and identify insects in natural environments further constrain the effectiveness of biodiversity learning in high school biology (Brown & White, 2024;

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Klopčič & Torkar, 2025). Without hands-on experiences, students tend to perceive insect diversity as a set of disconnected facts rather than as dynamic components of living ecosystems. This lack of authentic engagement restricts the development of conceptual understanding and hinders the acquisition of essential science process skills, such as systematic observation, classification, and evidence-based reasoning, which are central to biological inquiry (Hamidah et al., 2024; Siregar et al., 2025). Moreover, insufficient exposure to real-world biodiversity contexts may weaken students' environmental awareness and sense of responsibility toward ecological conservation. When learning experiences fail to connect biological concepts with students' immediate surroundings, the relevance of biodiversity education becomes diminished, reducing students' motivation and ecological concern (Fajri et al., 2025; Id Babou et al., 2023; Nursidin et al., 2022).

Within the Indonesian educational context, the implementation of the Merdeka Curriculum emphasizes deep learning approaches that promote meaningful understanding, student autonomy, and contextual learning experiences, particularly in high school biology at Phase E, where biodiversity topics are introduced. However, preliminary observations conducted in a public high school in Sukoharjo indicate that classroom practices have not yet fully reflected these principles. Biology learning activities were found to be predominantly teacher-centered, with limited opportunities for student discussion, environmental exploration, or direct observation of local biological resources. Learning was largely focused on content delivery, with minimal integration of practical work or field-based activities, resulting in less meaningful learning experiences. Moreover, the instructional materials used were mainly standard Grade X biology textbooks and commercially published supplementary books that present biodiversity, ecosystem, and classification topics in a generalized and theoretical manner. Locally relevant biological data, such as information on terrestrial insect diversity and other region-specific organisms in Sukoharjo, as well as findings from local research, were rarely incorporated, highlighting a gap between curriculum expectations and the actual implementation of contextual and exploration-based biology learning. These challenges underscore the need for biology learning approaches that are contextual, authentic, and exploration-based, enabling students to actively engage with local biological resources and construct meaningful understanding through direct interaction with terrestrial insect diversity.

Previous studies in biology education consistently report that field-based learning and inquiry-based approaches are effective in improving students' understanding of biological concepts, particularly in biodiversity-related topics. Research has shown that learning experiences involving direct exploration of natural environments enable students to actively construct knowledge through observation, data collection, and scientific investigation. Moreover, inquiry-based learning supports the development of higher-order thinking and scientific reasoning skills by engaging students in questioning and evidence-based explanation, thereby reinforcing the pedagogical value of exploration-oriented approaches in secondary biology education.

In addition to experiential approaches, the integration of local potential or local biodiversity as a learning resource has gained attention in recent educational research. Learning activities that draw on students' immediate environments have been shown to increase the relevance and meaningfulness of biology instruction, as students are able to relate abstract concepts to observable biological phenomena. Within this context, learning modules function as effective instructional tools by providing structured guidance for exploration-based activities, supporting independent learning,

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and ensuring alignment with learning objectives in secondary school biology.

Although prior research has demonstrated positive outcomes, existing studies still reveal notable limitations. Many learning modules remain generic and are not explicitly aligned with particular local ecosystems, limiting their potential to leverage local biodiversity as a learning resource. Moreover, relatively few studies have focused on terrestrial insects as primary objects of exploration, even though insects represent one of the most diverse and ecologically significant groups of organisms. This gap indicates a need for context-specific, exploration-based learning modules that systematically incorporate local terrestrial insect diversity into high school biology instruction.

Despite the documented effectiveness of field-based and local potential–based learning approaches, significant gaps remain in the development of biology learning modules that systematically integrate local terrestrial insect biodiversity into structured field exploration activities. In the Indonesian context, where the country is recognized as a global megabiodiversity hotspot, local biological resources are still underutilized in high school biology instruction. Learning environments such as the Integrated Agricultural Laboratory of Jagan, Sukoharjo, offer rich terrestrial insect diversity with strong potential as contextual learning resources; however, few existing modules are explicitly designed to leverage such local ecosystems while ensuring content validity, practical usability, and alignment with biology learning outcomes. This gap highlights the need for context-specific, empirically grounded exploration modules that connect biodiversity-rich local environments with meaningful and structured biology learning experiences.

To address these gaps, the present study offers a novel contribution through the development of a local potential-based exploration module that utilizes terrestrial insect diversity from the Jagan Sukoharjo area as a contextual learning resource for high school biology. The novelty of this study lies in the systematic integration of structured field exploration, insect identification activities, and inquiry-based reflective tasks within a single learning module designed to support meaningful and authentic learning experiences. Theoretically, this study enriches the framework for developing biology learning materials grounded in local biodiversity, while practically providing a contextual and adaptable module that can be replicated in other regions by aligning learning activities with locally available biological resources.

Accordingly, this study aims to 1) How is the terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, characterized as core content for the development of a local potential–based learning module? 2) design a local potential-based exploration module for learning about terrestrial insect diversity in high school biology, 3) evaluate the feasibility of the developed module through expert validation involving biology education specialists, as well as practical assessments by high school biology teachers and students. The findings of this study are expected to contribute to biology education by providing empirically validated, context-based instructional materials that enhance biodiversity learning, while also fostering awareness of local biological resources and supporting conservation-oriented education through formal schooling.

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METHOD

This study employed a Research and Development (R&D) design to develop and evaluate a local potential–based exploration module on terrestrial insect diversity for high school biology. The development procedure was adapted from the Borg and Gall model (Borg & Gall, 1983) and modified into seven stages following (Nugroho, 2017; Safitri & Nugroho, 2025): (1) Research and information collecting: literature review and

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a field study. The literature review examined relevant theories and curriculum requirements, while the field study identified the local potential of terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, which served as the empirical basis for the module content. (2) Planning: planning the learning objectives, determining the main topics and instructional content, designing the structure and components of the learning module, and selecting validators, including subject-matter experts, educational practitioners (biology teachers), and student users for product evaluation. (3) Develop preliminary form of product: developing the initial draft of a local potential-based terrestrial insect diversity learning module. (4) Preliminary field testing: content feasibility was evaluated through expert validation involving subject-matter experts and module design experts. (5) Main product revision: the module was revised based on feedback from expert validators. (6) Main field testing: practical validation was conducted by biology teachers and Grade X high school students. and (7) Operational product revision: The module was revised based on the results of practitioner and user evaluations. The modification was undertaken to enhance feasibility within the scope and timeframe of the study, as the original stages of dissemination and large-scale implementation require extended resources and were beyond the primary objective of this research, which focused on product development and feasibility evaluation at a limited scale. Despite this adjustment, the essential principles of R&D methodology were maintained. The study was conducted from March to August 2025. The detailed stages of the module development process are illustrated in Figure 1.

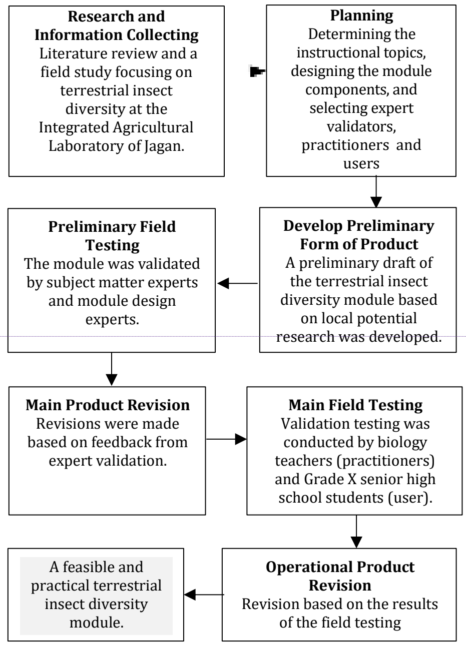

Figure 1. Research Procedure.

This study employed two data analysis techniques. First, qualitative descriptive analysis was used to interpret feedback obtained from the material experts, module design experts, biology teachers, and students during the initial product validation and limited field testing stages. The qualitative data consisted of comments, suggestions, critiques, and recommendations provided in the validation instruments, which were categorized and analyzed to inform product revision. Second, descriptive percentage analysis was applied to analyze quantitative data derived from the validation instruments (Rita T. Marpaung et al., 2025; Setiawan et al., 2024; Villamin et al., 2025; Zipser et al., 2025).

The module was evaluated by six validators, comprising subject-matter experts and module design experts holding master's degrees, as well as two professional biology teachers with a minimum of five years of teaching experience in insect-related biology topics. In addition, user validation

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was conducted involving 25 Grade X high school students in Sukoharjo. The quantitative scores provided by the experts and practitioners were analyzed to determine the level of feasibility of the module by calculating the percentage of achievement across the assessed aspects. The feasibility criteria were determined using the formula adapted from Safitri & Nugroho (2025):

$$N=\frac{k}{Nk} \times 100\%$$

Where:
N = percentage score for each assessed aspect;
k = total score obtained;
Nk = maximum possible score.
The feasibility criteria of the module are presented in Table 1.

Table 1. Module Feasibility Criteria

Score Range (%)	Feasibility Criteria
0-20	Very Infeasible
21-40	Infeasible
41-60	Moderately Feasible
61-80	Feasible
81-100	Very Feasible

RESULTS AND DISCUSSION

This study began with a research and information-gathering phase that included a literature review and field observations. The field study conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, recorded a total of 641 terrestrial insect individuals representing various taxa. Several groups, including mosquitoes, grasshoppers, crickets, and ants, showed relatively high abundances, indicating their adaptability to the local environment, while other taxa were represented by fewer individuals, reflecting variation in species distribution within the habitat. Overall, the calculated ecological indices indicated a moderate level of species diversity and richness, with uneven species distribution but no single taxon exhibiting strong dominance, suggesting a relatively stable and heterogeneous terrestrial insect community.

The use of locally generated biodiversity data offers greater educational value than generic instructional materials because it provides epistemically authentic and contextually meaningful learning experiences (Niemiller et al., 2021; Prasetyo et al., 2025; Yli-Panula et al., 2018). By engaging with real ecological data from their immediate environment, students are able to connect abstract biodiversity concepts such as species diversity, population structure, and ecological balance with observable phenomena, thereby strengthening conceptual understanding and environmental awareness (Mason et al., 2025; Oliveira et al., 2025). This contextual integration aligns with deep learning principles, which emphasize higher-order thinking, inquiry, and reflective reasoning, and ensures that biodiversity learning is not limited to memorization but grounded in analysis and interpretation of real ecological patterns (Saputri et al., 2026; Wafa Taqiyya et al., 2025).

In this study, these empirical findings were utilized as core content in the development of a local potential–based terrestrial insect diversity learning module. Information on species composition, abundance, and ecological indices was systematically transformed into instructional materials aligned with the principles of the Merdeka Curriculum, particularly the deep learning approach implemented in Phase E (Grade X) biodiversity topics. The module incorporates authentic local research data into structured learning activities such as insect identification, ecological index analysis, data interpretation, and guided inquiry tasks encouraging students to construct conceptual understanding through observation, investigation, and reflection. By explicitly connecting biodiversity concepts with real ecological conditions in their immediate environment, the module promotes meaningful learning, strengthens scientific reasoning and higher-order thinking skills, and fosters environmental awareness consistent with the learning

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outcomes of Phase E biology. (Azmi et al., 2023; Lema & Dewi, 2023).

After obtaining content materials derived from local potential–based terrestrial insect diversity data at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, the study proceeded to the planning stage (Islamiati et al., 2024; Salmia et al., 2024). This stage involved defining the learning outcomes and instructional objectives to be addressed in the module, designing the structure and key components of the learning module, and selecting expert validators to participate in the validation process. The local potential–based terrestrial insect module was developed for Grade X high school students and aligned with the biology learning outcomes of Phase E in the Merdeka Curriculum. Accordingly, the learning indicators embedded in the module were formulated to support deep learning through exploration-based activities, data analysis, and reflective tasks grounded in local biodiversity contexts. This terrestrial insect diversity module uses the following success indicators: 10.1 Analyze various levels of insect diversity and their role in the surrounding environment, along with threats and conservation, 10.2 Conduct observational research on various levels of insect diversity and their role in the surrounding environment by comparing insect diversity data from various regions in Indonesia from relevant sources, 10.3 Identify terrestrial insect species, analyze research data, calculate various ecological indices (Shannon-Wiener, Dominance Index, Evenness Index), and draw conclusions. 10.3 Identifying terrestrial insect species, analyzing research data, calculating various ecological indices (Shannon-Wiener, Dominance Index, Evenness Index), and drawing conclusions about ecosystem conditions based on insect diversity analysis results.

The module structure was designed in a systematic and comprehensive manner, encompassing an introductory section, core instructional content, presentation of identified local potential, student worksheets, observation activities, evaluation instruments, a concluding section, and references. Each component was developed to integrate conceptual knowledge with empirical research data, thereby supporting exploratory and contextual learning experiences. In the final stage of the planning process, validators were selected to assess the feasibility of the module, consisting of six subject-matter experts, six instructional media or module design experts, two biology teacher practitioners, and 25 Grade X high school students as users in a limited-scale trial. The involvement of these diverse stakeholders aimed to ensure that the developed module met content validity, presentation quality, readability, and instructional effectiveness criteria for high school biology learning (Homillano, 2023; Ula et al., 2025). Following the completion of the planning stage, the study proceeded to the development of the initial module prototype as the basis for subsequent validation and revision.

The design of the terrestrial insect module based on local potential at the Jagan Integrated Agricultural Laboratory, Sukoharjo, was developed with reference to the principles of systematic, contextual teaching material development that is in line with the characteristics of the students. This approach is in line with the findings of research on the development of modules based on local potential, which have been reported to have a high level of validity and effectiveness in supporting biology learning (Azmi et al., 2023; Wahyuni et al., 2025). The developed module draft was subsequently organized and formatted into a structured and user-friendly learning module to facilitate its implementation in instructional activities, as illustrated in Figure 2-7.

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Figure 2. Cover

Figure 3. Instructions for use

Figure 4. Lesson Plan

Figure 5. Material

Figure 6. Worksheet Based on Local Potential

Figure 7. Evaluation

Based on Figures 2–7, the developed module demonstrates a systematic and comprehensive structure, incorporating key instructional components such as usage guidelines, lesson planning, local potential–based content, student worksheets, and evaluation activities. The integration of empirical findings on terrestrial insect diversity from the Integrated Agricultural Laboratory of Jagan, Sukoharjo into the instructional materials reflects the implementation of authentic and exploration-based contextual learning. This module structure supports deep learning through inquiry, data analysis, and reflective activities, thereby enhancing students' conceptual understanding, science process skills, and environmental awareness in high school biology learning (Mettis & Väljataga, 2022; Sudarmi et al., 2024). Subsequently, the developed module was validated by six expert validators to assess the feasibility of the content and instructional design aspects, prior to practitioner (teachers) and user (students) validation. The content evaluation aspects included the quality of learning components, the adequacy of the instructional content, and the presentation and design of the module. The results of the

content validation conducted by subject-matter experts are presented in Table 2.

Table 2. Results of the evaluation of material validity

Validator	Percentage Score (%)	Criteria
1	94,17	Very Feasible
2	96,67	Very Feasible
3	95,00	Very Feasible
4	90,83	Very Feasible
5	87,50	Very Feasible
6	96,67	Very Feasible
Average	93,47	Very Feasible

The results of the material validation conducted by six experts indicate that the developed module demonstrates a very high level of feasibility. The percentage scores ranged from 87.50% to 96.67%, with all validators categorizing the module as very feasible. The highest score of 96.67% was awarded by the second and sixth validators, while the lowest score of 87.50% still fell within the very feasible category. These findings suggest that the module content is scientifically accurate, conceptually appropriate, and aligned with the learning objectives of high school biology. Furthermore, the relevance of the material to instructional needs and the clarity of its presentation indicate that the module meets content feasibility standards.

The terrestrial insect module based on local potential was subsequently validated by experts in biology instructional design to evaluate the quality of its structure and presentation. The validation process encompassed several aspects, including objectives and integration, module content, module presentation, learning and implementation, ethics, safety, and field context. The results of the module validity evaluation are presented in Table 3.

Table 3. Results of the evaluation of learning module validity

Validator	Percentage Score (%)	Criteria
1	93,18	Very Feasible
2	96,59	Very Feasible
3	94,32	Very Feasible
4	93,18	Very Feasible
5	87,50	Very Feasible
6	90,91	Very Feasible
Average	92,61	Very Feasible

The results presented in Table 3 demonstrate that the learning module achieved a very high level of validity based on evaluations by six expert validators. All validators assigned percentage scores above 87%, ranging from 87.50% to 96.59%, which consistently fall within the very feasible category. This classification aligns with the criteria proposed by Safitri & Nugroho (2025), who categorize scores within the range of 81–100 as indicating very high feasibility. The consistently high scores reflect strong agreement among experts regarding the quality of the module's instructional design, content organization, visual presentation, and adherence to ethical and copyright standards. These findings further indicate that the module meets established instructional quality criteria and possesses adequate content quality and pedagogical design to support effective implementation in high school biology learning, consistent with previous studies (Husna et al., 2021; Suwandi et al., 2024).

Overall, the results of the subject-matter expert and instructional module expert validations indicate that the validation process contributed substantially to improving the quality and strengthening the validity of the module for instructional use in biology learning. Throughout the expert validation process, constructive feedback and recommendations were provided to refine the local potential-based terrestrial insect module. Systematic revisions were subsequently implemented by incorporating suggestions from both content and module design experts prior to practitioner (teacher) and user (student) validation. Details of the revisions and adjustments made based on the subject-matter experts' feedback are presented in Table 4.

Table 6. Suggestions and Improvements from Subject Matter Experts and Modules

Suggestions	Improvements
Subject Matter Experts	
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.
Only corrections to the typing, there are some words with incorrect letters (typos) and inaccuracies.	Correct typos and inaccuracies. For example, "di bawah" on page 18 should be "di bawah," 'jagan' on page 29 should be "Jagan," etc.
Images should be of good resolution so that they are not unclear, broken, or blurred.	Improve images with good resolution so that they appear clear. Refer to pages 23-27.
It would be good to add illustrations of insects to the material, then check again whether the evaluation measures all learning objectives.	Add illustrations of insects to the material referring to pages 6-7 and 30-36.
Modules Experts	
Clearer instructions for use are needed.	Correct the module usage instructions on page 7.
Implementation for learning does not yet exist.	Add implementation for learning to the module on page 36.
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.

The suggestions provided by subject-matter experts and module design experts, as summarized in Table 6, indicate that the revisions primarily focused on enhancing scientific accuracy, instructional clarity, and visual quality of the module. Recommendations such as the inclusion of Latin names for each insect species, correction of typographical errors, and improvement of image resolution were essential for strengthening content accuracy and scientific rigor. These revisions ensure that the module meets academic standards in biology learning and supports precise conceptual understanding (Fahmi et al., 2025; Foster et al., 2014).

In addition, feedback from module design experts emphasized the need for clearer usage instructions and the inclusion of explicit learning implementation guidance. The incorporation of these suggestions improved the module's usability and instructional coherence, thereby enhancing its practicality for classroom application. Overall, the revisions addressed both content and design aspects, reinforcing the validity and feasibility of the module and ensuring its readiness for subsequent validation by practitioners and users.

After undergoing expert validation, the terrestrial insect diversity module was subsequently evaluated through practitioner validation involving two biology teachers, as well as user validation conducted with tenth-grade senior high school students who had previously studied insect diversity material. This validation aimed to obtain both qualitative and quantitative evaluations of the main product, namely the local potential-based terrestrial insect diversity module. The results of the validity assessment conducted by the biology teachers are presented in Table 7.

Table 7. Results of Validity Testing by practitioner validity

Practitioners	Percentage Score (%)		Criteria
	Module	Content	
1	89,77	93,30	Very Feasible
2	85,23	81,67	Very Feasible
Average	87,50	87,50	Very Feasible

The results of the practitioner validation presented in Table 7 indicate that the terrestrial insect diversity module achieved a high level of feasibility. Both biology teachers assigned percentage scores above 85% for the module and content aspects, with average scores of 87.50% for

each, placing the module in the very feasible category. These findings suggest that, from the practitioners' perspective, the module is pedagogically appropriate, systematically organized, and contextually relevant for classroom implementation in high school biology learning (Indah et al., 2022; Ravista et al., 2021; Solfitri et al., 2024). The strong ratings across both instructional design and content dimensions demonstrate that the module not only meets theoretical feasibility standards but also possesses practical value in real classroom settings. Specifically, the clarity of learning objectives, coherence of content structure, integration of local potential, and alignment with curriculum demands contribute to its ease of use and instructional effectiveness.

These results are consistent with previous module development studies reporting that well-structured, context-based instructional materials tend to be perceived by teachers as practical, efficient, and supportive of classroom management (Faizal et al., 2023; Janssen et al., 2014). The high level of agreement among practitioners therefore reinforces the module's practicality and confirms its readiness for broader implementation. Based on this strong practitioner endorsement, the module was subsequently considered appropriate for further evaluation through user validation involving Grade X high school students. This stage aimed to examine its readability, usability, and capacity to foster student engagement during learning activities, with the results of the student validation presented in Table 8.

Table 8. Results of Validity Testing by Student

Students	Percentage Score (%)	Criteria
1	87,66	Very Feasible
2	96,06	Very Feasible
3	89,32	Very Feasible
4	92,01	Very Feasible
5	97,35	Very Feasible
6	92,69	Very Feasible
7	90,72	Very Feasible
8	89,02	Very Feasible
9	96,52	Very Feasible
10	94,51	Very Feasible
11	97,35	Very Feasible
12	92,88	Very Feasible
13	93,83	Very Feasible
14	98,03	Very Feasible
15	100,00	Very Feasible
16	94,55	Very Feasible
17	94,81	Very Feasible
18	92,96	Very Feasible
19	98,34	Very Feasible
20	96,21	Very Feasible
21	96,37	Very Feasible
22	97,05	Very Feasible
23	96,06	Very Feasible
24	98,60	Very Feasible
25	98,18	Very Feasible
Average	94,96	Very Feasible

The user validation results presented in Table 8 demonstrate that the terrestrial insect diversity module achieved a very high level of feasibility from the students' perspective. All 25 Grade X students assigned scores exceeding 87%, with an average score of 94.96%, consistently categorizing the module as very feasible**.** These findings indicate that the module is highly readable, user-friendly, and engaging, effectively supporting students' understanding of insect diversity concepts through exploration-based learning activities. These results are consistent with previous studies which report that instructional modules grounded in contextual and locally relevant content enhance students' conceptual understanding, motivation, and learning engagement, particularly in biology education settings (Montgomery et al., 2024).

The consistently high validation scores suggest that the module successfully facilitates student engagement, comprehension, and independent learning. Nevertheless, both practitioner and user validations also generated constructive suggestions aimed at further improving

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clarity, presentation, and learning activities. Accordingly, the module was revised by incorporating feedback from biology teachers and students to enhance its overall quality and instructional effectiveness prior to finalization. The suggestions and revisions provided by the teachers and students are presented in Table 9.

Table 9. Suggestions and Improvements from teachers and Studenst

Suggestions	Improvements
Teachers	
Only corrections to the typing, there are some words with incorrect letters (typos) and do not yet comply with the rules of writing.	Correcting misspelled words (typos) and correcting them according to writing rules. For example, pitfall trap becomes pitfall trap, Density becomes Density.
Improve images with poor resolution/ blurring.	Improve the image with good resolution so that the image appears clear on pages 23-27.
Add the latest scientific references on insect diversity.	Add the latest scientific references regarding insect diversity to Chapter I.
Include a section for assessing student observation results.	Include a section for assessing student observation results.
Students	
More interesting illustrations are needed. The image quality needs to be improved to make it clearer.	Adding more interesting illustrations and improving image quality for greater clarity.

The suggestions and improvements summarized in Table 9 indicate that feedback from both teachers and students primarily focused on enhancing the technical accuracy, visual quality, and instructional completeness of the module. Recommendations related to correcting typographical errors, improving image resolution, updating scientific references, and adding sections for assessing student observation assessment contributed to strengthening the module's clarity, scientific rigor, and pedagogical coherence. Feedback from students further emphasized the importance of engaging and high-quality visual elements to support comprehension and learning interest. These findings are consistent with research by Ita (2024) and Shiyamsyah et al. (2024) , which emphasizes that iterative formative evaluation involving experts, practitioners, and users plays a crucial role in improving the quality, practicality, and validity of educational products. Their studies demonstrate that systematic revisions based on stakeholder feedback significantly enhance instructional effectiveness and usability.

Accordingly, the revisions were systematically incorporated to refine the final version of the local potential–based terrestrial insect diversity module. Following this stage of revision based on practitioner and user feedback, the research was concluded, as the study was limited to the development and feasibility evaluation phases and did not proceed to large-scale implementation or effectiveness testing. The final module is characterized by its integration of authentic local biodiversity data, structured exploration activities, guided inquiry tasks, and reflective learning components that support conceptual understanding and scientific reasoning. These characteristics strongly support contextual learning, as students engage directly with ecological data derived from their immediate environment, a strategy widely recognized for enhancing meaningful learning and biodiversity literacy (Lampert et al., 2025; Montgomery et al., 2024).

Compared to conventional biology textbooks that often present decontextualized and generalized content, this module offers greater relevance, learner engagement, and instructional clarity by linking abstract concepts to observable ecological phenomena, consistent with findings from prior module development studies (Bermudez & Krell, 2025; Diduck et al., 2020). Furthermore, although grounded

Commented [Le21]: Example of unclear revision (shows no change)

in the local context of the Jagan Integrated Agricultural Laboratory, the modular design and development framework allow the instructional structure to be replicated in other regions through adaptation to locally available biodiversity resources, as recommended in design-based research and local potential–based learning studies (Ijatuyi et al., 2025; Purwasih et al., 2025; Zidny et al., 2020).

The implications of this study indicate that integrating locally generated ecological research into high school biology modules can serve as a strategic model for strengthening biodiversity education and bridging the gap between scientific inquiry and classroom instruction. Such an approach aligns with research emphasizing the importance of place-based and context-responsive education in fostering environmental literacy, critical thinking, and student engagement (Ardoin et al., 2020; Rosyidah et al., 2025). Nevertheless, several limitations must be acknowledged. The study was restricted to the development and feasibility evaluation stages and did not include experimental testing to measure the module's effectiveness in improving learning outcomes, higher-order thinking skills, or long-term retention. In addition, the implementation was conducted within a single institutional and ecological context, which may limit broad generalization without contextual adaptation. Therefore, future research should involve quasi-experimental or experimental designs to examine comparative effectiveness against conventional textbooks, as well as longitudinal studies to evaluate impacts on biodiversity literacy and environmental attitudes. Replication studies across different ecological regions are also recommended to further test the scalability and adaptability of the local potential–based module development framework, consistent with recommendations in design-based research literature (McKenney & Is, 2019; Plomp & Nieveen, 2013).

CONCLUSIONS AND SUGGESTION

This study successfully characterized terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo and utilized the empirical findings as core content for developing a local potential–based exploration module for high school biology. The developed module demonstrated very high feasibility based on expert validation, practitioner evaluation, and user responses, indicating strong content quality, instructional design, practicality, and readability. These results confirm that integrating authentic local biodiversity data into structured, inquiry-oriented learning materials supports contextual and meaningful biology learning at the senior high school level. The findings imply that local potential–based modules can serve as effective alternatives to conventional textbooks by enhancing relevance, student engagement, and scientific reasoning. Future research is recommended to examine the effectiveness of the module through experimental implementation and to replicate the development framework in other ecological contexts to further test its scalability and impact on biodiversity literacy.

Commented [Le22]: It is necessary to clarify indicators of success (e.g. number of species, ecological index, or main findings).

Commented [Le23]: The relationship between empirical data and module structure has not been specifically defined (which parts of the data are integrated into the learning components?).

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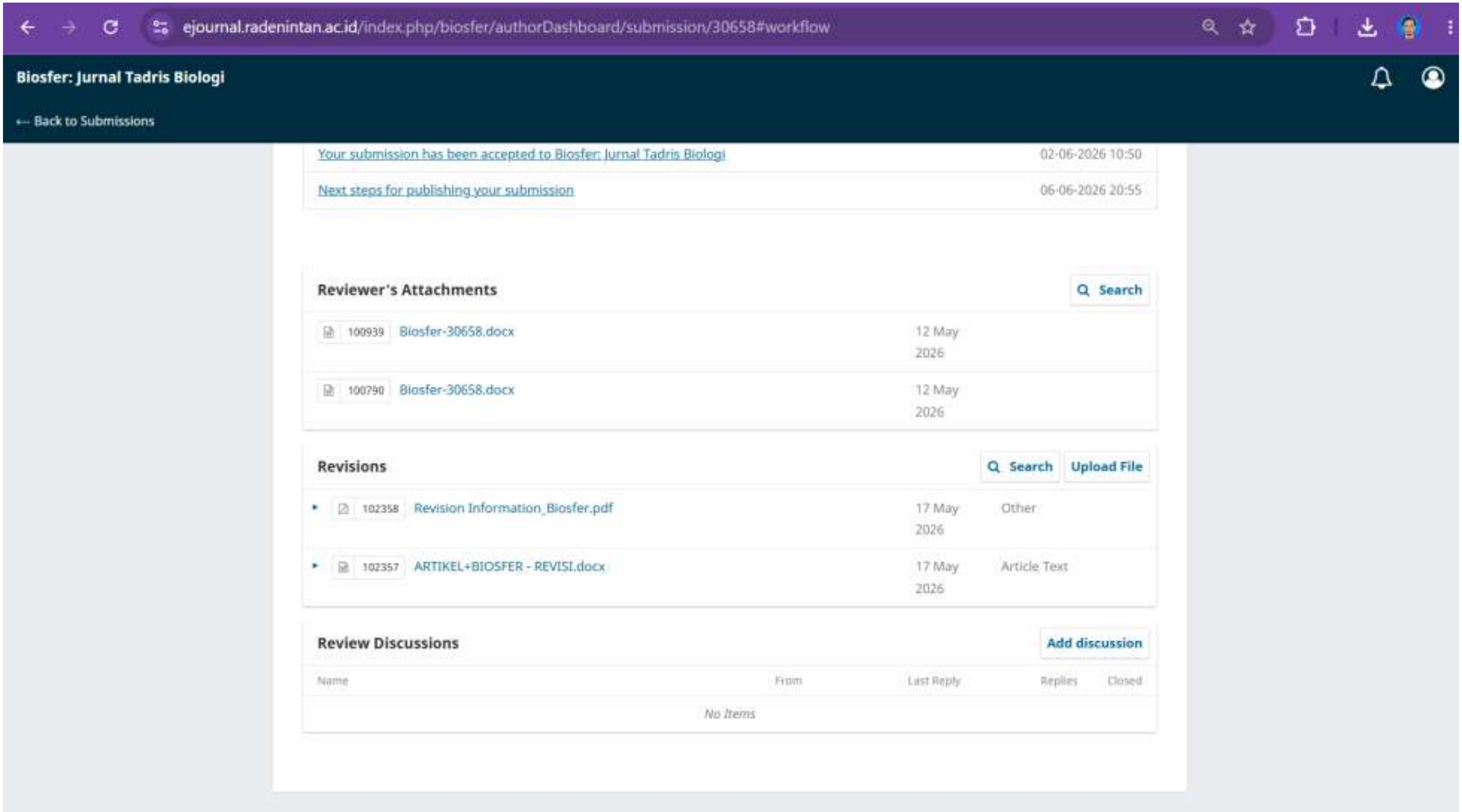
4. Artikel hasil revisi dan informasi revisi telah dikirim ke jurnal (17 Mei 2026)



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Link File informasi revisi: **https://drive.google.com/file/d/12kd00p2wFiw7DgGXDNYcKzum5moboGFy/view?usp=sharing**

Revision Information

DEVELOPMENT LOCAL POTENTIAL-BASED EXPLORATION MODULES FOR LEARNING ABOUT TERRESTRIAL INSECT DIVERSITY IN HIGH SCHOOLS

Reviewer 1

No	Review/ Comment	Explanation	Follow up/ improvement
Introduction			
1	This paragraph is repetitive with the previous paragraph; it needs to be summarized or combined to increase narrative efficiency.	Despite the recognized importance of biodiversity literacy, the teaching of insect diversity in high school biology remains largely dominated by textbook-based instruction that emphasizes classification and theoretical descriptions rather than direct engagement with living organisms Such abstract approaches often limit students' opportunities to observe, investigate, and interpret insect diversity within their surrounding environments, resulting in superficial understanding and reduced interest in ecological topics (Audrin & Audrin, 2023; Christ et al., 2022; White et al., 2025). Consequently, students may struggle to develop essential scientific skills, such as observation, identification, and data interpretation, which are fundamental to biological inquiry. These limitations highlight the need for instructional strategies that move beyond conventional classroom-based learning toward more concrete and experiential approaches in teaching insect biodiversity (Lampert et al., 2025; Siregar et al., 2025). The limited opportunities for students to directly observe and identify insects in natural environments further constrain the effectiveness of biodiversity learning in high school biology (Brown & White, 2024; Klopčič & Torkar, 2025). Without hands-on experiences, students tend to perceive insect diversity as a set of disconnected facts rather than as dynamic components of living ecosystems. This lack of authentic engagement restricts	Despite the recognized importance of biodiversity literacy, the teaching of insect diversity in high school biology remains largely dominated by textbook-based instruction emphasizing classification and theoretical descriptions rather than direct engagement with living organisms. Such abstract and classroom-centered approaches limit students' opportunities to directly observe, identify, investigate, and interpret insect diversity within authentic environmental contexts, resulting in superficial conceptual understanding and reduced interest in ecological topics (Audrin & Audrin, 2023; Brown & White, 2024; Christ et al., 2022; White et al., 2025). The lack of hands-on experiences further constrains the development of essential science process skills, including systematic observation, classification, and evidence-based reasoning, which are fundamental to biological inquiry (Hamidah et al., 2024; Siregar et al., 2025). Moreover, insufficient exposure to real-world biodiversity contexts may weaken students' environmental awareness and ecological responsibility, as learning experiences disconnected from students' immediate surroundings tend to reduce the relevance and meaningfulness of biodiversity education (Fajri et al., 2025; Id Babou et al., 2023; Nursidin et al., 2022). These limitations highlight the need for more contextual and experiential instructional approaches that actively engage students with biodiversity in their local environments (Klopčič & Torkar, 2025; Lampert et al., 2025).

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		the development of conceptual understanding and hinders the acquisition of essential science process skills, such as systematic observation, classification, and evidence-based reasoning, which are central to biological inquiry (Hamidah et al., 2024; Siregar et al., 2025). Moreover, insufficient exposure to real-world biodiversity contexts may weaken students' environmental awareness and sense of responsibility toward ecological conservation. When learning experiences fail to connect biological concepts with students' immediate surroundings, the relevance of biodiversity education becomes diminished, reducing students' motivation and ecological concern (Fajri et al., 2025; Id Babou et al., 2023; Nursidin et al., 2022). The introduction section has been revised by summarizing and integrating the overlapping paragraphs to improve narrative efficiency and coherence, as suggested by the reviewer. Repetitive explanations were reduced while maintaining the core arguments and supporting references related to contextual biodiversity learning, students' science process skills, and environmental awareness.	
2	The description is clear, but still narrative; can be strengthened with data or observational evidence.	Learning was largely focused on content delivery, with minimal integration of practical work or field-based activities, resulting in less meaningful learning experiences. Moreover, the instructional materials used were mainly standard Grade X biology textbooks and commercially published supplementary books that present biodiversity, ecosystem, and classification topics in a generalized and theoretical manner. The paragraph has been revised by incorporating observational and interview data obtained during a	Learning was largely focused on content delivery, with limited integration of practical work or field-based activities, resulting in less meaningful learning experiences. This condition was identified through observations and interviews conducted during a teaching assistance program in a private high school in Sukoharjo (Safitri & Nugroho, 2025). Interviews with five biology teachers revealed that 86% of learning was still dominated by lecture-based instruction, while local potential–based approaches had not been optimally implemented. In addition, questionnaire results showed that 72% of 50 students experienced difficulties in understanding biodiversity concepts because the instructional

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		teaching assistance program to strengthen the argument with empirical evidence. Quantitative findings from teachers and students were added to support the claim regarding the dominance of lecture based instruction and the limited use of contextual, local potential based learning materials	materials used were mainly theoretical and descriptive. Most learning resources consisted of standard biology textbooks and supplementary books that presented biodiversity topics in generalized ways with limited contextual and exploratory activities, causing learning to remain largely teacher-centered and less connected to students' surrounding environment (Safitri & Nugroho, 2025).
Method			
3	The term "identified" is too general; it is necessary to explain how the identification was carried out scientifically (e.g., insect sampling method, duration, tools).	The development procedure was adapted from the Borg and Gall model (Borg & Gall, 1983) and modified into seven stages following (Nugroho, 2017; Safitri & Nugroho, 2025): (1) Research and information collecting: literature review and a field study. The literature review examined relevant theories and curriculum requirements, while the field study identified the local potential of terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, which served as the empirical basis for the module content. The method description has been revised by clarifying the scientific procedures used to identify terrestrial insect diversity during the field study stage. Additional information regarding the sampling method, number of pitfall traps, sampling duration, trap composition, and identification procedures was incorporated to strengthen methodological transparency and scientific rigor.	The development procedure was adapted from the Borg and Gall model (Borg & Gall, 1983) and modified into seven stages (Nugroho & Subiyantoro, 2017; Safitri & Nugroho, 2025). The first stage, research and information collecting, included a literature review and a field study. The literature review examined relevant theories and curriculum requirements, while the field study investigated terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, as the empirical basis for the module content. The study employed a quantitative descriptive approach using the pitfall trap method, which is effective for sampling epigeic insects and representing terrestrial insect community structure (Császár et al., 2018; Fajar et al., 2023). A total of 12 pitfall traps were placed using stratified random sampling across different microhabitats. Sampling was conducted for three consecutive days with specimen collection every 24 hours. The captured insects were counted and identified to determine density, diversity, richness, evenness, and dominance indices, which were subsequently integrated into the module content (Armania & Nugroho, 2026).
4	The term "practical validation" is not defined; it needs clarification whether this measures practicality, usability, or implementation fidelity.	(6) Main field testing: practical validation was conducted by biology teachers and Grade X high school students The term "practical validation" has been clarified by specifying that the stage focused on evaluating the module's practicality and usability through teacher and	(6) Main field testing: practicality and usability evaluation of the module was conducted involving two biology teachers and Grade X high school students. The teachers evaluated the module using assessment instruments covering content quality, instructional organization, clarity, and suitability for classroom implementation, while students assessed readability, ease of use, and engagement during learning activities. The evaluation was carried out at the

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		student assessments. Additional explanations regarding the evaluation aspects, participants, and implementation setting were added to improve methodological clarity.	respective schools where the teachers conducted biology instruction.
5	Qualifications are too general; need to specify areas of expertise	The module was evaluated by six validators, comprising subject-matter experts and module design experts holding master's degrees, as well as two professional biology teachers with a minimum of five years of teaching experience in insect-related biology topics. The description of validator qualifications has been revised by specifying the areas of expertise of the subject-matter experts, instructional design experts, and biology teachers involved in the evaluation process to improve methodological clarity and credibility.	The module was evaluated by expert validators consisting of six subject-matter experts specializing in biology education, biodiversity, and entomology, and six instructional module design experts with expertise in biology learning materials and educational media development, all holding master's degrees. In addition, the module was assessed by two professional high school biology teachers with a minimum of five years of teaching experience, particularly in biodiversity and insect-related biology topics.
Results and Disscusion			
6	Quantitative data is presented, but the number of species/taxa is not specifically stated, so it is less ecologically informative.	The field study conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, recorded a total of 641 terrestrial insect individuals representing various taxa The results section has been revised by specifying the number of terrestrial insect species identified during the field study to provide clearer ecological information and improve the biological relevance of the findings.	The field study conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, recorded a total of 641 terrestrial insect individuals representing 23 terrestrial insect species from various taxa.
7	Index values (e.g. Shannon-Wiener, Evenness) are not shown so the interpretation of "moderate" is less transparent.	Overall, the calculated ecological indices indicated a moderate level of species diversity and richness, with uneven species distribution but no single taxon exhibiting strong dominance, suggesting a relatively stable and heterogeneous terrestrial insect community. The results section has been revised by explicitly presenting the ecological index values, including the Shannon–Wiener diversity index, Margalef richness index, evenness index, and dominance information, to improve transparency and strengthen the ecological	Overall, the ecological analysis showed that the terrestrial insect community had a moderate level of diversity, indicated by a Shannon–Wiener diversity index (H') of 1.978. The Margalef richness index (R1) of 3.558 indicated high species richness, while the evenness index (E) of 0.622 suggested uneven species distribution among taxa. In terms of dominance, the community was primarily dominated by insects from the orders Diptera and Hymenoptera, although no single species exhibited extreme dominance. The highest density value was recorded for *Scotinophara coarctata* (D = 0.007). These findings indicate a relatively heterogeneous terrestrial insect community structure

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		interpretation of the terrestrial insect community structure.	within the study area.
8	The claim is too general; it needs to be supported by the specific context of the research findings, not just the literature.	The use of locally generated biodiversity data offers greater educational value than generic instructional materials because it provides epistemically authentic and contextually meaningful learning experiences (Niemiller et al., 2021; Prasetyo et al., 2025; Yli-Panula et al., 2018). The discussion has been revised by linking the claim directly to the specific findings of the study. Additional explanations were added regarding how authentic terrestrial insect diversity data and ecological indices were integrated into exploration-based learning activities, thereby strengthening the contextual basis of the educational value discussed.	The use of locally generated biodiversity data in this study provided greater educational value than generic instructional materials because students learned through authentic ecological data derived directly from the terrestrial insect community at the Integrated Agricultural Laboratory of Jagan, Sukoharjo. The module integrated empirical findings such as species composition, abundance, diversity indices, and insect identification activities into exploration-based learning tasks, enabling students to connect abstract biodiversity concepts with observable ecological phenomena in their surrounding environment. Through these contextual learning experiences, students were encouraged to develop observation, classification, and data interpretation skills while engaging more actively in scientific inquiry. This finding is consistent with previous studies showing that biodiversity learning becomes more meaningful when supported by hands-on, experiential, and field-based activities that promote environmental awareness and higher-order thinking skills (Yli-Panula et al., 2018; Niemiller et al., 2021; Prasetyo et al., 2025).
9	The transformation process is not explained operationally (how data → material), this needs to be clarified.	In this study, these empirical findings were utilized as core content in the development of a local potential–based terrestrial insect diversity learning module. Information on species composition, abundance, and ecological indices was systematically transformed into instructional materials aligned with the principles of the Merdeka Curriculum, particularly the deep learning approach implemented in Phase E (Grade X) biodiversity topics. The discussion section has been revised by clarifying the operational process through which empirical biodiversity data were transformed into instructional materials. Additional explanations were added regarding	In this study, the empirical findings were operationally transformed into learning materials through several stages of content adaptation and instructional design. Data on terrestrial insect species composition, abundance, density, and ecological indices were first organized into terrestrial insect diversity topics and then integrated into module components such as insect identification guides, observation worksheets, and guided inquiry tasks. The empirical data were further contextualized into exploration-based learning activities that encouraged students to analyze local biodiversity patterns, compare ecological indices, and relate insect diversity to ecosystem stability within their surrounding environment. This transformation process was aligned with the principles of the Merdeka Curriculum, particularly the deep learning approach implemented in Phase E

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		the adaptation of ecological data into module components, including identification activities, observation worksheets, ecological data interpretation, and guided inquiry tasks aligned with the Merdeka Curriculum.	(Grade X) biodiversity topics, emphasizing active investigation, contextual understanding, and reflective learning.
10	Interpretation is too descriptive; no analysis of variation between validators	The results of the material validation conducted by six experts indicate that the developed module demonstrates a very high level of feasibility. The percentage scores ranged from 87.50% to 96.67%, with all validators categorizing the module as very feasible. The highest score of 96.67% was awarded by the second and sixth validators, while the lowest score of 87.50% still fell within the very feasible category. These findings suggest that the module content is scientifically accurate, conceptually appropriate, and aligned with the learning objectives of high school biology. Furthermore, the relevance of the material to instructional needs and the clarity of its presentation indicate that the module meets content feasibility standards. The interpretation of the validation results has been revised by incorporating an analysis of score variation among validators. Additional discussion was added to explain the possible differences in evaluative emphasis while highlighting the overall consistency and level of agreement regarding the module's feasibility and instructional quality.	The results of the material validation conducted by six experts indicate that the developed module demonstrates a consistently high level of feasibility, with percentage scores ranging from 87.50% to 96.67% and an average score of 93.47%, all categorized as very feasible. Although all validators agreed on the overall quality of the module, slight variations in scores suggest differences in evaluative emphasis among the experts. Validators who assigned higher scores (96.67%) considered the module to have strong content relevance, conceptual accuracy, and alignment with biology learning objectives, whereas the lower score (87.50%) indicates that several aspects, such as clarity of presentation, depth of explanation, or supporting visual components, still required refinement. Nevertheless, the relatively narrow range of score variation demonstrates a substantial level of agreement among validators regarding the module's academic quality and instructional suitability. These findings indicate that the module content is scientifically appropriate, pedagogically relevant, and capable of meeting content feasibility standards for high school biology learning.
11	The claim of "agreement" is not supported by statistical tests (e.g. inter-rater reliability).	The consistently high scores reflect strong agreement among experts regarding the quality of the module's instructional design, content organization, visual presentation, and adherence to ethical and copyright standards.	The consistently high scores indicate that all expert validators generally evaluated the module positively in terms of instructional design, content organization, visual presentation, and adherence to ethical and copyright standards. Although this study did not employ statistical analyses such as inter-rater reliability testing to formally measure the level of agreement among validators, the

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		The discussion has been revised to avoid overstating expert agreement. The statement was modified by clarifying that the study did not employ statistical measures such as inter-rater reliability testing, while still describing the consistent evaluation pattern reflected in the validation scores.	relatively narrow range of scores suggests a comparable pattern of evaluation across experts regarding the overall feasibility and quality of the module.
12	It's good, but it hasn't shown the concrete impact of the revision on product quality.	The suggestions provided by subject-matter experts and module design experts, as summarized in Table 6, indicate that the revisions primarily focused on enhancing scientific accuracy, instructional clarity, and visual quality of the module. The discussion has been revised by incorporating specific examples of expert suggestions and explaining their direct impact on improving the module's scientific accuracy, visual quality, instructional clarity, and pedagogical usability. This revision was intended to more clearly demonstrate how the expert feedback contributed to enhancing the overall product quality.	The suggestions provided by subject-matter experts and module design experts, as summarized in Table 6, indicate that the revisions focused on improving scientific accuracy, instructional clarity, visual quality, and pedagogical usability of the module. The revisions included adding Latin names for insect species to strengthen scientific precision, correcting typographical inaccuracies, improving image resolution, and adding insect illustrations to support conceptual understanding and visual engagement. In addition, the evaluation section was refined to better align with learning objectives, clearer module usage instructions were provided, and a learning implementation section was added to improve classroom applicability. Overall, these revisions enhanced the module's readability, scientific validity, visual attractiveness, and instructional functionality for high school biology learning. These revisions also ensure that the module meets academic standards in biology learning and supports precise conceptual understanding (Fahmi et al., 2025; Foster et al., 2014)
13		The results of the practitioner validation presented in Table 7 indicate that the terrestrial insect diversity module achieved a high level of feasibility. Has been revised according to suggestions.	The results of the practitioner validation presented in Table 7 indicate that the terrestrial insect diversity module achieved a very feasible.
14	There is no analysis of data distribution (e.g. variation or tendency towards extreme scores).	The user validation results presented in Table 8 demonstrate that the terrestrial insect diversity module achieved a very high level of feasibility from the students' perspective. All 25 Grade X students assigned	The user validation results presented in Table 8 indicate that the terrestrial insect diversity module received highly positive evaluations from Grade X students. All 25 students assigned scores exceeding 87%, with an average score of 94.96%, indicating a consistently positive perception. Although this study

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		scores exceeding 87%, with an average score of 94.96%, consistently categorizing the module as very feasible. The discussion has been revised by clarifying that the study did not include statistical analyses of data distribution, such as variance or tendency analysis. The interpretation was adjusted to describe the overall pattern of student responses without overstating statistical conclusions.	did not perform statistical analyses of data distribution, such as variance or distribution tendency analysis, the relatively high and closely clustered scores suggest that students generally shared similar positive evaluations regarding the quality and usability of the module.
Conclusions And Suggestion			
15	It is necessary to clarify indicators of success	Komentar reviewer: It is necessary to clarify indicators of success Bagian kesimpulan yang dikomentari: This study successfully characterized terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo and utilized the empirical findings as core content for developing a local potential–based exploration module for high school biology. The conclusion has been revised by clarifying the indicators of success in both the biodiversity characterization process and the module development outcomes.	This study successfully characterized terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, identifying 641 terrestrial insect individuals representing 23 species and generating ecological index data that were subsequently utilized as core content in the development of a local potential–based exploration module for high school biology.
16	it is necessary to mention key quantitative values (e.g. average percentage) to strengthen the claim of "very high feasibility".	The developed module demonstrated very high feasibility based on expert validation, practitioner evaluation, and user responses, indicating strong content quality, instructional design, practicality, and readability. The conclusion has been revised by incorporating key quantitative validation results to strengthen the claim regarding the module's very high feasibility. Average percentage scores from expert, practitioner, and student	The developed module demonstrated a very high level of feasibility, as indicated by the expert validation results for learning module design (92.61%) and material content (93.47%), both categorized as very feasible. In addition, practitioner evaluations conducted by biology teachers yielded average scores of 87.50% for both module and content aspects, while student user validation produced an average score of 94.96%, consistently indicating very feasible criteria. These findings demonstrate that the module possesses strong content quality, instructional design, practicality, readability, and suitability for high school biology

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		validations were added to provide clearer empirical support for the conclusion.	learning.
17	There is no direct data that measures engagement or reasoning; these need to be avoided or supported with data.	The findings imply that local potential–based modules can serve as effective alternatives to conventional textbooks by enhancing relevance, student engagement, and scientific reasoning. The conclusion has been revised by removing claims related to student engagement and scientific reasoning, as these variables were not directly measured in the study. The statement was refined to remain aligned with the actual research findings and available data.	The findings imply that local potential–based modules can serve as effective alternatives to conventional textbooks by providing more contextual, relevant, and authentic learning resources for high school biology learning.

Reviewer 2

No	Review/ Comment	Explanation	Follow up/ improvement
Abstract			
1	The objective is clear, but it is too long and contains two focuses at once (biodiversity analysis and module development). It would be better to summarize it and emphasize the direct relationship between the two.	This study aimed to analyze terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, and to develop a local potential–based learning module aligned with Phase E of the Merdeka Curriculum for Grade X biology. The objective statement in the abstract has been revised by simplifying the sentence structure and integrating the biodiversity analysis and module development aspects into a more concise and directly connected research objective.	This study aimed to develop a local potential–based learning module on terrestrial insect diversity for Grade X biology by utilizing biodiversity data obtained from the Integrated Agricultural Laboratory of Jagan, Sukoharjo.
2	Redundant ("research employed a research…"). The sentence needs to be simplified and a brief explanation of the R&D model used (e.g., Borg & Gall) is needed to be more specific.	The research employed a research and development (R&D) design consisting of biodiversity data collection, module planning and design, expert validation, practitioner validation, and limited user testing. The sentence has been revised to eliminate redundancy and to specify the research and development model used in the study, namely the modified Borg and Gall R&D model.	The study employed a modified Borg and Gall research and development (R&D) model consisting of biodiversity data collection, module planning and design, expert validation, practitioner evaluation, and limited user testing.
3	The term "very high feasibility" is too general. A brief explanation of the criteria or standards used to determine this category is necessary	The validation results indicated very high feasibility, with expert scores exceeding 87% and positive evaluations from teachers and students in terms of clarity, relevance, readability, and usability. The abstract has been revised by clarifying that the "very feasible" category was determined based on established validation criteria and supported by quantitative evaluation scores from experts, teachers, and students.	The validation results indicated that the module met the very feasible criteria based on the established validation standards, with expert, teacher, and student evaluation scores exceeding 87%, particularly in aspects of clarity, relevance, readability, and usability.

No	Review/ Comment	Explanation	Follow up/ improvement
Introduction			
4	The opening sentence is strong and relevant, but still general; it could be sharpened by adding global quantitative data to increase urgency.	Terrestrial insects play a fundamental role in maintaining global ecosystem stability through their functions as pollinators, decomposers, components of food webs, and biological indicators of environmental change. The introductory paragraph has been revised by incorporating global quantitative data and recent scientific evidence regarding insect decline and pollination dependency to strengthen the urgency and ecological relevance of the study.	Terrestrial insects play a fundamental role in maintaining global ecosystem stability through their functions as pollinators, decomposers, components of food webs, and biological indicators of environmental change. Globally, more than 75% of food crops depend partly on animal pollination, primarily by insects, while recent studies indicate that over 40% of insect species are threatened with extinction due to habitat degradation and environmental disturbances (Potts et al., 2010). These conditions highlight the ecological importance of insects and their significant contribution to ecosystem services that support biodiversity, agricultural productivity, and ecological resilience.
5	The term "unprecedented threats" needs to be strengthened with indicators or empirical data so that it does not seem normative.	However, terrestrial insect diversity is currently facing unprecedented threats driven by habitat loss, land-use change, rapid urbanization, and climate change, which have led to declining insect populations across many regions worldwide. The introductory paragraph has been revised by replacing the normative term “unprecedented threats” with empirical indicators and quantitative data from recent global studies on insect population decline and extinction risk to strengthen the scientific basis of the statement.	However, terrestrial insect diversity is currently experiencing significant declines due to habitat loss, land-use change, rapid urbanization, pesticide exposure, and climate chang. (Farooq et al., 2025; Vaz et al., 2023). Recent global assessments estimate that more than 40% of insect species are threatened with extinction, while insect populations in several regions have declined by approximately 1–2% annually, potentially disrupting ecosystem stability and ecological services (Sánchez-bayo & Wyckhuys, 2019; Wagner et al., 2021).
6	The explanation is good, but still generic; it could be strengthened with concrete examples of learning practices.	Such abstract approaches often limit students’ opportunities to observe, investigate, and interpret insect diversity within their surrounding environments, resulting in superficial understanding and reduced interest in ecological topics (Audrin & Audrin, 2023; Christ et al., 2022; White et al., 2025). The statement has been revised by adding concrete examples of classroom learning practices, such as textbook reading, worksheet-based activities, and image	Such abstract approaches often limit learning activities to textbook reading, worksheet completion, and image-based identification without direct field observation or interaction with real insect specimens. As a result, students have limited opportunities to authentically observe, investigate, and interpret insect diversity within real ecological contexts, which may lead to superficial conceptual understanding and reduced interest in ecological topics (Audrin & Audrin, 2023; Christ et al., 2022; White et al., 2025).

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		identification without field observation, to provide a clearer contextual explanation of how abstract instruction limits authentic biodiversity learning experiences.	
7	This observation is important, but the methodology is not explained; it could potentially be considered academically weak.	Within the Indonesian educational context, the implementation of the Merdeka Curriculum emphasizes deep learning approaches that promote meaningful understanding, student autonomy, and contextual learning experiences, particularly in high school biology at Phase E, where biodiversity topics are introduced. However, preliminary observations conducted in a public high school in Sukoharjo indicate that classroom practices have not yet fully reflected these principles. The statement regarding preliminary observations has been revised by clarifying the method used to obtain the information, namely classroom observations and interviews conducted during a teaching assistance program. This revision was intended to strengthen the academic credibility and methodological clarity of the observation findings.	However, classroom observations and interviews conducted during a teaching assistance program in a high school in Sukoharjo revealed that learning practices were still predominantly teacher-centered and focused on textbook-based instruction, with limited integration of contextual and exploration-based learning activities aligned with the principles of the Merdeka Curriculum.
8	Research objectives format is inconsistent (mix of questions and statements); needs to be standardized	Accordingly, this study aims to 1) How is the terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, characterized as core content for the development of a local potential–based learning module? The research objectives have been revised to improve consistency in format by converting the first objective from an interrogative form into a declarative statement, ensuring uniformity across all stated objectives.	Accordingly, this study aims to 1) characterize the terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, as core content for the development of a local potential–based learning module,
Method			

No	Review/ Comment	Explanation	Follow up/ improvement
9	The statement is still general; it is necessary to explicitly state the evaluation objectives (validity, practicality, or effectiveness) so that the methodological focus is clearer.	This study employed a Research and Development (R&D) design to develop and evaluate a local potential–based exploration module on terrestrial insect diversity for high school biology. The methodological statement has been revised by explicitly specifying the evaluation focus of the study, particularly the validity and practicality aspects of the developed module, to improve methodological clarity and consistency with the research procedures	This study employed a Research and Development (R&D) design to develop and evaluate the validity and practicality of a local potential–based exploration module on terrestrial insect diversity for high school biology.
10	Model modifications have not been explained conceptually; a stronger theoretical rationale is needed for why certain stages are changed or removed.	The development procedure was adapted from the Borg and Gall model (Borg & Gall, 1983) and modified into seven stages following. The method section has been revised by providing a conceptual rationale for modifying the Borg and Gall development model. Additional explanation was added to clarify that the modification was intended to align the development stages with the scope and objectives of the study, which focused on product development, validity evaluation, and limited practicality testing rather than large-scale implementation and dissemination.	The development procedure was adapted from the Borg and Gall model (Borg & Gall, 1983) and modified into seven stages following Nugroho & Subiyantoro (2017) and Safitri & Nugroho (2025). The modification was conducted to adjust the original model to the scope and objectives of this study, which focused on product development, validity evaluation, and limited practicality testing rather than large-scale dissemination and effectiveness testing. Therefore, several stages of the original Borg and Gall model, such as operational field testing, dissemination, and mass implementation, were not included. The simplified seven-stage procedure was considered more appropriate for developing and evaluating the feasibility of a local potential–based biology learning module within a limited educational context. Despite this adjustment, the essential principles of R&D methodology were maintained.
11	The criteria for selecting validators are not clear (e.g. specific areas of expertise, experience, minimum number).	Planning: planning the learning objectives, determining the main topics and instructional content, designing the structure and components of the learning module, and selecting validators, The planning stage description has been revised by clarifying the criteria used for selecting validators, including their areas of expertise and professional	Planning: planning the learning objectives, determining the main topics and instructional content, designing the structure and components of the learning module, and selecting validators for product evaluation. The validators consisted of subject-matter experts in biology education, biodiversity, and entomology, module design experts specializing in instructional media and biology learning materials, professional biology teachers with teaching experience in high school biology, and Grade X students as user evaluators for limited field testing.

No	Review/ Comment	Explanation	Follow up/ improvement
		teaching experience, to strengthen the methodological transparency of the study.	
12	Justification is administrative (time/resources), not methodological; it needs to be supported by scientific arguments/design-based research rationale.	The modification was undertaken to enhance feasibility within the scope and timeframe of the study, as the original stages of dissemination and large-scale implementation require extended resources and were beyond the primary objective of this research, which focused on product development and feasibility evaluation at a limited scale. This explanation is omitted because it has been explained at the beginning of the method.	
13	It is not clear how the numbers are divided between subject-matter vs design experts.	The module was evaluated by six validators, The description of validator qualifications has been revised by specifying the areas of expertise of the subject-matter experts, instructional design experts, and biology teachers involved in the evaluation process to improve methodological clarity and credibility.	The module was evaluated by expert validators consisting of six subject-matter experts specializing in biology education, biodiversity, and entomology, and six instructional module design experts with expertise in biology learning materials and educational media development, all holding master's degrees. In addition, the module was assessed by two professional high school biology teachers with a minimum of five years of teaching experience, particularly in biodiversity and insect-related biology topics.
Results and Disscusion			
14	Need numerical data or percentages to support the claim of "relatively high abundances".	Several groups, including mosquitoes, grasshoppers, crickets, and ants, showed relatively high abundances, Data on the number of individuals has been added	Several groups, including mosquitoes (number of species: 215) and javelins (number of species: 156), showed relatively high abundances, indicating their adaptability to the local environment, while other taxa were represented by fewer individuals, reflecting variation in species distribution within the habitat.
15	Index values (e.g. Shannon-Wiener, Evenness) are not shown so the interpretation of "moderate" is less transparent	Overall, the calculated ecological indices indicated a moderate level of species diversity and richness, The results section has been revised by explicitly presenting the ecological index values, including the Shannon–Wiener diversity index, Margalef richness index, evenness index, and dominance information, to improve transparency and strengthen the ecological interpretation of the terrestrial insect community structure.	Overall, the ecological analysis showed that the terrestrial insect community had a moderate level of diversity, indicated by a Shannon–Wiener diversity index (H') of 1.978. The Margalef richness index (R1) of 3.558 indicated high species richness, while the evenness index (E) of 0.622 suggested uneven species distribution among taxa. In terms of dominance, the community was primarily dominated by insects from the orders Diptera and Hymenoptera, although no single species exhibited extreme dominance. The highest density value was recorded for *Scotinophara coarctata* (D = 0.007). These findings indicate a

No	Review/ Comment	Explanation	Follow up/ improvement
			relatively heterogeneous terrestrial insect community structure within the study area.
16	The statement is still assumptive because it is not supported by empirical data from this study (there is no effectiveness test).	By engaging with real ecological data from their immediate environment, students are able to connect abstract biodiversity concepts such as species diversity, population structure, and ecological balance with observable phenomena, thereby strengthening conceptual understanding and environmental awareness. The statement has been revised to avoid assumptive claims regarding student learning outcomes, conceptual understanding, and environmental awareness, as these variables were not empirically measured through effectiveness testing in the present study.	By incorporating real ecological data derived from the students' surrounding environment, the module provides contextual learning materials that relate biodiversity concepts, such as species diversity, population structure, and ecological balance, to observable ecological phenomena.
17	The term "success indicators" is not precise; you should use "learning indicators" or "learning outcomes".	This terrestrial insect diversity module uses the following success indicators: The term has been replaced with learning indicators	This terrestrial insect diversity module uses the following learning indicators:
18	Normative claims; need to be supported by the framework/model design used	This terrestrial insect diversity module uses the following success indicators: 10.1 Analyze various levels of insect diversity and their role in the surrounding environment, along with threats and conservation, 10.2 Conduct observational research on various levels of insect diversity and their role in the surrounding environment by comparing insect diversity data from various regions in Indonesia from relevant sources, 10.3 Identify terrestrial insect species, analyze research data, calculate various ecological indices (Shannon-Wiener, Dominance Index, Evenness Index), and draw conclusions.	The terrestrial insect diversity module was developed based on Phase E biology learning indicators related to biodiversity concepts and ecological investigation skills. The indicators include: (1) analyzing levels of insect diversity, ecological roles, environmental threats, and conservation efforts; (2) conducting observational investigations of insect diversity in the surrounding environment using relevant biodiversity data sources; and (3) identifying terrestrial insect species, analyzing ecological research data, calculating ecological indices such as the Shannon–Wiener diversity index, dominance index, and evenness index, and interpreting ecosystem conditions based on the obtained results.

No	Review/ Comment	Explanation	Follow up/ improvement
		The learning indicators section has been revised by simplifying repetitive statements, improving consistency in the indicator structure, and clarifying the relationship between biodiversity concepts, ecological investigation activities, and data analysis skills developed through the module.	
19	Claims are not supported by specific indicators from the assessment instrument.	These findings suggest that, from the practitioners' perspective, the module is pedagogically appropriate, systematically organized, and contextually relevant for classroom implementation in high school biology learning. The discussion has been revised by explicitly linking the interpretation to specific assessment indicators evaluated by practitioners, including content clarity, instructional organization, readability, learning activities, and contextual relevance, thereby avoiding unsupported general claims.	These findings suggest that, from the practitioners' perspective, the module demonstrates strong instructional usability in terms of content clarity, organization of learning materials, suitability of learning activities, readability, and relevance to high school biology learning contexts. The high evaluation scores across both module and content aspects indicate that the module is considered appropriate for supporting classroom implementation and biodiversity learning activities
20	Example of unclear revision (shows no change)	Correcting misspelled words (typos) and correcting them according to writing rules. For example, pitfall trap becomes pitfall trap, Density becomes Density.	Correcting misspelled words (typos) and correcting them according to writing rules. For example, pitfal trap becomes pitfall trap, Density becomes Density.
Conclusions And Suggestion			
21	It is necessary to clarify indicators of success (e.g. number of species, ecological index, or main findings).	This study successfully characterized terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo and utilized the empirical findings as core content	This study successfully characterized terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, documenting 641 terrestrial insect individuals representing 23 species. The ecological analysis revealed a moderate level of diversity (Shannon–Wiener index, H' = 1.978), high species richness (Margalef index, R1 = 3.558), and low evenness (E = 0.622), with the insect community predominantly dominated by Diptera and Hymenoptera. The highest density value was recorded for *Culicida* (D = 0.010). These empirical findings were subsequently utilized as core content in the development of a local potential–based exploration module for high school biology

No	Review/ Comment	Explanation	Follow up/ improvement
22	The relationship between empirical data and module structure has not been specifically defined (which parts of the data are integrated into the learning components?).	These empirical findings were subsequently utilized as core content in the development of a local potential–based exploration module for high school biology. The conclusion has been revised by clarifying how the empirical biodiversity data were specifically integrated into the module structure, including identification materials, ecological analysis activities, observation worksheets, and guided inquiry tasks.	These empirical findings were subsequently integrated into several module components, including insect identification materials, ecological index analysis activities, observation worksheets, biodiversity data interpretation tasks, and guided inquiry activities used to support contextual biodiversity learning in high school biology.

Note: Thank you for the feedback and suggestions. We have revised the article according to the reviewer's comments and recommendations. We hope these revisions meet the reviewer's expectations and improve the quality of our article.

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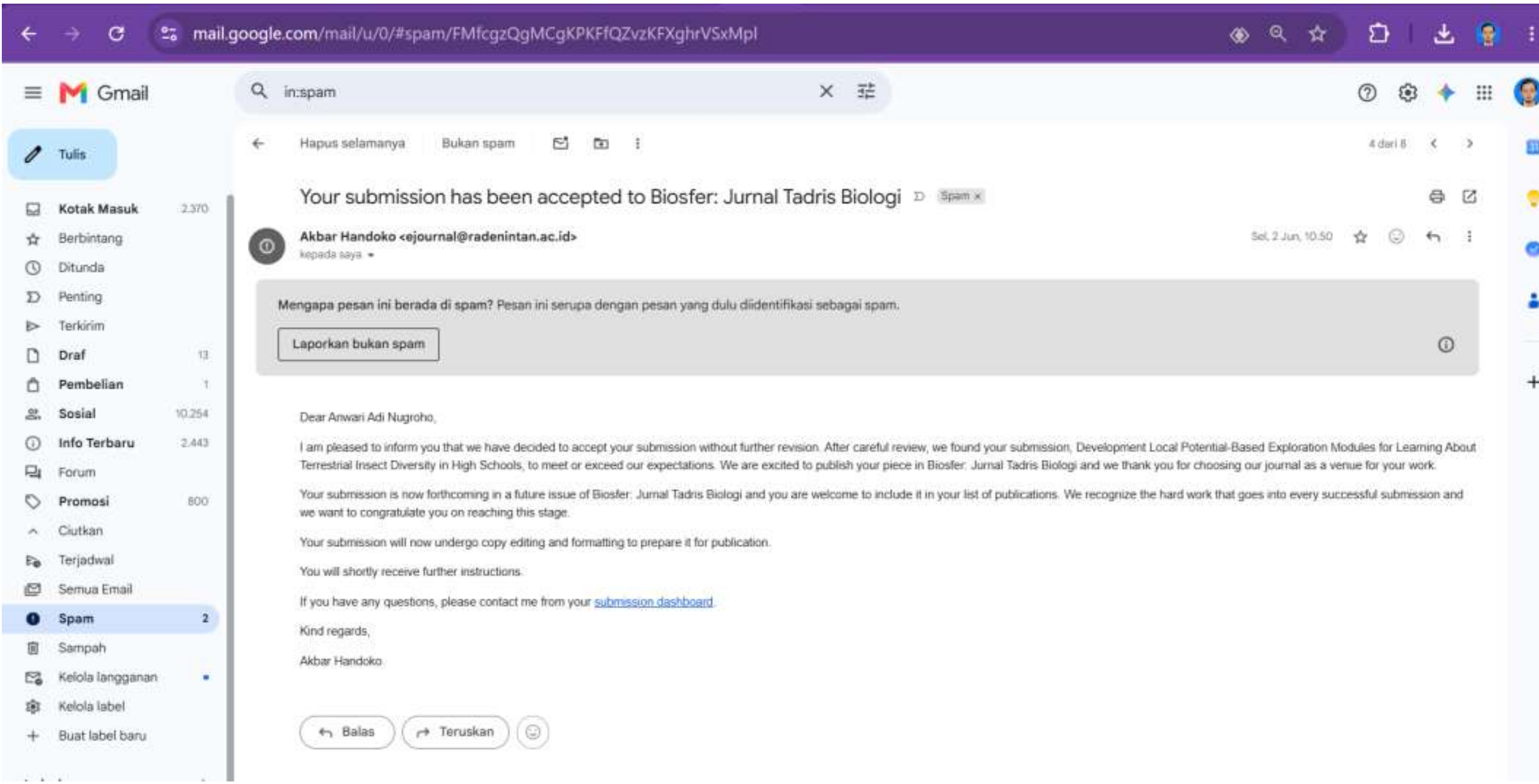

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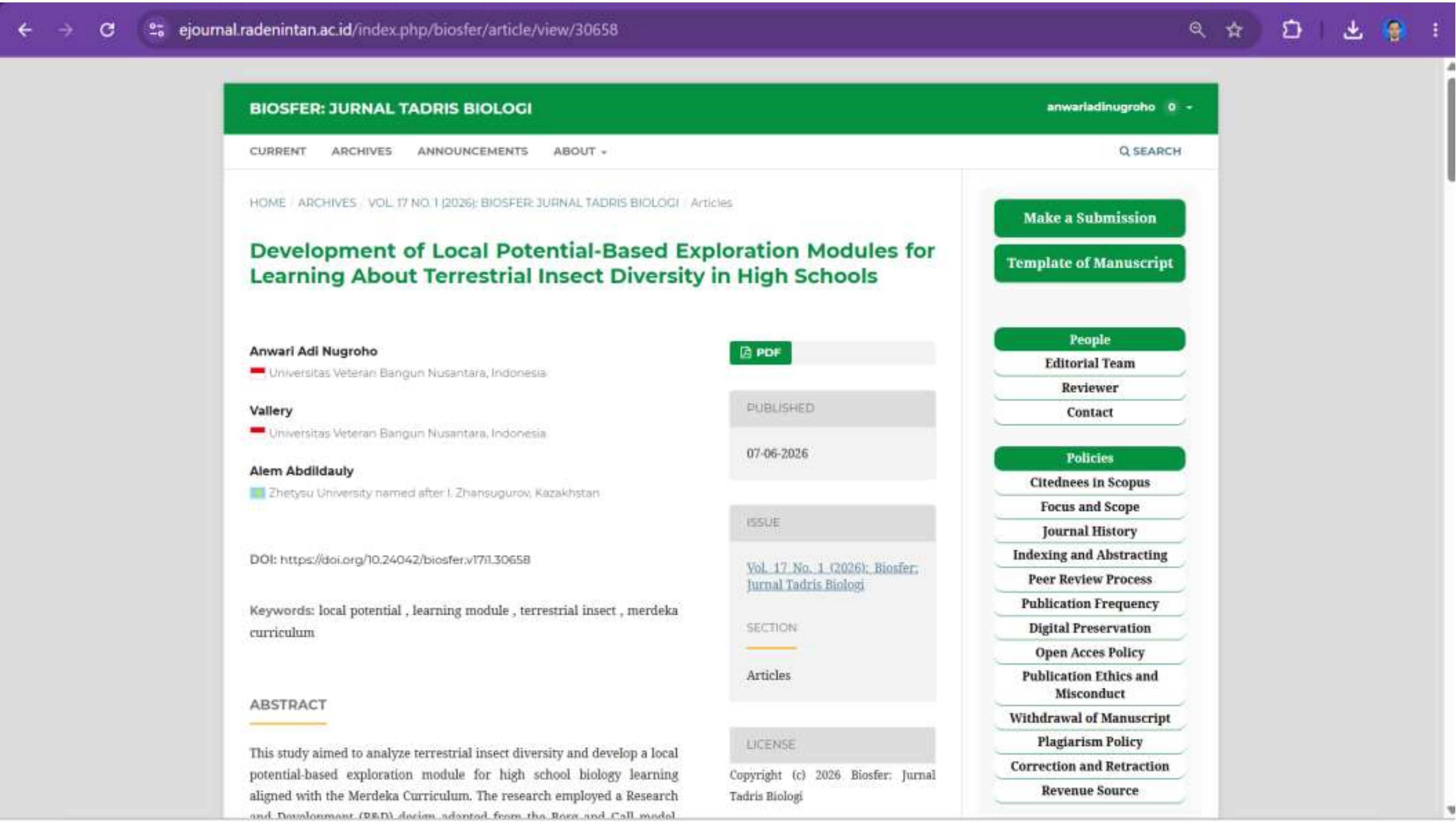

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Development of Local Potential-Based Exploration Modules for Learning About Terrestrial Insect Diversity in High Schools

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Keywords: local potential , learning module , terrestrial insect , merdeka curriculum

ABSTRACT

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Development of Local Potential-Based Exploration Modules for Learning About Terrestrial Insect Diversity in High Schools

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ABSTRACT

This study aimed to analyze terrestrial insect diversity and develop a local potential-based exploration module for high school biology learning aligned with the Merdeka Curriculum. The research employed a Research and Development (R&D) design adapted from the Borg and Gall model, consisting of biodiversity data collection, module design, expert validation, and limited field testing. Field observations conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo recorded 641 terrestrial insect individuals with a moderate level of species diversity and a relatively stable ecological structure. These empirical data were transformed into structured learning materials incorporating exploration activities, guided inquiry, and reflective tasks. The developed module was validated by subject-matter experts, instructional design experts, biology teachers, and Grade X students. The validation results indicated a very high level of feasibility, with expert scores exceeding 87% and positive responses from both teachers and students in terms of clarity, relevance, readability, and usability. These findings suggest that integrating authentic local biodiversity data into instructional modules enhances the quality and meaningfulness of biology learning. The module also demonstrates strong potential for adaptation in other regions through contextualization based on local biodiversity resources.

Pengembangan Modul Eksplorasi Berbasis Potensi Lokal untuk Pembelajaran Keanekaragaman Serangga Darat di Sekolah Menengah Atas

ABSTRAK: *Penelitian ini bertujuan untuk menganalisis keanekaragaman serangga darat serta mengembangkan modul eksplorasi berbasis potensi lokal untuk pembelajaran biologi SMA yang selaras dengan Kurikulum Merdeka. Penelitian menggunakan desain Research and Development yang diadaptasi dari model Borg dan Gall, meliputi pengumpulan data biodiversitas, perancangan modul, validasi ahli, dan uji coba terbatas. Hasil observasi lapangan di Laboratorium Pertanian Terpadu Jagan, Sukoharjo mencatat 641 individu serangga darat dengan tingkat keanekaragaman sedang dan struktur ekologi yang relatif stabil. Data empiris tersebut kemudian diintegrasikan ke dalam bahan ajar yang memuat aktivitas eksplorasi, penyelidikan terbimbing, dan refleksi. Modul yang dikembangkan divalidasi oleh ahli materi, ahli desain pembelajaran, guru biologi, dan siswa kelas X. Hasil validasi menunjukkan tingkat kelayakan yang sangat tinggi, dengan skor ahli di atas 87% serta respons positif dari guru dan siswa terkait kejelasan, relevansi, keterbacaan, dan kegunaan. Temuan menunjukkan integrasi data keanekaragaman hayati lokal dalam modul pembelajaran mampu meningkatkan kualitas dan kebermaknaan serta dimanfaatkan di berbagai daerah berbasis potensi lokal.*

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INTRODUCTION

Terrestrial insects play a crucial role in maintaining ecosystem stability through their functions as pollinators, decomposers, and key components of food webs. Their ecological contributions are fundamental to sustaining biodiversity, supporting agricultural productivity, and maintaining environmental balance (Angon et al., 2023; Rehman et al., 2022). However, recent global trends indicate a significant decline in insect populations, driven by habitat loss, climate change, and anthropogenic disturbances (Wagner, 2020; Wilson & Fox, 2021). This decline not only threatens ecological resilience but also reduces the availability of biological resources essential for environmental education. In this context, strengthening biodiversity literacy has become increasingly important, particularly within formal education systems. High school biology education represents a strategic platform for fostering ecological awareness and scientific understanding among students (Honra, 2025; Sembiring & Yusuf, 2025). Therefore, integrating authentic biodiversity knowledge into educational practices is essential to address both ecological and pedagogical challenges.

Despite the recognized importance of biodiversity education, classroom practices often remain detached from real ecological contexts. Biology instruction at the secondary school level frequently emphasizes theoretical knowledge and textbook-based learning, limiting students' opportunities to engage directly with living organisms (Park et al., 2020; Situmorang et al., 2024). As a result, students tend to perceive biodiversity as abstract information rather than as dynamic ecological phenomena. This gap between theory and real-world experience can lead to superficial understanding and reduced interest in environmental topics (Chawla, 2020; Grennfelt et al., 2020). Furthermore, limited exposure to local biodiversity restricts the development of essential scientific skills such as observation, classification, and data interpretation (Echeverria et al., 2021; Ekström, 2021). These conditions highlight a persistent issue in biology education, where learning remains conceptually isolated from students' immediate environments. Consequently, there is a need to reorient instructional approaches toward more contextual and experiential learning.

The urgency of improving biodiversity education is further emphasized within the framework of the Merdeka Curriculum in Indonesia, which promotes deep learning, student autonomy, and contextual learning experiences. In practice, however, the implementation of these principles remains inconsistent, particularly in biology classrooms (Hastangka et al., 2025; Hunaepi & Suharta, 2024). Preliminary observations indicate that teaching practices are still predominantly teacher-centered, with limited opportunities for student exploration and inquiry-based activities. Instructional materials are often generalized and fail to incorporate local ecological data, reducing their relevance to students' lived experiences (Duggan et al., 2020; Hunaepi & Suharta, 2024). This disconnect undermines the effectiveness of learning and weakens students' environmental awareness. Moreover, the absence of locally contextualized learning resources prevents students from recognizing the ecological significance of their surrounding environments. Therefore, developing instructional materials that integrate local biodiversity is both an educational necessity and a curriculum demand.

One promising approach to addressing these challenges is the use of local potential-based learning, which emphasizes the integration of locally available resources into instructional design. By utilizing local biodiversity as a learning context, students can connect abstract biological concepts with observable phenomena in their environment (Hamzah & Nurahasana, 2023; Wiegelmann & Zabel, 2021). This approach aligns with place-based education principles, which have been shown to enhance student engagement, conceptual understanding, and environmental responsibility (Hernandez, 2023; Yemini et al., 2025). In addition, incorporating authentic ecological data into learning materials can

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foster higher order thinking skills and scientific reasoning (Kwangmuang et al., 2021; Li et al., 2024). Learning modules, in particular, offer a structured format for implementing such approaches by guiding students through exploration, inquiry, and reflection. Consequently, local potential-based modules represent a pedagogically sound strategy for improving biodiversity learning in high school settings. This rationale underscores the importance of developing context-specific instructional materials grounded in empirical data.

Previous studies have demonstrated the effectiveness of inquiry-based and field-based learning approaches in enhancing students' understanding of biodiversity. Research indicates that direct engagement with natural environments enables students to construct knowledge through observation, data collection, and scientific investigation (Bae & Lai, 2020; Schilhab, 2021). Additionally, modules incorporating local contexts have been reported to improve science literacy, motivation, and conceptual comprehension (Uslan et al., 2024). Several studies also highlight the role of research-based learning materials in promoting conservation awareness and critical thinking skills (Philokyprou, 2025; Restović & Bulic, 2024). Furthermore, the integration of citizen science and project-based learning has been shown to strengthen students' connection to nature and biodiversity knowledge (Forti, 2023; Niemiller et al., 2021). These findings collectively suggest that contextual and experiential approaches are highly beneficial in biology education. However, the implementation of such approaches remains limited in many educational contexts.

Although existing studies provide valuable insights, several limitations remain evident. Many instructional modules are designed in a generalized manner and do not explicitly incorporate specific local ecosystems, reducing their contextual relevance (Duggan et al., 2020; Setiyanika et al., 2023). In addition, research focusing specifically on terrestrial insects as primary learning objects is still relatively scarce, despite their ecological importance and diversity (Slade & Ong, 2023; Stoler & Relyea, 2020). Most studies also emphasize either inquiry-based learning or local potential integration separately, rather than combining both approaches in a single instructional framework. Moreover, limited attention has been given to the systematic integration of empirical biodiversity data into structured learning modules. These gaps indicate the need for more comprehensive and context-specific instructional designs that bridge theoretical knowledge with real ecological conditions. Addressing these limitations is essential for advancing the quality and relevance of biology education.

Based on the identified gaps, there is a clear need to develop a learning module that integrates local biodiversity data, particularly terrestrial insect diversity, into structured exploration-based activities. Such a module should not only provide scientific content but also facilitate inquiry, data analysis, and reflective learning. By utilizing real ecological data from local environments, students can develop deeper conceptual understanding and stronger connections to biodiversity issues. In addition, integrating empirical research findings into instructional materials can enhance the authenticity and credibility of the learning process. This approach also aligns with design-based research principles, which emphasize the development of practical and adaptable educational solutions (Fowler & Leonard, 2024; Tinoca et al., 2022). Therefore, a context-specific exploration module based on local potential offers a meaningful contribution to both theory and practice in biology education. This perspective forms the foundation for the present study.

Accordingly, this study aims to: (1) characterize terrestrial insect diversity at the Integrated Agricultural Laboratory of Jagan, Sukoharjo as core content for learning; (2) develop a local potential-based exploration module for high school biology; and (3) evaluate the feasibility of the developed module through expert, practitioner, and student validation. Theoretically, this study contributes to the development of contextual learning frameworks

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that integrate local biodiversity into biology education. Practically, it provides a structured and adaptable instructional module that can be implemented in high school classrooms and replicated in other regions. By combining empirical ecological data with inquiry-based learning design, this study offers an innovative approach to enhancing biodiversity literacy. Furthermore, the findings are expected to support the implementation of the Merdeka Curriculum by promoting meaningful, student-centered learning experiences. Ultimately, this research seeks to bridge the gap between ecological knowledge and classroom instruction through context-based educational innovation.

METHOD

This study employed a Research and Development (R&D) design aimed at developing and evaluating a local potential-based exploration module on terrestrial insect diversity for high school biology. The R&D approach was selected because it enables the systematic development of educational products while simultaneously assessing their feasibility and practicality in real learning contexts. The study adapted the Borg and Gall development model, which was modified into seven operational stages to suit the scope and feasibility of this research. This design is appropriate as it integrates empirical data collection, product development, validation, and iterative revision, thereby ensuring that the resulting module meets both scientific and pedagogical standards.

The research was conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, Indonesia, which served as both the source of empirical biodiversity data and the contextual basis for module development. The implementation phase involving users took place in a public senior high school in Sukoharjo. The study was carried out over a six-month period, from March to August 2025, encompassing field data collection, module design, validation, and revision stages. The selected location is characterized by diverse terrestrial insect populations, making it a suitable site for contextual biodiversity-based learning development.

The population of this study consisted of three groups: subject-matter experts, instructional design experts, and end users (teachers and students). The sample included six subject-matter experts and six instructional design experts, all of whom held at least a master's degree in biology education or a related field and had experience in curriculum or instructional material development. Additionally, two biology teachers with a minimum of five years of teaching experience were involved as practitioner validators. The user testing involved 25 Grade X high school students, selected using purposive sampling based on their prior exposure to biodiversity topics. This sampling approach was employed to ensure that participants possessed sufficient background knowledge to evaluate the usability and relevance of the module.

Data were collected using multiple research instruments designed to capture both qualitative and quantitative information. The primary instruments included validation questionnaires, observation sheets, and documentation forms. The validation questionnaires were developed based on established instructional design and content evaluation criteria, encompassing aspects such as content accuracy, instructional clarity, relevance to curriculum, visual presentation, and usability. Each item was measured using a Likert-scale format ranging from 1 (very inappropriate) to 5 (very appropriate). In addition, open-ended sections were included to gather qualitative feedback and suggestions from validators. The instrument indicators were adapted from previous module development studies and aligned with the principles of contextual and inquiry-based learning.

The validity and reliability of the instruments were ensured through a multi-step process. Content validity was established through expert judgment, involving senior

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academics in biology education who reviewed the relevance and clarity of each item. Revisions were made based on their feedback prior to implementation. Construct validity was examined by aligning instrument indicators with theoretical frameworks of instructional design and biodiversity learning. To ensure reliability, a pilot test was conducted with a small group of respondents, and internal consistency was analyzed using Cronbach's alpha, with a threshold value of ≥ 0.70 indicating acceptable reliability. This process ensured that the instruments were both valid and reliable for measuring module feasibility.

The data collection procedure was conducted in several sequential stages. First, a field study was carried out to collect empirical data on terrestrial insect diversity, including species composition, abundance, and ecological indices. Second, a literature review was conducted to identify relevant theories and curriculum requirements. Third, the initial module prototype was developed by integrating empirical findings into structured learning materials. Fourth, the module underwent expert validation, during which subject-matter and design experts evaluated its quality. Fifth, revisions were made based on expert feedback. Sixth, practitioner and user testing were conducted to assess the module's practicality and usability in real classroom contexts. Finally, a final revision was implemented to produce the operational version of the module.

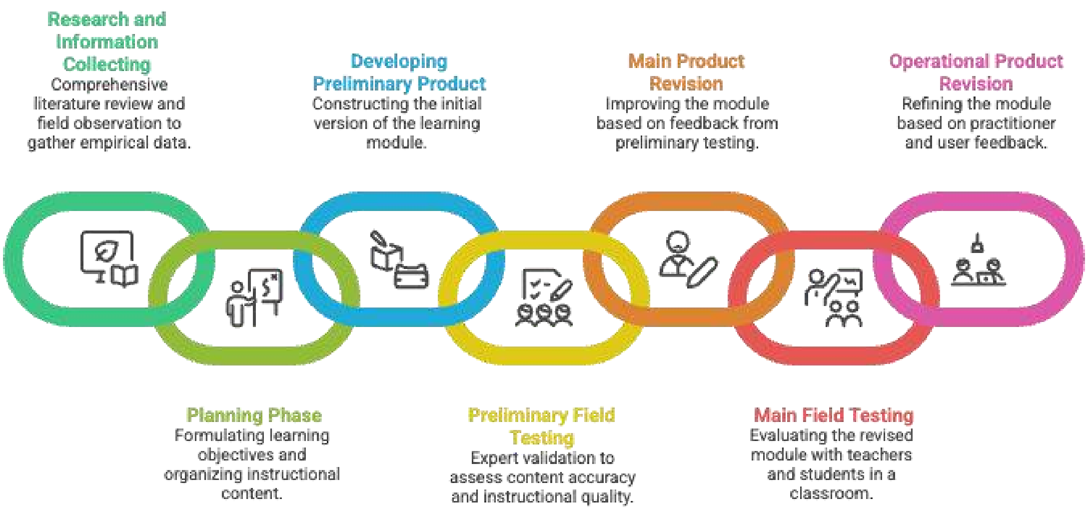

Figure 1. Research Procedure

Quantitative data obtained from validation questionnaires were analyzed using descriptive percentage analysis. The feasibility score for each aspect was calculated using the formula:

$$N = \frac{\Sigma x}{N_{max}} \times 100\%$$

where N represents the percentage score, Σ_X is the total score obtained, and N_{max} is the maximum possible score. The results were then interpreted based on predefined feasibility criteria: 0–20% (very infeasible), 21–40% (infeasible), 41–60% (moderately feasible), 61–80% (feasible), and 81–100% (very feasible). Qualitative data from open-ended responses were analyzed using thematic analysis, involving data reduction, categorization, and interpretation to identify patterns and inform module revision. The integration of quantitative and qualitative analyses allowed for a comprehensive evaluation of the module's quality.

This study adhered to established research ethics principles. All participants were

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informed about the purpose of the study and provided voluntary consent prior to participation. Confidentiality and anonymity were strictly maintained by ensuring that no personal identifiers were disclosed in the data reporting. Participants were also given the right to withdraw from the study at any stage without any consequences. Furthermore, the study ensured academic integrity by properly citing all sources and avoiding data manipulation. Ethical considerations were particularly emphasized during student involvement to ensure a safe and respectful research environment.

RESULTS AND DISCUSSION

Results

The initial stage of this study involved field observation and biodiversity data collection conducted at the Integrated Agricultural Laboratory of Jagan, Sukoharjo. The results indicated that a total of 641 terrestrial insect individuals were recorded, representing a range of taxonomic groups. Several taxa, including mosquitoes, grasshoppers, crickets, and ants, exhibited relatively high abundance, suggesting their adaptability to the local environmental conditions. In contrast, other taxa were present in lower numbers, indicating variability in species distribution within the habitat. The calculated ecological indices showed a moderate level of species diversity and richness, with relatively even distribution and no dominant species. These findings demonstrate that the study area supports a stable and heterogeneous terrestrial insect community.

Based on the empirical findings, the study proceeded to the development of a local potential-based exploration module. The biodiversity data obtained from the field were systematically transformed into instructional content aligned with the learning outcomes of Phase E in the Merdeka Curriculum. The module was designed to incorporate activities such as insect identification, ecological data analysis, and guided inquiry tasks. The learning indicators included analyzing levels of insect diversity, conducting observations, comparing biodiversity data, and drawing conclusions based on ecological analysis. The module structure consisted of an introduction, core materials, presentation of local potential, student worksheets, observation activities, evaluation instruments, and references.

Figure 2. Cover

Figure 3. Instructions for use

Figure 4. Lesson Plan

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Figure 5. Material

Figure 6. Worksheet Based on Local Potential

Figure 7. Evaluation

The module components presented in Figures 2–7 illustrate a systematic and comprehensive instructional design. The module includes usage instructions, lesson plans, local potential-based materials, student worksheets, and evaluation sections. Each component was developed to integrate empirical biodiversity data with structured learning activities, ensuring that students can engage in exploration, analysis, and reflection. The organization of the module supports independent learning and facilitates the implementation of contextual and inquiry-based learning approaches.

The feasibility of the module content was evaluated through validation by six subject-matter experts. The results showed that all validators rated the module within the "very feasible" category. The percentage scores ranged from 87.50% to 96.67%, with an average score of 93.47%. These results indicate that the content of the module is scientifically accurate, relevant to learning objectives, and appropriate for high school biology instruction.

Table 2. Results of Material Validity Evaluation

Validator	Percentage Score (%)	Criteria
1	94.17	Very Feasible
2	96.67	Very Feasible
3	95.00	Very Feasible
4	90.83	Very Feasible
5	87.50	Very Feasible
6	96.67	Very Feasible
Average	93.47	Very Feasible

In addition to content validation, the module was evaluated by instructional design experts to assess its structure, presentation, and usability. The results showed that all validators provided scores above 87%, with an average score of 92.61%, categorized as very feasible. This indicates that the module has a well-organized structure, clear presentation, and appropriate instructional design for facilitating student learning.

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Table 3. Results of Learning Module Validity Evaluation

Validator	**Percentage Score (%)**	**Criteria**
1	93.18	Very Feasible
2	96.59	Very Feasible
3	94.32	Very Feasible
4	93.18	Very Feasible
5	87.50	Very Feasible
6	90.91	Very Feasible
Average	92.61	Very Feasible

The validation process also generated feedback and suggestions for improving the module. The main recommendations included adding Latin names for insect species, correcting typographical errors, improving image resolution, and enhancing instructional clarity. These suggestions were systematically incorporated into the revised version of the module.

Table 4. Suggestions and Improvements from Subject-Matter Experts and Module Experts

Suggestions	**Improvements**
Subject Matter Experts	
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.
Some typographical errors and inaccuracies need to be corrected.	Correct typos and inaccuracies. For example, “di bawah” on page 18 should be “di bawah,” ‘jagan’ on page 29 should be “Jagan,” etc.
Images should be of good resolution so that they are not unclear, broken, or blurred.	Improve images with good resolution so that they appear clear. Refer to pages 23-27.
It would be good to add illustrations of insects to the material, then check again whether the evaluation measures all learning objectives.	Add illustrations of insects to the material referring to pages 6-7 and 30-36.
Modules Experts	
Clearer instructions for use are needed.	Correct the module usage instructions on page 7.
Implementation for learning does not yet exist.	Add implementation for learning to the module on page 36.
It is recommended that all individual names be accompanied by their Latin names.	List the Latin names of each insect on pages 23-27.

Following expert validation, the module was evaluated by practitioners, namely two biology teachers. The results showed that the module achieved an average feasibility score of 87.50%, which falls within the “very feasible” category. The teachers indicated that the module is suitable for classroom use, with clear learning objectives, relevant content, and a well-structured format.

Table 5. Results of Validity Testing by Practitioners

Practitioners	Percentage Score (%)		Criteria
	Module	Content	
1	89.77	93.30	Very Feasible
2	85.23	81.67	Very Feasible

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Practitioners	Percentage Score (%)		Criteria
	Module	Content	
Average	87.50	87.50	Very Feasible

The module was further evaluated through user testing involving 25 Grade X high school students. The results showed that all students rated the module as "very feasible," with scores exceeding 87% and an average score of 94.96%. These results indicate that the module is easy to understand, engaging, and supportive of student learning activities.

Table 6. Results of Validity Testing by Students

Students	**Percentage Score (%)**	**Criteria**
1	87.66	Very Feasible
2	96.06	Very Feasible
3	89.32	Very Feasible
4	92.01	Very Feasible
5	97.35	Very Feasible
6	92.69	Very Feasible
7	90.72	Very Feasible
8	89.02	Very Feasible
9	96.52	Very Feasible
10	94.51	Very Feasible
11	97.35	Very Feasible
12	92.88	Very Feasible
13	93.83	Very Feasible
14	98.03	Very Feasible
15	100.00	Very Feasible
16	94.55	Very Feasible
17	94.81	Very Feasible
18	92.96	Very Feasible
19	98.34	Very Feasible
20	96.21	Very Feasible
21	96.37	Very Feasible
22	97.05	Very Feasible
23	96.06	Very Feasible
24	98.60	Very Feasible
25	98.18	Very Feasible
Average	94.96	Very Feasible

Feedback from teachers and students was also collected to improve the final version of the module. The suggestions included improving visual quality, adding more engaging illustrations, updating references, and including assessment components for observation activities. These inputs were used to refine the module before finalization.

Table 7. Suggestions and Improvements from Teachers and Students

Suggestions	**Improvements**
Teachers	
Only corrections to the typing, there are some words with incorrect letters (typos) and do not yet comply with the rules of writing.	Correcting misspelled words (typos) and correcting them according to writing rules. For example, pitfall trap becomes pitfall trap, Density becomes Density.
Improve low-resolution or blurred images.	Improve the image resolution so that all images

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Suggestions	Improvements
	on pages 23–27 appear clear.
Add the latest scientific references on insect diversity.	Add the latest scientific references regarding insect diversity to Chapter I.
Include a section for assessing student observation results.	Include a section for assessing student observation results.
Students	
More interesting illustrations are needed. The image quality needs to be improved to make it clearer.	Adding more interesting illustrations and improving image quality for greater clarity.

Overall, the results indicate that the developed module meets the criteria of feasibility in terms of content, instructional design, and usability. The consistent high scores across expert, practitioner, and user evaluations demonstrate that the module is appropriate for implementation in high school biology learning.

Discussion

The findings of this study reveal that the terrestrial insect community in the Integrated Agricultural Laboratory of Jagan, Sukoharjo exhibits a moderate level of species diversity with a relatively stable ecological structure. This condition suggests a balanced ecosystem in which no single species dominates excessively, allowing for functional ecological interactions such as pollination, decomposition, and trophic regulation. From an ecological perspective, moderate diversity often reflects environments that are neither highly disturbed nor entirely pristine, but rather dynamically stable (Wagner, 2020; Wilson & Fox, 2021). This finding aligns with ecological resilience theory, which posits that ecosystems with moderate diversity can maintain stability through functional redundancy and species complementarity. Previous studies by Slade & Ong (2023) and Stoler & Relyea (2020) similarly report that terrestrial insect communities in semi-managed habitats tend to exhibit moderate diversity due to a balance between natural and anthropogenic influences. However, compared to highly conserved ecosystems, the diversity level observed here may be lower, potentially due to agricultural activities and habitat modification. This suggests that local environmental conditions play a critical role in shaping biodiversity patterns. Consequently, the ecological data generated in this study provide not only descriptive insights but also a meaningful basis for contextualized learning.

Building on these ecological findings, the transformation of empirical biodiversity data into structured learning materials represents a significant pedagogical contribution. The integration of real-world data into instructional modules reflects the principles of constructivist learning theory, where knowledge is actively constructed through interaction with authentic contexts (Hernandez, 2023; Kwangmuang et al., 2021). The use of local insect diversity as learning content allows students to connect abstract biological concepts with observable phenomena, thereby enhancing conceptual understanding. This finding supports previous research indicating that contextualized learning materials improve cognitive engagement and knowledge retention (Hamzah & Nurahasana, 2023; H. Li et al., 2024). Compared to traditional textbook-based approaches, which often present decontextualized information, this module offers a more meaningful learning experience. However, the effectiveness of such integration depends on the accuracy and relevance of the empirical data used. In this study, the use of systematically collected biodiversity data strengthens the scientific validity of the module. Therefore, the integration of empirical ecological data into instructional design can be seen as an effective strategy for bridging the gap between theory and practice.

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Another important finding is the high feasibility of the developed module based on expert validation, with scores consistently exceeding 87%. This indicates that the module meets key criteria of instructional quality, including content accuracy, clarity, and alignment with curriculum standards. From the perspective of instructional design theory, particularly the ADDIE framework and design-based research principles, high feasibility reflects the effectiveness of iterative development and validation processes (Fowler & Leonard, 2024; Tinoca et al., 2022). The involvement of both subject-matter experts and instructional design experts ensures that the module is not only scientifically sound but also pedagogically appropriate. Similar findings have been reported by Uslan et al. (2024), who demonstrated that expert-validated modules tend to exhibit higher usability and instructional effectiveness. However, it is important to note that validation scores alone do not guarantee actual learning outcomes. The absence of experimental testing in this study limits the ability to assess the module's impact on student achievement. Nevertheless, the high validation results provide strong initial evidence of the module's quality and potential applicability.

The positive responses from biology teachers further reinforce the practical relevance of the developed module in real classroom settings. Teachers rated the module as highly feasible, indicating that it aligns well with instructional needs and classroom realities. This finding can be interpreted through the lens of curriculum implementation theory, which emphasizes the importance of teacher acceptance and usability in determining the success of educational innovations (Hastangka et al., 2025; Hunaepi & Suharta, 2024). The module's clear structure, contextual content, and alignment with the Merdeka Curriculum likely contributed to its positive reception. Previous studies by Duggan et al. (2020) and Situmorang et al. (2024) highlight that instructional materials lacking contextual relevance often face resistance from educators. In contrast, the present module demonstrates how local potential-based resources can enhance teacher engagement and instructional effectiveness. However, variations in teacher readiness and pedagogical competence may influence the implementation of such modules in different contexts. Thus, while the findings are promising, broader implementation studies are needed to confirm their generalizability.

In addition to teacher validation, the very high level of student acceptance indicates that the module is engaging, accessible, and supportive of learning processes. Students reported that the module was easy to understand and facilitated active participation, which suggests that it effectively promotes inquiry-based learning. This aligns with experiential learning theory, which posits that direct engagement with real-world phenomena enhances learning outcomes (Bae & Lai, 2020; Schilhab, 2021). The inclusion of activities such as observation, data analysis, and reflection enable students to develop higher-order thinking skills. Similar findings have been reported by Forti (2023) and Niemiller et al. (2021), who emphasize the role of inquiry-based and citizen science approaches in fostering scientific literacy. However, student perceptions may also be influenced by novelty effects, where new learning materials generate temporary enthusiasm. Therefore, long-term studies are needed to evaluate whether the observed engagement translates into sustained learning gains. Despite this limitation, the high student validation scores provide evidence of the module's usability and pedagogical value.

A critical aspect of this study is the integration of local potential-based learning with inquiry-based instructional design, which addresses a significant gap in previous research. While earlier studies often focus on either contextual learning or inquiry-based approaches separately, this study combines both within a single framework. This integration reflects the principles of place-based education, which emphasize the use of local environments as a foundation for learning (Wiegelmann & Zabel, 2021; Yemini et al., 2025). The findings suggest that such integration not only enhances conceptual understanding but also fosters

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environmental awareness and responsibility. Compared to studies by Philokyprou (2025) and Restović & Bulic (2024), which primarily examine research-based learning materials, this study extends the theoretical framework by incorporating empirical biodiversity data into module design. This represents a novel contribution to the field of biology education. However, the effectiveness of this integrated approach may vary depending on the availability of local biodiversity resources. Therefore, adaptation to different ecological contexts requires careful consideration.

Furthermore, the study highlights the importance of contextual factors in shaping both ecological findings and educational outcomes. The specific characteristics of the research site, including its agricultural setting and biodiversity composition, influence the type of data generated and its applicability to learning. This suggests that local potential-based modules are inherently context-dependent and may not be directly transferable without modification. This finding is consistent with the work of Echeverria et al. (2021) and Ekström (2021), who emphasize the role of local context in environmental education. At the same time, this context-dependency can be seen as a strength, as it allows for the development of highly relevant and meaningful learning experiences. However, it also raises questions about scalability and standardization. Alternative explanations for the observed effectiveness may include factors such as teacher facilitation and student motivation, which were not explicitly controlled in this study. Therefore, future research should explore these variables in more detail.

Finally, this study contributes both theoretically and practically to the field of biology education by demonstrating how empirical ecological data can be systematically integrated into instructional design. Theoretically, it extends existing frameworks of contextual and inquiry-based learning by incorporating local biodiversity as a central component. Practically, it provides a validated and adaptable module that can be implemented in high school settings. This contribution addresses a critical gap identified in previous studies, particularly the lack of context-specific instructional materials (Duggan et al., 2020; Setiyanika et al., 2023). Moreover, the study positions itself within the broader global discourse on sustainability education and biodiversity literacy. By linking ecological research with classroom practice, it offers a model for interdisciplinary integration. Nevertheless, the absence of experimental validation remains a limitation that should be addressed in future studies. Overall, the findings underscore the potential of local potential-based modules to transform biology learning into a more meaningful, contextual, and scientifically grounded process.

CONCLUSION AND SUGGESTIONS

This study successfully characterized the diversity of terrestrial insects at the Integrated Agricultural Laboratory of Jagan, Sukoharjo, and utilized the empirical findings as the core content for developing a local potential based exploration module for high school biology learning. The results of biodiversity analysis indicated a moderate level of species diversity and a relatively stable ecological structure, providing a meaningful and contextually relevant foundation for instructional material development. The developed module integrates authentic local biodiversity data with structured exploration activities, guided inquiry tasks, and reflective learning components aligned with the Phase E learning outcomes of the Merdeka Curriculum.

The feasibility evaluation results demonstrate that the module possesses a very high level of validity and practicality. Validation by subject matter experts and instructional design experts confirmed that the module meets scientific accuracy, instructional quality, and design standards. Furthermore, practitioner validation indicated that the module is

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pedagogically appropriate and applicable in real classroom contexts, while user validation showed that the module is highly readable, engaging, and effective in supporting student learning. These findings suggest that integrating local biodiversity data into instructional materials enhances the relevance, meaningfulness, and effectiveness of biology learning at the secondary school level.

Despite these positive outcomes, this study has several limitations. The research was limited to the development and feasibility evaluation stages and did not include experimental testing to measure the effectiveness of the module in improving learning outcomes, higher order thinking skills, or long-term retention. In addition, the implementation was conducted within a single ecological and institutional context, which may limit the generalizability of the findings without further adaptation.

Therefore, future research is recommended to conduct experimental or quasi-experimental studies to examine the effectiveness of the module compared to conventional learning materials. Longitudinal studies are also needed to evaluate its impact on students' biodiversity literacy, environmental awareness, and scientific reasoning over time. Furthermore, replication of this module development framework in different ecological regions is encouraged to test its adaptability and scalability. From a practical perspective, educators are encouraged to integrate local potential into biology learning as a strategy to promote contextual, inquiry-based, and meaningful learning experiences.

LIMITATIONS

This study has several limitations that should be acknowledged. First, the research was limited to the development and feasibility validation stages of the module and did not include experimental implementation to measure its direct effectiveness on students' learning outcomes, critical thinking skills, or long-term biodiversity literacy. The evaluation focused primarily on expert judgment, teacher responses, and student perceptions regarding the usability and appropriateness of the module. Consequently, although the module demonstrated a very high level of feasibility, the extent to which it significantly improves cognitive achievement and environmental awareness remains empirically untested. In addition, the sample size for field implementation was relatively limited and involved students from a single senior high school, which may restrict the broader generalizability of the findings.

Another limitation relates to the contextual nature of the module development process. The instructional materials were specifically designed based on terrestrial insect diversity data collected from the Integrated Agricultural Laboratory of Jagan, Sukoharjo, meaning that the ecological content and examples may not fully represent biodiversity conditions in other regions. Differences in local ecosystems, school resources, teacher readiness, and student characteristics could influence the applicability and effectiveness of the module in different educational settings. Furthermore, the study relied mainly on descriptive quantitative analysis and qualitative feedback without incorporating more advanced statistical approaches or comparative experimental designs. Therefore, future studies are recommended to conduct wider-scale implementation, experimental testing, and cross-regional adaptation to strengthen the validity, scalability, and educational impact of the developed module.

AUTHOR CONTRIBUTIONS

AAN contributed to the conceptualization of the study, research design, field data collection, module development, data analysis, and manuscript drafting. **VA** and **AA** contributed to instructional design validation, data interpretation, literature review,

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manuscript revision, and final editing. All authors reviewed and approved the final version of the manuscript.

CONFLICT OF INTEREST STATEMENT

The authors declare that there are no conflicts of interest regarding the publication of this study. The research was conducted independently without any commercial or financial relationships that could be interpreted as potential conflicts of interest.

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