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Development of a Biology Module Incorporating Minangkabau Local Wisdom on Biodiversity to Enhance Phase E Students' Learning Motivation and Critical Thinking Skills

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Abstract
This study developed a biology module integrating Minangkabau local wisdom into biodiversity learning for Phase E students at MAN 2 Tanah Datar, with the aim of supporting learning motivation and critical thinking skills. The study addressed students' low motivation and critical thinking performance, as well as difficulties in understanding biodiversity because of its broad scope and limited connections to the local environment. Preliminary assessments showed critical thinking performance of 55.8% and learning motivation of 58.7%; the mean daily assessment score for biodiversity was 65.46, below the learning achievement criterion of 78. The research employed a research-and-development approach based on the ADDIE model (analysis, design, development, implementation, and evaluation). The printed module connects biodiversity concepts with Minangkabau local wisdom, including local plant varieties, distinctive West Sumatran flora and fauna, biological resource use, Rimbo Larangan, and the philosophy of Alam Takambang Jadi Guru. It includes structured learning activities, exercises, assessments, and reflection tasks. The research design included expert validation of content, media, and language, teacher and student practicality assessments, and a pretest–posttest comparison of motivation and critical thinking outcomes. The module is intended to provide a contextual and culturally relevant resource for biology learning. The available results should be interpreted in light of the still-incomplete reporting of validation, practicality, and inferential effectiveness outcomes.

Keywords: Biodiversity; Biology Module; Critical Thinking; Learning Motivation; Minangkabau Local Wisdom

INTRODUCTION

Twenty-first-century educational developments have shifted learning from teacher-centered instruction toward student-centered approaches in which students actively participate in constructing knowledge and developing higher-order thinking skills. Under the Merdeka Curriculum, instruction is expected to provide meaningful, contextual, and reflective experiences that enable students to develop not only conceptual knowledge but also problem-solving, communication, collaboration, creativity, and critical thinking skills (Indriani & Suryani, 2023). Therefore, biology instruction should move beyond transmitting factual information and provide opportunities for students to investigate phenomena, evaluate information, formulate arguments, and solve problems based on evidence.

Critical thinking is particularly important in biology because biological phenomena are complex, dynamic, and closely related to real-life conditions. Students need to interpret information, analyze relationships among concepts, evaluate evidence, draw reasoned conclusions, explain their reasoning, and monitor their thinking processes. Facione (2020) identifies six major dimensions of critical thinking: interpretation, analysis, evaluation, inference, explanation, and self-regulation. These skills are essential for understanding biological phenomena and addressing environmental problems rationally and systematically.

However, conventional learning practices that emphasize memorization and teacher-centered instruction tend to provide limited opportunities for students to engage in analytical and reflective thinking. Previous research has also indicated that students' critical thinking skills may remain low when learning materials and learning activities do not sufficiently stimulate higher-order thinking (Mulyati et al., 2024; Gómez et al., 2025).

Alongside critical thinking, learning motivation influences students' engagement and achievement during learning. Motivation helps determine the extent to which students exhibit interest, attention, persistence, and willingness to achieve learning goals. Students with strong learning motivation tend to participate more actively and persist in completing learning activities, whereas low motivation may contribute to passivity and limited engagement. Motivation is particularly important in science learning because meaningful learning requires students to actively interact with learning materials, phenomena, and problems. Research has shown that innovative learning models and interactive learning materials can contribute to increased student motivation and critical thinking (Indriyani et al., 2025). Thus, learning materials need to be designed not only to facilitate conceptual understanding but also to create learning experiences that are engaging, relevant, and meaningful.

Biodiversity is a fundamental biology topic that benefits from this approach. The topic involves the diversity of organisms at the genetic, species, and ecosystem levels, as well as the benefits of biodiversity, human activities affecting biodiversity, and conservation efforts. Its broad scope and numerous scientific concepts can make biodiversity difficult for students to understand when it is presented mainly through abstract explanations and memorization. Learning biodiversity therefore requires learning resources that connect scientific concepts with phenomena that students can observe and recognize in their surrounding environment. Contextualization of biodiversity learning through local environmental conditions can help students construct more meaningful understanding and develop greater awareness of biodiversity and conservation (Mulyati et al., 2025).

One promising response is to integrate local wisdom into biology learning materials. Local wisdom represents knowledge, values, practices, and ways of interacting with the environment that have developed within a particular community. In science education, local wisdom can serve as a meaningful learning context by connecting scientific knowledge with students' social, cultural, and ecological environments. Connecting local knowledge with school science can support students' learning while simultaneously contributing to the preservation of local knowledge and cultural heritage (Kasi et al., 2024). Similarly, Hasni and Sriyati (2026) emphasize that local wisdom can function as a contextual biology learning resource because it contains ecological knowledge, adaptation practices, and conservation values that can be connected to biological concepts.

This approach is highly relevant to the Minangkabau cultural context of West Sumatra. Minangkabau society possesses various forms of local wisdom associated with the utilization, management, and conservation of natural resources. Practices related to local plant varieties, traditional agricultural systems, protected forests, water-resource management, and the preservation of natural ecosystems provide authentic contexts for understanding biodiversity. The Minangkabau philosophy *Alam Takambang Jadi Guru* also reflects the close relationship between human beings, nature, and learning. Local wisdom is therefore not merely a cultural element but can serve as a source of contextual knowledge for biology education (Adlin et al., 2022; Iksan et al., 2023; Muslim, 2017). Integrating these contexts into biology learning may enable students to connect scientific concepts with their own cultural and environmental experiences.

Several studies have demonstrated the potential of local wisdom-based learning materials in biology education. Mumpuni et al. (2022) developed a module for learning plant biodiversity that incorporated local potential and local wisdom conservation, demonstrating the potential of a module to connect biodiversity learning with local knowledge. Ambarwati

and Wilujeng (2023) developed an electronic worksheet on biodiversity based on local wisdom and culture and reported its potential to enhance students' learning motivation. In another study, Hidayat et al. (2024) found that a contextual science e-module integrated with local wisdom could improve students' critical thinking skills. Similarly, Marlina et al. (2025) developed an ecosystem e-module integrated with local wisdom to support students' social-cultural awareness and critical thinking skills. These findings indicate that local wisdom can be incorporated substantively into learning materials rather than being used merely as supplementary illustrations.

More recent studies further demonstrate the relevance of local wisdom in biodiversity learning. Sriyati et al. (2026) reported that an e-module integrating local potential and local wisdom in digital biology learning was effective in enhancing students' critical thinking skills. Other research has also demonstrated that biodiversity learning materials incorporating local wisdom and problem-based learning can support critical thinking and science literacy (Ivaningtias et al., 2024; Iwan et al., 2025). Likewise, Julianti et al. (2023) demonstrated that a biology learning module based on local wisdom could be developed as a feasible learning resource for ecosystem topics. These studies provide empirical support for the use of local contexts in biology learning while also indicating that the effectiveness of such materials depends on the relevance of the local context, the learning objectives, and the characteristics of the learning product.

Despite these developments, a research gap remains. Previous studies have generally focused on different forms of learning resources, such as electronic worksheets, e-modules, or modules developed for particular topics and local contexts. Mumpuni et al. (2022), for example, focused on plant biodiversity and local conservation wisdom, whereas Ambarwati and Wilujeng (2023) focused primarily on learning motivation. Hidayat et al. (2024) examined critical thinking through a local-wisdom-integrated e-module on pressure, while Marlina et al. (2025) focused on ecosystems and social-cultural awareness. Furthermore, Sriyati et al. (2026) investigated biodiversity learning using Torajan local wisdom and primarily emphasized critical thinking. Consequently, there remains a need for a biology learning module that specifically integrates Minangkabau local wisdom into biodiversity learning while simultaneously targeting students' learning motivation and critical thinking skills.

The need for such a learning resource is also supported by the preliminary conditions identified at MAN 2 Tanah Datar. The preliminary critical thinking assessment showed an average achievement of 55.8%, which was categorized as low, with analysis and evaluation being the weakest indicators. The preliminary learning motivation questionnaire also showed an average score of 58.7%, which was categorized as low. In addition, students' average achievement in biodiversity was 65.46, below the established learning achievement criterion of 78. A substantial proportion of students also reported that biodiversity was difficult to understand and that the learning materials used in biology classes were insufficiently attractive and contextual. These conditions indicate that the problem is not limited to students' conceptual understanding but also involves the quality and relevance of their learning experiences.

Therefore, developing a biology module containing Minangkabau local wisdom on biodiversity is important to provide a more contextual, meaningful, and engaging learning experience. The module can integrate scientific concepts with local examples, such as local rice varieties, *ikan bilih*, *Rafflesia arnoldii*, the Andalas tree, *Rimbo Larangan*, and the philosophy *Alam Takambang Jadi Guru*. Such integration can help students understand genetic, species, and ecosystem diversity through phenomena that are geographically and culturally familiar to them. At the same time, learning activities designed around observation, analysis, evaluation, problem solving, and reflection can provide opportunities for students to develop critical thinking while increasing their engagement and motivation (Kasi et al., 2024; Sriyati et al., 2026).

Based on this rationale, the present study focuses on the development of a biology module containing Minangkabau local wisdom on biodiversity for Phase E students at MAN 2 Tanah Datar. The study is intended to produce a learning module that is valid, practical, and effective in supporting students' learning motivation and critical thinking skills. By integrating biodiversity concepts with the environmental knowledge and cultural practices of the Minangkabau community, the developed module is expected to bridge scientific knowledge with students' lived experiences and contribute to more contextual and meaningful biology learning.

METHODS

This study employed a Research and Development (R&D) approach aimed at developing a biology module incorporating Minangkabau local wisdom on biodiversity to improve students' learning motivation and critical thinking skills. Research and Development is used to produce an educational product and examine its quality and effectiveness when implemented during learning (Sugiyono, 2019). The development process followed the ADDIE model, which consists of five systematic stages: analysis, design, development, implementation, and evaluation. The ADDIE model provides a systematic framework for identifying learning needs, designing learning materials, developing and validating the product, implementing it with learners, and evaluating its quality and effectiveness (Branch, 2009; Sutomo & Mashudi, 2022).

The study was conducted at MAN 2 Tanah Datar during the 2026/2027 academic year. The target population comprised all Phase E students at MAN 2 Tanah Datar. The sample was selected using purposive sampling based on criteria aligned with the study objectives. The selected students were involved in the practicality and effectiveness testing of the developed Biology module. For the practicality assessment, the module was evaluated by one Biology teacher and 33 Phase E students. The effectiveness test involved an experimental class that used the developed module and a control class that used the printed learning materials normally used at the school. Both classes received the same pretest and posttest. Development began with the analysis stage. This stage examined learning needs, learner characteristics, instructional materials, and existing classroom conditions. Information was collected through observations, interviews with Biology teachers, student questionnaires, and an analysis of students' learning outcomes and critical thinking abilities. The analysis focused particularly on the learning difficulties experienced by Phase E students in biodiversity topics and the need for learning materials that could connect biological concepts with the students' surrounding environment and Minangkabau local wisdom. The needs analysis informed the content and characteristics of the module to be developed.

The design stage involved preparing the conceptual framework and initial structure of the Biology module. Relevant references and learning resources were collected, together with appropriate high-resolution images related to biodiversity and Minangkabau local wisdom. The content was organized by integrating biodiversity concepts with local biological resources and cultural practices found in the Minangkabau community. The module design included the cover, content layout, typography, color composition, learning activities, exercises, and evaluation components. The research instruments were also designed at this stage, including the product validity questionnaire, teacher and student practicality questionnaires, learning motivation questionnaire, and essay-based critical thinking test. The integration of local wisdom was intended to make biological concepts more contextual and meaningful by connecting scientific knowledge with students' social, cultural, and environmental experiences (Kasi et al., 2024; Mumpuni et al., 2022).

The development stage focused on producing and validating the Biology module. The developed module was submitted to four validators: two Biology lecturers, one language lecturer, and one Biology teacher from MAN 2 Tanah Datar. The validators assessed the appropriateness and accuracy of the module content, presentation, language, and media aspects and provided comments and suggestions for improvement. The module was

subsequently revised according to the validators' recommendations, and the resulting data were analyzed to determine the level of product validity. This validation procedure is consistent with previous studies showing that learning modules integrating local wisdom need to undergo expert validation before being implemented in classroom learning (Sary et al., 2023; Fatmawati et al., 2023).

The implementation stage took place after the module had been declared valid by the validators. The validated module was implemented during learning with Phase E students. The practicality of the module was assessed by one Biology teacher and 33 students in the experimental class. The respondents were asked to read, use, and evaluate the module based on its appearance and attractiveness, ease of use, usefulness, and time efficiency. Their responses were analyzed to determine the practicality of the developed module. The use of practicality assessment is important in determining whether a learning material can be used effectively and conveniently by both teachers and students in actual learning situations (Yanto et al., 2022; Fatmawati et al., 2023).

The evaluation stage was conducted to determine the effectiveness of the developed module and to provide formative evaluation throughout the development process. Effectiveness was assessed in terms of students' learning motivation and critical thinking skills. The effectiveness test employed a pretest–posttest control group design. The experimental class received learning using the Biology module incorporating Minangkabau local wisdom, whereas the control class received learning using the conventional printed learning materials available at the school. Both classes completed pretests before the treatment and posttests after the learning process. This design was used to identify changes in students' motivation and critical thinking skills following the implementation of the developed module.

Several instruments were employed to collect the research data. A teacher interview guide was used to identify problems and conditions in Biology learning at MAN 2 Tanah Datar, while a student questionnaire was used to identify student characteristics and learning problems. A product validity questionnaire was administered to the expert validators to assess the quality and appropriateness of the module. A practicality questionnaire was administered to the Biology teacher and students to assess the module's attractiveness, ease of use, usefulness, and learning-time efficiency. For the effectiveness assessment, a learning motivation questionnaire and an essay-based critical thinking test were administered to obtain data concerning changes in students' motivation and critical thinking skills.

Validity data were obtained from the validators' assessments using a four-point Likert scale modified from Riduwan (2012). The validation scores were converted into percentages and interpreted according to the validity criteria established in the study. Practicality data were analyzed similarly by calculating the percentage of responses obtained from the teacher and students. The use of structured validity and practicality analysis enables the quality of an instructional module to be evaluated systematically before and during its classroom implementation (Riduwan, 2012; Fatmawati et al., 2023).

Students' learning motivation was measured using a questionnaire addressing the desire and willingness to succeed, learning needs and encouragement, expectations and future aspirations, appreciation in learning, interest in learning activities, and a conducive learning environment. These indicators were adapted from Uno (2013) and Hidayah and Anisa (2019). The percentage of students' responses was calculated and interpreted using the motivation criteria adopted from Hendraya (2014). Before hypothesis testing, the data were examined for normality using the Shapiro–Wilk test and for homogeneity using Levene's test. When the data met the assumptions of normality and homogeneity, the hypothesis was tested using a t-test at a significance level of $\alpha = 0.05$ with the assistance of SPSS 26.

Critical thinking skills were assessed using an essay test based on Facione's six indicators: interpretation, analysis, evaluation, inference, explanation, and self-regulation. These indicators represent students' abilities to understand information, identify relationships, evaluate evidence or arguments, draw logical conclusions, explain reasoning, and reflect on

their thinking processes (Facione, 2020). The test items were examined in terms of content and empirical validity. Test reliability was analyzed using ANATES version 4.0, with reliability coefficients interpreted according to the criteria used in the study. Items with high to very high reliability were considered suitable for use.

Critical thinking scores were summarized by indicator and calculating the percentage of achievement for each critical thinking ability. The resulting percentages were interpreted using the criteria adopted from Arikunto (2016), in which scores of 80–100% were categorized as very good, 60–79% as good, 40–59% as moderate, 20–39% as poor, and 0–19% as very poor. The effectiveness of the module was further examined through statistical hypothesis testing. Normality was tested using the Shapiro–Wilk test and homogeneity using Levene's test. When the data were normally distributed and homogeneous, the t-test was applied at a significance level of 0.05 using SPSS 26.

The methodological framework was designed to ensure that the developed Biology module was not only appropriate in terms of content and presentation but also practical for classroom use and effective in improving the targeted learning outcomes. The integration of local wisdom into Biology learning was based on previous evidence that contextualizing biodiversity with local environments, knowledge, and cultural practices can support meaningful learning and develop students' critical thinking. Previous studies have demonstrated the potential of local-wisdom-based Biology modules and electronic learning materials to improve critical thinking and learning motivation (Mumpuni et al., 2022; Rosidi et al., 2023; Hidayat et al., 2024; Iwan et al., 2025; Sriyati et al., 2026)

RESULTS AND DISCUSSION

Results

The preliminary analysis identified several challenges in biology instruction of Phase E students at MAN 2 Tanah Datar, particularly in biodiversity learning. The initial critical thinking assessment showed that students' overall critical thinking performance was 55.8%, which was categorized as low. Among the six critical thinking indicators, interpretation reached 60.0%, analysis 52.5%, evaluation 47.5%, inference 55.0%, explanation 57.5%, and self-regulation 62.5%. The lowest results were found in the analysis and evaluation indicators. These findings indicate that students still experienced difficulties in analyzing relationships among biological concepts, evaluating scientific information, and determining the validity of arguments or solutions to biological problems. The findings also demonstrate the need for learning materials that provide students with opportunities to interpret information, analyze phenomena, evaluate evidence, draw conclusions, explain their reasoning, and reflect on their thinking processes.

The preliminary analysis also indicated relatively low learning motivation. The average motivation score was 58.7%. The indicators of having a desire and willingness to succeed and having expectations and future aspirations were categorized as low, while the indicators related to learning needs, interesting learning activities, and a conducive learning environment were in the moderate category. These results suggest that the existing learning process had not fully stimulated students' interest, attention, persistence, and motivation to achieve optimal learning outcomes. The findings are consistent with the view that learning motivation is an important factor influencing students' engagement and persistence in learning (Santrock, 2020). In addition, innovative and interactive learning materials have been reported to contribute positively to students' learning motivation (Indriyani et al., 2025).

Students' academic achievement provided further evidence of the need for improvement. The average daily assessment score for biodiversity was 65.46, which was below the established Learning Objective Achievement Criteria (KKTP) of 78. In comparison, the average scores for other biology topics were 80.65 for viruses, 85.33 for biotechnology, 73.21 for environmental change, and 69.98 for ecosystems. Biodiversity therefore represented one of the topics with the greatest learning difficulties among the materials examined. Furthermore,

82% of the students reported that biodiversity was difficult to understand because of its broad scope, numerous scientific terms, and classification concepts, while 83% stated that the learning materials used in the classroom were less attractive and had not sufficiently supported interactive and contextual learning.

The needs analysis also indicated that biology instruction at MAN 2 Tanah Datar was still dominated by lectures and printed textbooks. Students had limited opportunities to explore real biological phenomena independently, while the existing teaching materials had not adequately facilitated critical thinking and problem-solving activities. The biodiversity topic was considered particularly suitable for contextual learning because it is closely related to the students' surrounding environment and cultural practices. Consequently, the development of a biology module integrating Minangkabau local wisdom was considered relevant to address the identified learning needs.

The module was designed as a printed biology learning resource integrating biodiversity concepts with Minangkabau local wisdom. The local contexts incorporated into the module include local rice varieties, ikan bilih, Rafflesia arnoldii, the Andalas tree, Rimbo Larangan, Lubuk Larangan, parak practices, and the philosophical principle of Alam Takambang Jadi Guru. These contexts were intended to connect biological concepts at the genetic, species, and ecosystem levels with phenomena familiar to students in West Sumatra.

Development followed the five ADDIE stages: analysis, design, development, implementation, and evaluation. During the development stage, the module was planned to undergo validation by two biology lecturers, one language lecturer, and one biology teacher. The implementation stage involved a biology teacher and 33 Phase E students, while effectiveness was designed to be examined through a pretest–posttest control group involving an experimental class using the local-wisdom-based module and a control class using the conventional printed teaching material. Learning motivation was measured through a questionnaire, whereas critical thinking was measured through an essay test based on the established critical thinking indicators.

Following the instructional intervention, students' critical thinking skills were assessed using a pretest and posttest in both the control and experimental classes. The mean pretest and posttest scores of each class are presented in Table 1.

Table 1. Mean Scores of Students' Critical Thinking Skills

Class	N	Pretest	Posttest
Control	33	53.55	66.00
Experimental	33	53.27	79.82

Source: Results of the critical thinking skills analysis, 2026.

Table 1 indicates similar initial critical thinking scores in the two classes, with mean pretest scores of 53.55 in the control class and 53.27 in the experimental class. After the treatment, the mean posttest score of the control class increased to 66.00, whereas that of the experimental class reached 79.82. The experimental class, which used the Minangkabau local-wisdom-based biology module, therefore obtained a higher posttest score than the control class, which used the conventional printed teaching material.

Improvement in critical thinking skills was further examined using normalized gain (N-gain). The results are presented in Table 2.

Table 2. N-gain Score Results of Students' Critical Thinking Skills

Aspect	Class	N	Pretest	Posttest	N-gain score	Category
Critical thinking	Control	33	53.55	66.00	25.63	Low / Ineffective
	Experimental	33	53.27	79.82	56.00	Moderate / Fairly Effective

Source: Results of the N-gain score analysis of Phase E students' critical thinking skills, 2026.

As shown in Table 2, the N-gain score of the control class was 25.63, which falls into the low category and is interpreted as ineffective. In contrast, the experimental class obtained an N-gain score of 56.00, which falls into the moderate category and is interpreted as fairly effective. These findings indicate that the use of the biology module integrating Minangkabau local wisdom produced a greater improvement in students' critical thinking skills than the conventional printed teaching material.

Discussion

The preliminary findings demonstrate that the development of a biology module containing Minangkabau local wisdom is strongly justified by the actual learning conditions at MAN 2 Tanah Datar. The low critical thinking score, particularly in the analysis and evaluation indicators, suggests that students need learning experiences that go beyond memorizing biological concepts. Critical thinking involves interpretation, analysis, evaluation, inference, explanation, and self-regulation, all of which are essential in scientific learning (Facione, 2020). The present findings indicate that conventional learning practices have not provided sufficient opportunities for students to engage in these cognitive processes. This condition is consistent with Mulyati et al. (2024), who reported that biology learning dominated by conceptual memorization tends to result in relatively low critical thinking because students have limited opportunities to analyze and reflect on scientific problems.

Integrating local wisdom into the module offers a potential response because it enables abstract biological concepts to be connected with phenomena that students encounter in their social and environmental surroundings. The biodiversity of local rice varieties, for example, can be used to introduce genetic diversity, whereas local flora and fauna can provide concrete examples of species diversity. Similarly, practices such as Rimbo Larangan and Lubuk Larangan can be used to discuss conservation and ecosystem sustainability. Such contextualization enables students to understand that biodiversity is not merely a collection of scientific terms but is closely related to their environment, culture, and everyday lives. This approach is consistent with Hasni and Sriyati (2026), who emphasized that local wisdom can function as a contextual biology learning resource because it contains ecological knowledge, adaptation practices, and conservation values.

These findings are consistent with Mumpuni et al. (2022), who demonstrated that a biodiversity learning module based on local potential could integrate local biodiversity and community wisdom into biology learning. Similarly, Julianti et al. (2023) found that a biology module based on local wisdom received good feasibility ratings and positive responses from students. These findings support the argument that local environmental and cultural resources can be transformed into meaningful biology learning materials. However, the present development has a more specific focus because it integrates Minangkabau local wisdom with biodiversity learning while simultaneously targeting students' learning motivation and critical thinking.

Integrating local wisdom is also theoretically relevant to the development of scientific understanding because it can bridge local science and school science. Kasi et al. (2024) explained that connecting local science with school science can support learning while contributing to the preservation of local wisdom. In the present module, Minangkabau knowledge and practices are not positioned merely as cultural illustrations but are used as contexts through which students can examine biological concepts. This is important because effective local-wisdom-based learning should maintain scientific concepts as the main substance while using local phenomena to facilitate observation, analysis, problem solving, and reflection.

The low learning motivation identified in the preliminary analysis also underscores the need for contextual and engaging teaching materials. The average motivation score of 58.7% indicates that students' interest and persistence in biology learning still require improvement. When students encounter biological concepts through familiar cultural and environmental

contexts, learning may become more relevant and meaningful. Santrock (2020) argues that motivation is strengthened when students perceive learning as relevant to their lives and are actively involved during learning. This is also supported by Ambarwati and Wilujeng (2023), whose study demonstrated that biodiversity learning materials integrating local wisdom and culture could generate positive student responses and strong learning motivation.

The relationship between local context and motivation is particularly important in biodiversity learning because the subject itself is closely related to the environment in which students live. Rather than presenting biodiversity only through textbook definitions and classifications, the module provides opportunities for students to examine biological diversity through local examples. This contextual orientation may reduce the cognitive distance between scientific concepts and students' everyday experiences. Dewi et al. (2025) similarly demonstrated that integrating local cultural contexts into biodiversity learning through an e-module could improve both critical thinking and learning motivation. Their findings provide empirical support for the present research because both studies address biodiversity and seek to improve critical thinking and motivation through the integration of local wisdom, although the cultural context and learning-material format are different.

The potential contribution of the developed module to critical thinking is also supported by previous studies involving problem-based and local-wisdom-based learning materials. Hidayat et al. (2024) found that a contextual science e-module integrated with local wisdom could effectively support students' critical thinking. Marlina et al. (2025) likewise reported that an ecosystem e-module integrating local wisdom could support the development of students' social cultural awareness and critical thinking. Furthermore, Iwan et al. (2025) developed a biodiversity module based on problem-based learning and local wisdom assisted by augmented reality and reported very high validity and practicality as well as positive critical thinking outcomes. These studies suggest that local wisdom can function as a substantive component of biology learning materials for stimulating higher-order thinking rather than serving merely as an additional cultural element.

These observations are relevant to the critical thinking indicators used in this study. Local biodiversity problems can require students to interpret biological information, analyze relationships between human activities and biodiversity loss, evaluate conservation practices, infer possible consequences, explain arguments based on evidence, and regulate their own thinking during problem solving. Therefore, the use of local contexts has the potential to create learning situations that naturally encourage the six critical thinking indicators proposed by Facione (2020). This is important because the preliminary results showed that analysis and evaluation were precisely the weakest dimensions of students' critical thinking.

The development of the module is also consistent with the demands of the Merdeka Curriculum, which emphasizes contextual learning, scientific inquiry, problem solving, and the ability to formulate solutions to local, national, and global issues. The biodiversity topic provides an appropriate context for these competencies because students can investigate biological diversity, human activities affecting biodiversity, and conservation practices. Integrating Minangkabau local wisdom therefore provides not only cultural relevance but also opportunities for students to develop scientific reasoning through authentic environmental and social contexts.

The ADDIE model provides a structured development sequence beginning with analysis of learning problems and student characteristics, followed by design, development, implementation, and evaluation. Branch (2009) describes ADDIE as a systematic instructional design framework that enables learning products to be developed according to identified needs. Supardi (2020) also emphasizes that systematic development is important to ensure that teaching materials are relevant to learning objectives and learner characteristics. In the present study, the analysis stage identified low motivation, low critical thinking, low biodiversity achievement, and limited contextual learning materials. These findings subsequently became the basis for designing the module.

The preliminary findings therefore provide an empirical rationale for the development of the Minangkabau local-wisdom-based biology module. The module is expected to address not only the content difficulties experienced by students but also the limitations of the existing learning process. Its contextual design, integration of local biodiversity and conservation practices, and incorporation of activities targeting critical thinking are expected to make biodiversity learning more meaningful and engaging. Nevertheless, the manuscript does not report complete validation or practicality outcomes, and the effectiveness results are limited to descriptive pretest–posttest and N-gain data. Claims about effectiveness should therefore remain cautious pending complete statistical reporting.A comprehensive evaluation requires the validation scores, teacher and student practicality responses, detailed pretest–posttest results, assumption checks, and hypothesis-testing results.

Overall, the preliminary results indicate that the development of a biology module integrating Minangkabau local wisdom is pedagogically relevant and empirically justified. The approach is supported by previous studies showing that local-wisdom-based learning materials can improve contextual understanding, motivation, critical thinking, and engagement in biology learning (Mumpuni et al., 2022; Ambarwati & Wilujeng, 2023; Hidayat et al., 2024; Marlina et al., 2025; Dewi et al., 2025; Sriyati et al., 2026). The specific contribution of the present study lies in combining biodiversity content, Minangkabau local wisdom, learning motivation, and critical thinking within a single biology module for Phase E students at MAN 2 Tanah Datar.

CONCLUSION

Based on the development process and theoretical foundation of this study, the development of a biology module incorporating Minangkabau local wisdom on biodiversity is relevant to the learning needs of Phase E students at MAN 2 Tanah Datar. The initial analysis identified several important problems in biology learning, including students' low motivation, limited critical thinking skills, and difficulties in understanding biodiversity concepts. The preliminary findings showed that students' critical thinking ability was categorized as low, with an average percentage of 55.8%, while their learning motivation was also categorized as low, with an average percentage of 58.7%. In addition, the average achievement in biodiversity was 65.46, which was below the learning achievement criterion of 78. These conditions indicate the need for learning materials that are more contextual, meaningful, and capable of actively engaging students during learning.

The development of the module through the ADDIE model provides a systematic framework for responding to these learning needs. The module is designed to integrate biodiversity concepts with the environmental knowledge, values, practices, and cultural contexts of the Minangkabau community. Local contexts such as local rice varieties, bilih fish, *Rafflesia arnoldii*, the Andalas tree, *Rimbo Larangan*, and the philosophy of *Alam Takambang Jadi Guru* provide meaningful examples through which students can connect biological concepts with their surrounding environment and cultural experiences. Such integration is consistent with the view that local wisdom can function as a contextual source of biology learning because it contains ecological knowledge, adaptation practices, and conservation values that can be connected with scientific concepts.

Therefore, the development of a biology module incorporating Minangkabau local wisdom on biodiversity represents a relevant instructional approach for Phase E biology learning at MAN 2 Tanah Datar. The module is expected to provide a contextual, systematic, and student-oriented learning resource that connects biodiversity concepts with local environmental and cultural knowledge while creating opportunities for students to develop motivation and critical thinking. The research consequently contributes to the development of biology learning materials that not only support the achievement of scientific competencies but also strengthen students' understanding of and appreciation for the biodiversity and local wisdom surrounding them. The final quality of the developed module, however, must be established through the validity, practicality, and effectiveness testing specified in the research

design.

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