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Development of an Ecosystem Module Based on Papuan Local Wisdom Using the ADDIE Model to Enhance Students' Higher Order Thinking Skills (HOTS)

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Abstract
This study aims to develop an ecosystem module based on Papuan local wisdom using the ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) and to examine its validity, practicality, and effectiveness in improving students' Higher Order Thinking Skills (HOTS). This research employs a Research and Development (R&D) approach with an effectiveness test design using a one-group pretest–posttest design. The subjects of this study were students of the Biology Education Study Program at STKIP PGRI Papua. The module development process was carried out through the five stages of the ADDIE model, including needs analysis, design, product development, implementation, and evaluation. The research instruments consisted of expert validation sheets, practicality questionnaires, and HOTS-based essay tests. Data were analyzed using descriptive quantitative techniques, N-gain analysis, paired t-test, and effect size calculation. The results showed that the developed module had a very high level of validity with an average score of 3.69 and a very high level of practicality with a percentage of 89%. The effectiveness test indicated a significant improvement in students' HOTS, with an N-gain score of 0.61 (moderate category), a t-test significance value of $p < 0.05$, and an effect size of 1.25 (large category). These findings indicate that the ecosystem module based on Papuan local wisdom is effective in enhancing students' abilities in analysis, evaluation, and creation. Therefore, the developed module is considered valid, practical, and effective, and can be used as an innovative teaching material in contextual biology learning based on local wisdom.

Keywords: Learning module, Papuan local wisdom, ADDIE, HOTS, ecosystem

INTRODUCTION

Education plays a crucial role in preparing students to meet the demands of the 21st century. In this context, biology learning, particularly on ecosystem topics, is expected not only to emphasize conceptual understanding but also to develop Higher Order Thinking Skills (HOTS), including analysis, evaluation, and creation. These skills are essential for students to address complex environmental problems at both local and global levels. However, previous studies indicate that biology learning in higher education still tends to focus on lower-order thinking skills and has not optimally developed students' HOTS.

One of the main contributing factors is the limitation of teaching materials used in the learning process. Existing materials are generally generic, less contextual, and do not adequately integrate students' local ecological realities. In fact, contextual learning has been proven to enhance cognitive engagement and promote meaningful learning experiences. Therefore, integrating local wisdom into teaching materials becomes a strategic approach to bridge scientific concepts with students' real-life experiences (Aikenhead, 2006; Creswell,

2014).

Papua is a region with high biodiversity and rich local wisdom in environmental management. Traditional practices such as customary-based conservation, sustainable use of natural resources, and harmonious relationships between humans and nature reflect valuable ecological knowledge that is highly relevant to ecosystem concepts in biology (Marshall & Beehler, 2007; Mittermeier et al., 2011). In addition, local knowledge systems in Papua have been shown to contribute to environmental sustainability and biodiversity conservation (Boissière et al., 2013; van Vliet et al., 2015). However, this potential has not been systematically integrated into teaching materials in higher education.

Previous studies have shown that the integration of local wisdom in science learning can improve environmental literacy, conceptual understanding, and students' critical thinking skills (Rahmawati et al., 2020; Lestari et al., 2024). Furthermore, ethnoscience-based learning approaches can enhance the relevance of learning and strengthen students' cultural identity (Snively & Corsiglia, 2016).

On the other hand, the development of high-quality teaching materials requires a systematic instructional design model. The ADDIE model (Analysis, Design, Development, Implementation, and Evaluation) is widely used due to its structured and flexible framework in producing valid, practical, and effective learning products (Molenda, 2015; Pribadi, 2017). Previous studies also indicate that teaching materials developed using the ADDIE model can improve learning quality and students' understanding (Rustandi & Rismayanti, 2021).

Based on these considerations, there is a need to develop contextual teaching materials that integrate Papuan local wisdom and are systematically designed to enhance students' HOTS. Therefore, this study focuses on the development of an ecosystem module based on Papuan local wisdom using the ADDIE model to improve students' Higher Order Thinking Skills.

METHODS

This study employed a Research and Development (R&D) approach aimed at developing an ecosystem module based on Papuan local wisdom and evaluating its quality in terms of validity, practicality, and effectiveness in improving students' Higher Order Thinking Skills (HOTS). The development model used in this study was the ADDIE model, which consists of five stages: Analysis, Design, Development, Implementation, and Evaluation. This model was selected due to its systematic and flexible structure in producing effective instructional products and has been widely used in the development of teaching materials (Molenda, 2015; Pribadi, 2017; Branch, 2009).

The effectiveness of the developed module was tested using a quasi-experimental design with a one-group pretest–posttest approach. This design was used to measure the improvement of students' HOTS before and after the implementation of the module and is commonly used in educational research to evaluate the impact of instructional interventions (Creswell, 2014; Gall et al., 2003). Although this design is appropriate for preliminary effectiveness testing, this study acknowledges that the absence of a control group may limit causal interpretation because other factors such as prior knowledge, maturation, or testing effects could also influence students' learning outcomes.

The participants of this study were 30 students of the Biology Education Study Program at STKIP PGRI Papua who were enrolled in ecosystem-related courses during the 2025/2026 academic year. The sampling technique used was purposive sampling, considering that the participants had taken or were currently taking courses related to ecosystem or ecology topics (Creswell, 2014). The participants consisted of undergraduate students with relatively similar academic backgrounds to ensure the suitability of the module implementation.

The development procedure followed the five stages of the ADDIE model. In the analysis

stage, a needs analysis was conducted through classroom observation, interviews with lecturers, and literature review to identify problems in biology learning, particularly related to the lack of contextual teaching materials and the low level of students' HOTS. In the design stage, learning objectives, module structure, learning activities, assessment techniques, and HOTS indicators were systematically designed. The development stage involved creating the module, integrating Papuan local wisdom into ecosystem topics, and conducting expert validation by specialists in material, instructional media, and language. The implementation stage consisted of limited trials involving 10 students and field trials involving 30 students. Finally, in the evaluation stage, formative and summative evaluations were conducted to assess the quality and effectiveness of the developed module (Molenda, 2015; Branch, 2009).

The integration of Papuan local wisdom in this module was adapted from several traditional ecological practices, such as *sasi* (customary prohibition on resource exploitation during a certain period), traditional forest conservation, and sustainable utilization of natural resources by indigenous communities. These local ecological practices were contextualized into ecosystem learning materials and transformed into HOTS-based learning activities, including environmental case analysis, evaluation of ecological problems, and development of conservation solutions based on local values. This integration aimed to connect scientific concepts with students' socio-cultural environment, thereby making learning more meaningful and contextual (Selasih & Sudarsana, 2018; Darmadi, 2018).

The instruments used in this study included expert validation sheets, practicality questionnaires, and HOTS tests in the form of essay questions. The validation sheets were used to assess the content, media, presentation, graphics, and language aspects of the module. The practicality questionnaire consisted of indicators related to ease of use, clarity of instructions, attractiveness of design, effectiveness in learning, and usefulness of the module. Meanwhile, the HOTS test was designed to measure students' abilities in analysis (C4), evaluation (C5), and creation (C6), referring to the revised Bloom's taxonomy (Anderson & Krathwohl, 2001; Brookhart, 2010).

The HOTS essay test consisted of eight open-ended questions distributed across three cognitive domains: three items for analysis (C4), three items for evaluation (C5), and two items for creation (C6). A scoring rubric with a scale of 0-4 was used to assess students' responses based on the accuracy of concepts, analytical depth, argument quality, and originality of solutions. Prior to implementation, the instruments were validated by three expert validators consisting of one biology education expert, one instructional media expert, and one language expert. The validity process included evaluation of content relevance, language clarity, contextual suitability, and alignment with HOTS indicators.

Instrument reliability testing was conducted using Cronbach's Alpha coefficient. The practicality questionnaire obtained a reliability coefficient of 0.87, while the HOTS test obtained a reliability coefficient of 0.84, indicating that both instruments had high reliability and were suitable for research purposes. Revisions of the module and instruments were carried out based on suggestions and feedback provided by the validators before field implementation.

Data were analyzed using descriptive quantitative techniques. The validity of the module was determined based on the average scores of expert judgments. The practicality of the module was analyzed using percentage scores from student responses. The effectiveness of the module was analyzed using N-gain to determine the level of improvement, paired t-test to examine the significance of differences between pretest and posttest scores, and effect size to measure the magnitude of the treatment effect. In addition, the improvement of each HOTS indicator (analysis, evaluation, and creation) was analyzed separately to identify which cognitive skills showed the most significant improvement after the implementation of the module. These analytical approaches are commonly used in educational research to evaluate

the effectiveness of instructional interventions (Hattie, 2009).

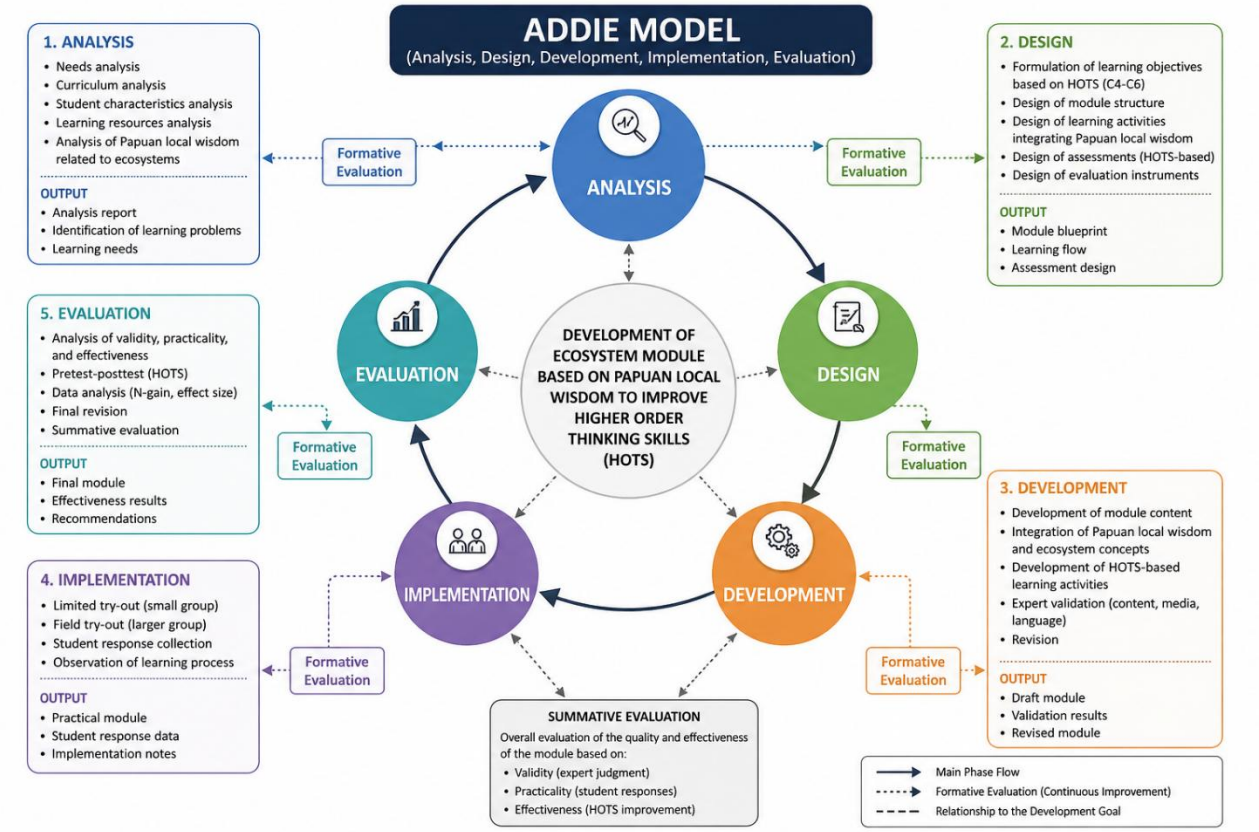


Figure 1. ADDIE model

RESULT AND DISCUSSION

Product Development Results

Product Description

The product developed in this study is an ecosystem learning module based on Papuan local wisdom, designed using the ADDIE model. The module is intended for Biology Education students and aims to enhance Higher Order Thinking Skills (HOTS) through contextual and student-centered learning.

Structure of the Module

The module is systematically organized into several components, including an introduction, learning objectives, conceptual materials, HOTS-based activities, contextual case studies, and evaluation. The content covers key ecosystem topics such as ecosystem components, energy flow, food chains, and ecosystem balance, presented in a structured and progressive manner.

Characteristics of the Module

The module integrates HOTS and Papuan local wisdom as its main characteristics. HOTS-oriented activities are designed at the levels of analysis (C4), evaluation (C5), and creation (C6) through problem-based tasks and open-ended questions. Meanwhile, local wisdom is incorporated through real environmental contexts, such as traditional conservation practices and sustainable resource management. This integration enhances the relevance, meaningfulness, and effectiveness of learning.

Module Appearance

Examples of HOTS-based learning activities integrated with Papuan local wisdom are presented in Figures 1–4.

Each figure represents a different ecosystem topic, including ecosystem components, energy flow, food chains, and ecosystem balance. The activities are designed to engage students in analyzing environmental problems, evaluating ecological impacts, and proposing solutions

based on local contexts.

These examples demonstrate that the developed module consistently integrates higher-order thinking skills across all learning topics, while also incorporating relevant local wisdom to enhance contextual understanding and meaningful learning.



Figure 1. HOTS-based activity on ecosystem components integrated with Papuan local wisdom



Figure 2. HOTS-based activity on energy flow integrated with Papuan local wisdom



Figure 3. HOTS-based activity on food chains integrated with Papuan local wisdom

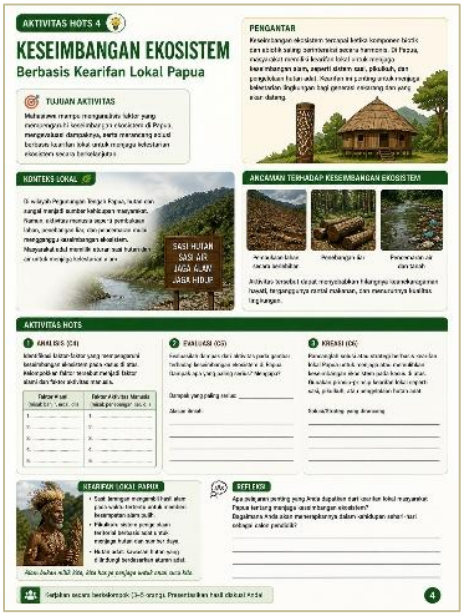


Figure 4. HOTS-based activity on ecosystem balance integrated with Papuan local wisdom

Figures 1–4 illustrate the integration of HOTS-based learning activities with Papuan local wisdom across four key ecosystem topics. Figure 1 presents an activity on ecosystem components that guides students to identify, classify, and analyze biotic and abiotic elements within a locally contextualized environment. Figure 2 focuses on energy flow, encouraging students to examine the transfer of energy among producers, consumers, and decomposers through ecological examples relevant to Papuan natural settings. Figure 3 depicts a food-chain activity that facilitates students' analytical understanding of feeding relationships among organisms while connecting the concept to local ecological resources and community life. Figure 4 highlights ecosystem balance by requiring students to evaluate factors that maintain or disrupt

ecological stability, thereby fostering critical reflection on environmental sustainability. Collectively, these activities demonstrate that the developed module not only embeds higher-order thinking processes, such as analysis, evaluation, and problem-solving, but also situates scientific concepts within meaningful local-cultural contexts to enhance students' ecological literacy and contextual learning experiences.

Product Validity

The validity of the developed module was evaluated by three experts covering content, media, and language aspects. The results of the validation are presented in Table 1.

Table 1. Results of Expert Validation

Aspect	Mean Score	Category
Content	3.72	Very Valid
Media	3.65	Very Valid
Language	3.70	Very Valid
Average	**3.69**	**Very Valid**

The results indicate that the module achieved a very high level of validity across all assessed aspects. This suggests that the developed module successfully integrates scientific ecosystem concepts, HOTS-oriented activities, and contextual learning based on Papuan local wisdom into a coherent instructional product.

The high content validity score reflects that the learning materials are conceptually aligned with ecosystem learning objectives and HOTS indicators. Meanwhile, the media and language validation results indicate that the module design, layout, readability, and presentation are appropriate for university-level students. The integration of contextual environmental issues from Papua also contributes to the relevance of the learning materials, enabling students to connect scientific concepts with real-life ecological situations.

These findings support the view that systematic instructional development through the ADDIE model can produce valid and contextually meaningful teaching materials (Branch, 2009; Molenda, 2015).

Practicality of the Module

The practicality of the module was assessed based on students' responses after implementation. The results are presented in Table 2.

Table 2. Practicality Test Results (N = 30)

Indicator	Percentage	Category
Ease of use	88%	Very Practical
Attractiveness	91%	Very Practical
Readability	87%	Very Practical
Content suitability	90%	Very Practical
Average	**89%**	**Very Practical**

The findings show that the module is highly practical in terms of usability, attractiveness, and content clarity. Students found the module easy to understand and engaging, which indicates that it supports independent and active learning.

The high attractiveness score (91%) suggests that the integration of visual elements, contextual cases, and HOTS-based activities increased students' motivation and participation during learning. In addition, the integration of Papuan local wisdom made the learning materials more familiar and meaningful to students because the environmental issues discussed were closely related to their socio-cultural environment.

This contextualization process plays an important role in increasing students' cognitive engagement. Students tend to participate more actively when learning materials are connected to their daily experiences and local realities. Therefore, the module not only functions as a source of information but also as a medium that facilitates meaningful learning experiences.

Effectiveness of the Module

Pretest and Posttest Results

The comparison of students' HOTS scores before and after using the module is presented in Table 3.

Table 3. Pretest and Posttest Scores (N = 30)

Test	Mean	SD
Pretest	56.4	8.5
Posttest	82.7	7.2

The results show a substantial increase in students' HOTS scores after the implementation of the module. The increase in the posttest mean score indicates that the module effectively facilitated students' higher-order thinking processes, particularly in analyzing ecological problems, evaluating environmental impacts, and proposing solutions based on local wisdom.

In addition, the lower standard deviation in the posttest results suggests that students' learning achievements became more evenly distributed after the intervention. This indicates that the module was able to support not only high-achieving students but also students with initially lower HOTS performance.

The improvement in HOTS occurred because the module consistently engaged students in problem-based and contextual learning activities. Rather than focusing on memorization, students were encouraged to interpret environmental phenomena, discuss ecological issues in Papua, and develop alternative solutions through analytical and reflective thinking processes.

N-Gain Analysis

Table 4. N-Gain Results

N-Gain Value	Category
0.61	Moderate

The N-gain value of 0.61 indicates a moderate improvement in students' HOTS. This improvement demonstrates that the developed module contributed meaningfully to the enhancement of students' cognitive abilities.

Further analysis showed that the highest improvement occurred in the analysis indicator (C4). Students were able to identify relationships among ecosystem components and analyze environmental problems more effectively after using the module. The evaluation indicator (C5) also improved significantly because students were trained to assess ecological impacts and compare different environmental management approaches.

Meanwhile, the creation indicator (C6) showed relatively lower improvement compared to analysis and evaluation. This finding is understandable because creative thinking skills generally require more extensive practice and longer learning experiences. However, students were still able to propose contextual conservation solutions based on Papuan local wisdom, indicating the potential of the module to support creative problem-solving abilities.

Paired t-test Results

Table 5. Paired t-test Results

Variable	Sig. (p-value)	Interpretation
Pretest–Posttest	0.000	Significant difference

The paired t-test result confirms that the improvement in students' HOTS is statistically significant. This means that the difference between pretest and posttest scores was not caused by random variation but was associated with the implementation of the developed module.

The significant improvement can be attributed to the module design, which consistently integrates HOTS-oriented tasks with contextual environmental issues. Students were not only required to understand ecosystem concepts theoretically but also to apply them in analyzing real ecological situations found in Papua.

This contextual and problem-based approach encourages deeper cognitive processing, which is essential for the development of higher-order thinking skills.

Effect Size

Table 6. Effect Size Results

Effect Size (d)	Category
1.25	Large

The effect size value of 1.25 indicates a strong educational impact of the developed module on students' HOTS. This finding demonstrates that the module was highly effective in facilitating cognitive improvement.

One important factor contributing to this strong effect was the integration of Papuan local wisdom into learning activities. Contextual examples such as traditional conservation practices, sustainable resource management, and local environmental issues enabled students to relate scientific concepts to their real-life experiences.

As a result, students became more engaged in analytical discussions and were better able to evaluate environmental problems critically. The integration of local wisdom also supported students in generating creative and culturally relevant solutions to ecosystem-related issues.

These findings indicate that contextual learning based on local wisdom can strengthen the development of analysis, evaluation, and creation skills simultaneously, making learning more meaningful and cognitively engaging.

Discussion

The findings of this study demonstrate that the ecosystem module based on Papuan local wisdom, developed through the ADDIE model, achieved strong instructional quality and produced a meaningful improvement in students' Higher Order Thinking Skills (HOTS). The expert validation score of 3.69 indicates that the module was very valid in terms of content accuracy, media design, presentation, and language appropriateness. Similarly, the practicality score of 89% suggests that students perceived the module as accessible, engaging, and relevant to their learning needs. More importantly, the effectiveness results showed a substantial increase in students' HOTS, as reflected in the improvement from the pretest mean score of 56.4 to the posttest mean score of 82.7, an N-gain value of 0.61 in the moderate category, a significant paired t-test result, and a large effect size of 1.25. These findings indicate that the module not only functioned as a valid teaching material but also served as an effective pedagogical intervention for strengthening students' analytical, evaluative, and creative thinking in ecosystem learning.

The improvement in HOTS can be interpreted as a consequence of the module's contextual and problem-oriented design. Students were not merely asked to recall ecosystem concepts, but were required to analyze ecological relationships, evaluate environmental problems, and formulate conservation-oriented solutions grounded in Papuan local wisdom. This finding is consistent with Hamzah et al. (2022), who emphasized that HOTS-oriented modules should integrate metacognitive activities, problem-solving tasks, and reflective learning processes to guide students toward deeper cognitive engagement. Similarly, Artika et al. (2023) found that systematic exposure to HOTS-based science questions significantly improved students' critical thinking skills. However, the present study extends these findings by demonstrating that HOTS development becomes more meaningful when scientific reasoning is embedded in students' local ecological and cultural contexts.

In relation to global studies, the findings align with the growing international discourse on integrating Indigenous and local knowledge into science education. Demssie et al. (2020) argued that combining Indigenous knowledge with modern education can foster sustainability competencies by connecting learners' cultural experiences with scientific problem-solving. In a similar vein, Zidny et al. (2020) emphasized that Indigenous knowledge can enrich science education by promoting epistemic pluralism, environmental responsibility, and culturally responsive learning. The present study supports these arguments by showing that Papuan ecological knowledge, such as customary conservation practices and sustainable resource use,

can be transformed into structured HOTS-based learning activities. Nevertheless, unlike broader global discussions that often remain conceptual, this study provides empirical evidence through validation, practicality, and effectiveness testing, thereby strengthening the practical relevance of Indigenous knowledge integration in higher education science learning.

Recent international studies also suggest that local and Indigenous knowledge can enhance students' sustainability awareness and interdisciplinary understanding. El Yazidi and Rijal (2024), for example, reported that Indigenous knowledge integration in science learning helped students understand local ecosystems and develop sustainable thinking. Latip et al. (2024) further showed that Local and Indigenous Knowledge (LIK) has increasingly been used in science education to contextualize abstract concepts and improve the relevance of classroom learning. The present findings are consistent with these studies, particularly in demonstrating that ecological concepts become more accessible when linked to familiar environmental realities. However, the Papuan context provides a distinctive contribution because it represents a biodiversity-rich region where ecological knowledge is deeply connected with cultural identity, customary norms, and community-based environmental management.

In the Indonesian context, the findings reinforce previous studies indicating the pedagogical value of local wisdom-based learning. Hidayati et al. (2020) found that local wisdom-based education can strengthen students' values, cultural identity, and contextual understanding. Lestari et al. (2024), in their systematic review, also concluded that local wisdom contributes significantly to sustainability-oriented science education in Indonesia. Furthermore, Wardani et al. (2023) developed an ethnoscience-based science module and reported that such materials were valid for supporting contextual science learning, while Widiyawati et al. (2023) showed that teachers considered ethnoscience relevant to the implementation of the Independent Curriculum. The present study is in line with these findings, but it advances the discussion by focusing specifically on Papuan local wisdom and by measuring its effect on HOTS among Biology Education students. This is important because most Indonesian studies on local wisdom-based science learning have focused on Java, Bali, or other western Indonesian contexts, whereas Papua remains underrepresented in educational innovation research.

Theoretically, this study supports the view that HOTS development is strengthened when cognitive learning objectives are connected with authentic sociocultural contexts. Based on the revised Bloom's taxonomy, the module successfully targeted analysis, evaluation, and creation through activities that required students to interpret ecosystem components, examine energy flow, evaluate food-chain interactions, and propose solutions for maintaining ecosystem balance. The findings also extend contextual learning theory by showing that context is not merely a motivational element, but an epistemic resource that helps students construct scientific meaning from culturally situated experiences. In this sense, Papuan local wisdom operates as a bridge between formal biological concepts and students' lived ecological realities. Theoretically, the study suggests that HOTS-based science learning models should not be designed as culturally neutral interventions; rather, they should be refined to include local knowledge systems, environmental ethics, and community-based problem-solving.

From a pedagogical perspective, the module offers practical implications for improving student engagement, emotional connection to learning, and ecological literacy. By presenting ecosystem topics through Papuan environmental cases, students are encouraged to see biology as relevant to their own lives and communities. This relevance may increase learning motivation, support positive emotional engagement, and reduce the perceived distance between scientific knowledge and everyday experience. In addition, the module's visual components, contextual cases, and open-ended tasks can strengthen students' scientific media literacy by helping them interpret ecological information, evaluate environmental claims, and communicate evidence-based solutions. From a policy perspective, the findings suggest that curriculum developers and

higher education institutions should provide stronger support for local wisdom-based teaching materials, particularly in regions with rich ecological and cultural knowledge. Educational policy should also encourage the development of locally contextualized modules, lecturer training in ethnoscience-based pedagogy, and assessment systems that measure not only factual knowledge but also HOTS, sustainability reasoning, and culturally responsible environmental decision-making.

The novelty of this study lies in its integration of three elements that are often treated separately in science education research: ADDIE-based instructional design, HOTS-oriented ecosystem learning, and Papuan local wisdom. While previous studies have examined HOTS modules or ethnoscience-based materials, this study contributes a more context-specific model by positioning Papuan ecological wisdom as both content and pedagogical strategy. Methodologically, the study also contributes by combining expert validation, practicality testing, N-gain analysis, paired t-test, and effect size calculation to provide a more comprehensive evaluation of the developed module. This contribution is particularly significant because it offers a replicable framework for developing culturally grounded science learning materials in other Indigenous or local contexts.

Despite these contributions, several limitations should be acknowledged. First, the study involved only 30 Biology Education students from one institution, which limits the generalizability of the findings to broader student populations. Second, the one-group pretest–posttest design did not include a control group, making it difficult to fully rule out alternative explanations such as prior knowledge, maturation, or testing effects. Third, the study measured HOTS primarily through essay tests, which may not capture the full complexity of students' reasoning, collaboration, and real-world problem-solving practices. Future research should involve larger and more diverse samples, employ quasi-experimental or experimental designs with comparison groups, and explore the long-term impact of Papuan local wisdom-based modules on ecological literacy, sustainability attitudes, and conservation behavior. Further studies may also develop digital or interactive versions of the module to examine how multimedia learning environments can strengthen HOTS, scientific media literacy, and culturally responsive science education.

CONCLUSION

This study aimed to develop an ecosystem module based on Papuan local wisdom using the ADDIE model and to evaluate its validity, practicality, and effectiveness in improving students' Higher Order Thinking Skills (HOTS). The findings revealed that the developed module met the criteria of a high-quality instructional product, as indicated by its very high validity, high practicality, and strong effectiveness in enhancing students' HOTS. The improvement in HOTS was reflected in the moderate N-gain score, significant paired t-test results, and large effect size, indicating that the module effectively facilitated students' analytical, evaluative, and creative thinking skills. The integration of Papuan local wisdom into ecosystem learning also contributed to making the learning process more contextual, meaningful, and relevant to students' real-life experiences. This study contributes to biology education by integrating HOTS-oriented learning, contextual learning, and local wisdom into a single instructional product through a systematic ADDIE-based design. However, this study was limited by the use of a one-group pretest–posttest design without a control group, which may restrict broader causal interpretation. Therefore, future studies are recommended to involve larger samples, apply experimental designs with comparison groups, and integrate digital or interactive learning features to further improve the effectiveness of the module.

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