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Integrated Science Learning Design Based on Local Wisdom of Wetlands to Improve High-Order Thinking Skills (HOTS) of Junior High School Students

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Abstract: This study aims to develop and evaluate an integrated science learning design based on wetland local wisdom to enhance junior high school students' Higher Order Thinking Skills (HOTS). The study addresses the limited integration of local environmental contexts in science instruction, which often leads to low student engagement and suboptimal development of higher-order cognitive skills. A Research and Development (R&D) approach was employed using the 4D model (Define, Design, Develop, Disseminate). The developed products included lesson plans, integrated teaching materials, student worksheets, and HOTS-based assessment instruments designed to facilitate contextual and meaningful learning experiences. The validity of the developed learning design was assessed by experts, resulting in a high average validation score of 0.92, indicating strong content, construct, and language appropriateness. Practicality was evaluated through classroom implementation and student responses, showing a high implementation rate (94%) and positive student responses (88.5%), both categorized as very practical. The effectiveness of the learning design was measured using N-gain analysis, which yielded a score of 0.72, indicating a high level of improvement in students' HOTS. Statistical analysis further confirmed significant improvements ($p < 0.05$), particularly in analytical (C4) and evaluation (C5) skills. In conclusion, the developed learning design is empirically proven to be valid, practical, and effective in improving students' HOTS. It also provides a robust and innovative framework for contextual science learning through the integration of wetland local wisdom, contributing to the advancement of science education in environmentally relevant contexts.

Keywords: 4D model; HOTS; Integrated science; Local wisdom; Wetland

Introduction

Science education at the Junior High School (SMP) level in the 21st century faces increasingly complex challenges in preparing students to adapt to the dynamic developments of science and technology. Scientific literacy is no longer understood merely as the mastery of concepts, but encompasses the ability to interpret data, evaluate evidence, and make science-based decisions within real-life contexts. The Organization for Economic Co-operation and Development (OECD) emphasizes that scientific literacy is a key competency individuals must possess to address global issues (Sulaiman et al., 2017; Saido et al., 2018). Nevertheless, the scientific literacy achievements of Indonesian students, as indicated by the Programme for International Student Assessment (PISA), remain below the international average, particularly in aspects of Higher Order Thinking Skills (HOTS) such as analysis, evaluation, and creation (OECD, 2023). This condition indicates a gap between the objectives of science education and pedagogical practices in the field.

Higher-order thinking skills are an essential component of science learning as they play a role in

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developing students' ability to understand phenomena deeply and contextually. Anderson et al. (2001) classify HOTS as higher-level cognitive processes involving analysis, evaluation, and creation. However, various studies show that science learning in schools is still dominated by textual approaches, oriented toward rote memorization, and provides insufficient space for students to engage in critical and reflective thinking (Billah et al., 2021; Muhibbuddin et al., 2023; Muliyadi et al., 2026). Furthermore, the implementation of integrated science at the junior high level is often suboptimal because physics, biology, and chemistry materials are taught separately, making it difficult for students to understand the interconnections between concepts in explaining natural phenomena holistically (Fogarty, 2009; Winarno et al., 2020; Azwir et al., 2024). Consequently, science learning becomes less meaningful and fails to optimally foster the development of HOTS.

One approach with the potential to address these issues is the integration of local wisdom into science learning through an ethnoscience approach. Learning based on local wisdom allows students to relate scientific concepts to the realities of daily life, making the learning process more contextual and meaningful. This approach aligns with the constructivist perspective, which emphasizes the importance of direct experience and socio-cultural context in the learning process (Jawas, 2017; Dhumcak et al., 2024; Dumchak et al., 2024). In the context of South Kalimantan, the wetland ecosystem serves as a learning resource rich in scientific phenomena, such as tidal dynamics, swamp biodiversity, and traditional community practices in environmental management (Fajeriadi et al., 2024).

These phenomena contain complex scientific concepts relevant to the science curriculum, particularly regarding the classification of living things and environmental changes. Research indicates that utilizing local contexts, such as wetlands, in science learning can enhance student motivation, conceptual understanding, and critical thinking skills (Astimer et al., 2019; Hariana et al., 2023; Irhayuarna et al., 2023; Trisnowati et al., 2023). Additionally, the integration of local wisdom contributes to building environmental awareness and student character (Fahmi et al., 2021; Irhasyuarna et al., 2022; Putra et al., 2023). However, currently available learning materials tend to be generic and do not yet accommodate the uniqueness of the local environment; thus, the potential of wetlands as a learning resource has not been optimally utilized in science education.

To address this need, the development of systematic, structured, and research-based teaching materials and instructional designs is required. The 4D development model proposed by Thiagarajan (1974)—comprising the define, design, develop, and disseminate stages—is a widely used model in instructional tool development due to its ability to produce valid, practical, and effective products. In the context of integrated science, this model enables the integration of various cross-disciplinary concepts into a single contextual theme (Kartini et al., 2019; Alika & Radia, 2021). The use of HOTS-based teaching materials, in both printed and digital forms, has been proven to significantly improve student learning outcomes and critical thinking skills (Noor et al., 2023; Fahmi et al., 2025; Musniar et al., 2025).

Despite this, studies specifically integrating integrated science, the local wisdom context of wetlands, and HOTS development at the junior high level, particularly for Grade VII, remain relatively limited (Hikmawati et al., 2021; Dini & Kuswanto, 2025). This limitation indicates a research gap that needs to be filled through the development of innovative and contextual instructional designs. Therefore, this study focuses on developing integrated science teaching materials based on wetland local wisdom using the 4D model, which is expected to improve learning quality and students' higher-order thinking skills.

Method

Type of Research

This study is a Research and Development (R&D) project. The objective of this research is to evaluate and ensure the validity of a developed product. The development model employed in this study is the Four-D (4D) model proposed by Thiagarajan. As the name suggests, the 4D model consists of four primary stages: Define, Design, Develop, and Disseminate.

Research Subjects

This study involved 30 seventh-grade students from a junior high school (SMP). The participants consisted of 15 males and 15 females, with an age range of 12–14 years. The trial was conducted at a middle-tier school in Banjarmasin. The selection of subjects was based on several considerations, including the school's environmental conditions and location, the local community culture surrounding the school, and the effective communication between the researchers and the science teacher.

Research Procedure

The initial stage of the Four-D (4D) model is the Define phase, which involves determining the product to be developed along with its specific requirements. This stage is conducted to analyze needs through empirical research and literature studies. The subsequent stage is Design, which focuses on creating the blueprint for the predetermined product. This is followed by the Development stage, where the design is transformed into a tangible product, and its validity is iteratively tested until it meets the specified standards. Finally, the Dissemination stage involves the full-scale implementation of the validated product in an instructional setting to be utilized by others (Sugiyono, 2015).

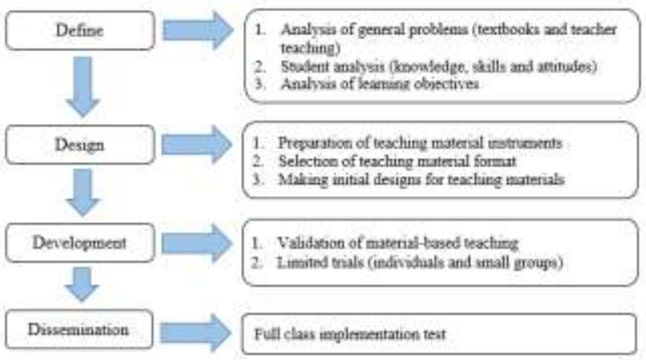

Figure 1. The four-D (4D) research implementation flowchart

Data Analysis

The data obtained in this study were analyzed using both quantitative and qualitative approaches to provide a comprehensive overview of the validity, effectiveness, and implementation of the learning product. Product validation data were analyzed through descriptive quantitative analysis by calculating validity score percentages, which were subsequently categorized into levels of feasibility: highly valid, valid, sufficiently valid, or less valid.

Meanwhile, student learning outcomes were analyzed using a paired sample t-test to identify significant differences between scores before and after the implementation of the learning product. This analysis aimed to statistically measure the product's effectiveness in enhancing student competence. Furthermore, qualitative data obtained through observations and interviews were analyzed using descriptive qualitative techniques to provide a deeper understanding of the product's feasibility and implementation process in the classroom, including teacher and student responses during learning activities. By integrating these two approaches, this study aims to provide a thorough evaluation of product validity, user acceptance, and its impact on improving student learning outcomes.

Table 1. Summary of Research Data Analysis Techniques (Irhasyuarna et al., 2025)

Type of Data	Data Collection Instrument	Analysis Technique	Purpose of Analysis
Product Validation Data	Expert validation questionnaires	Descriptive statistics (percentage and category)	To determine the validity level of the product
Student Learning Outcome Data	Pre-test and post-test assessments	Paired t-test	To examine significant improvement in students' learning outcomes
Qualitative Data	Observation and interview	Descriptive qualitative analysis	To describe the feasibility and implementation process of the product

Result and Discussion

Validity of Learning Tools

The validity of the integrated science learning tools based on wetland local wisdom was evaluated by three expert validators, comprising a subject matter expert, a media expert, and an instructional design expert. The validation process was conducted to assess the alignment of the content with the curriculum, the clarity of the instructional construction, the accuracy of language usage, and the integration of local contexts into the science materials. The validation results indicate that all components of the learning tools fall within the highly valid category, demonstrating that the product possesses high theoretical feasibility for instructional use. A summary of the validation results is presented in Table 2.

Table 2. Expert Validation Results of the Learning Tools

Learning Tool Component	Mean Score	Category
Syllabus and Lesson Plan (RPP)	0.91	Highly Valid
Integrated Science Teaching Materials	0.94	Highly Valid
HOTS Assessment Instrument	0.9	Highly Valid
Student Worksheets (LKPD)	0.93	Highly Valid
Grand Mean / Overall Average	0.92	Highly Valid

The overall mean score of 0.92 indicates that the developed learning tools have met the criteria for exceptionally high validity. This result is consistent with previous research, which states that HOTS-based and contextual learning tools generally exhibit high levels of validity when designed based on student needs and the specific characteristics of the subject matter (Hartik et al., 2021; Fahmi et al., 2025). Furthermore, the integration of local wisdom into teaching materials has been proven to enhance the relevance of the content to students' lives, thereby strengthening content validity (Sianturi et al., 2021; Widiyastuti et al., 2021). Consequently, these learning tools are declared theoretically feasible and ready for use in the instructional implementation phase at the junior high school level.

Practicality of the Learning Tools

The practicality of the learning tools was measured based on the teacher's implementation of the lesson plans and the students' responses following the learning process. Observation results revealed that the instructional implementation reached an average of 94%, placing it in the highly practical category. This indicates that all designed learning stages were successfully executed in the classroom without significant obstacles. Furthermore, the teacher noted that the developed tools were user-friendly due to their systematic structure, clear instructions, and learning activities that foster active student engagement. The practicality data are presented in Figure 2 below.

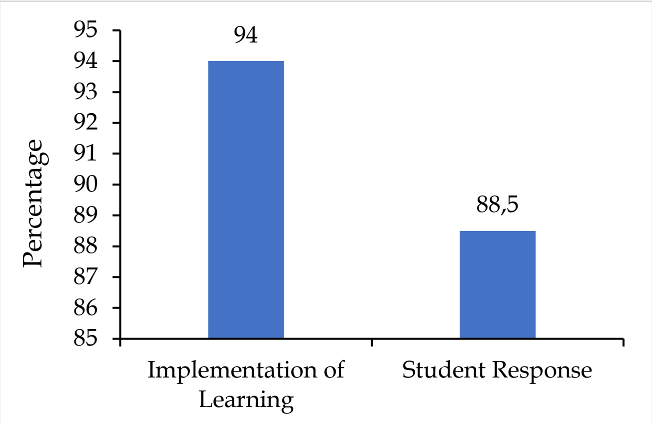

Figure 2. Average practicality scores of the developed learning tools

The results of the student response questionnaire showed an average agreement rate of 88.5%, falling into the highly practical category. Students stated that learning based on the wetland context is more engaging and easier to comprehend because it relates directly to their daily environment. The use of context-based problem-solving worksheets (LKPD) also assisted students in developing conceptual understanding and encouraged active involvement in group discussions. These findings are consistent with studies by Herayanti et al. (2025) and Rayis et al. (2025), which indicate that ethnoscience-based learning can enhance student engagement and motivation. Furthermore, Afnizar (2018) and Albar et al. (2025) reported that utilizing the wetland context in instruction improves implementation practicality, as it aligns with students' real-world experiences.

Consequently, it can be concluded that the developed learning tools are not only user-friendly for teachers but also received positive feedback from students as the primary users. Thus, the tools satisfy the practicality criteria for educational product development.

Effectiveness of the Teaching Materials

The effectiveness of the teaching materials was evaluated based on the improvement of students' Higher Order Thinking Skills (HOTS), which was analyzed using the N-gain score derived from pretest and posttest results. The results of this analysis are presented in Table 3.

Table 3. Comparison of learning effectiveness

Group	Pretest Mean	Posttest Mean	N-gain Score	Category
Class	42.50	83.90	0.72	High

High: ≥ 0.7; Moderate: 0.3 – 0.69; Low: < 0.3

Based on Table 3, it is evident that there was a substantial improvement in student learning outcomes. The N-gain score of 0.72 for the implementation class falls into the high category. This indicates that the use of integrated science teaching materials based on wetland local wisdom is more effective in enhancing students' HOTS compared to conventional learning methods.

The results of the Independent Sample T-test yielded a significance value (2-tailed) of 0.000 ($p < 0.05$), signifying a significant difference between the two groups. This finding strengthens previous research stating that HOTS-based and contextual teaching materials can significantly improve students' critical thinking skills (Noor et al., 2023; Fajeriadi et al., 2024; Herawati et al., 2024; Fahmi et al., 2025). Furthermore, the integration of local wisdom in instruction has proven effective in enhancing students' conceptual understanding and analytical abilities.

Further analysis shows that the most significant improvements occurred in the indicators of analysis (C4) and evaluation (C5), particularly when students were presented with real-world problems related to wetland ecosystem conservation. This suggests that contextual learning encourages students to think critically and reflectively in problem-solving. These findings align with research by Palloan et al. (2021), which asserts that HOTS-oriented learning can significantly enhance higher-order thinking skills.

Overall, the results of this study demonstrate that the developed teaching materials are not only valid and practical but also effective in improving students' higher-order thinking skills. The integration of the wetland local wisdom context has proven to be an innovative and relevant strategy in supporting meaningful science learning oriented toward 21st-century competencies.

Research Novelty and Scientific Impact

This study offers significant novelty by integrating three core components into a comprehensive instructional framework: integrated science learning, wetland local wisdom, and the development of Higher Order Thinking Skills (HOTS) at the junior high school level. Unlike previous studies that generally emphasize HOTS-based materials or local wisdom-based learning in isolation, this research systematically combines these three aspects within a 4D (Define, Design, Develop, Disseminate) development model. This approach facilitates learning that is not only conceptually integrated across disciplines (biology, physics, and chemistry) but also contextually relevant to the students' real-world environment, specifically the wetland ecosystems of South Kalimantan.

Another novelty lies in the utilization of wetlands as a primary learning resource, functioning not merely as a supplementary context but as a foundational base for building scientific conceptual understanding and HOTS (Astimar et al., 2019). This approach expands the concept of ethnoscience into a structured, experiential pedagogical strategy, aligning with constructivist principles that emphasize the interaction between knowledge and socio-cultural contexts. Furthermore, this study specifically targets HOTS enhancement at the cognitive levels of analysis (C4) and evaluation (C5), measured empirically through an experimental design with statistical testing, thereby contributing to a more focused and data-driven assessment of higher-order thinking skills (Anderson & Krathwohl, 2001).

Regarding scientific impact, this research contributes significantly to the development of science education theory and practice, particularly in strengthening contextual learning approaches based on local wisdom. The results, which show a significant improvement in students' HOTS (high N-gain and significant inter-group differences), provide empirical evidence that integrating local contexts into science education can substantially enhance instructional quality. These findings are consistent with prior research asserting that ethnoscience and HOTS-based learning effectively improve students' critical thinking and conceptual mastery (Noor et al., 2023; Fajeriadi et al., 2024; Herawati et al., 2024; Fahmi et al., 2025).

Methodologically, this study contributes a validated, practical, and effective 4D-based instructional development model that can be replicated or adapted in other local contexts. This opens opportunities for culture-based curriculum development across various regions while enriching international literature on contextual and culturally responsive science education.

Furthermore, this research has broad implications for supporting sustainable education, particularly in raising students' environmental awareness of wetland ecosystems. By linking scientific concepts with real-world environmental issues, the learning process serves not only as a means of knowledge transfer but also as a medium for character building and ecological stewardship. Therefore, this study provides both academic contributions and practical relevance in developing innovative, contextual science education oriented toward 21st-century global challenges.

Conclusion

This study successfully developed integrated science learning tools based on wetland local wisdom that meet the criteria for validity, practicality, and effectiveness. Validation results indicate a high level of feasibility, while practicality testing demonstrates that the tools are easily implemented in the classroom and received positive responses from students. Furthermore, effectiveness testing shows a significant improvement in students' Higher Order Thinking Skills (HOTS), particularly in the aspects of analysis and evaluation, as evidenced by the N-gain scores in the high category. Consequently, the integration of wetland local wisdom into integrated science learning is proven capable of creating a more contextual, meaningful, and 21st-century skill-oriented learning environment. The developed learning tools not only contribute to the improvement of student learning outcomes but also serve as an innovative model for culture- and environment-based instructional development that is adaptable to other contexts.

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Author Contributions

The authors in this research are divided into executor and advisor.

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Conflicts of Interest

The authors declare no conflict of interest in this research.

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