



Nested-local Wisdom Model for Sustainable Science Education: Enhancing Students' Conceptual Knowledge and Communication Skills

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Received: December 12, 2025

Revised: April 29, 2026

Accepted: June 25, 2026

Published: June 30, 2026

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DOI: [10.29303/jppipa.v12i6.13865](https://doi.org/10.29303/jppipa.v12i6.13865)

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Abstract: When science is perceived as disconnected from learners' social dan cultural contexts, students' engagement and identity in learning science decline. This study evaluates a nested-local wisdom approach integrating the cultural context of *Pinisi* boats to enhance students' conceptual knowledge, communication skills, and concept maps, supporting more meaningful and sustainable science education. This study employed a quasi-experimental design with a non-equivalent control group pretest-posttest involving students from SMPN 32 Bulukumba. Two intact classes ($n = 31$ each) were selected, and their equivalence was verified using pretest scores and academic records. Data were analyzed using MANOVA dan ANOVA. The results revealed a significant multivariate effect the learning model on all dependent variables (Wilks' Lambda = 0.212, $p < 0.001$, $\eta^2 = 0.788$), indicating a large effect size. Furthermore, ANOVA results revealed the largest effect size in concept maps ($\eta^2 = 0.682$), followed by communication skills ($\eta^2 = 0.642$) and conceptual knowledge ($\eta^2 = 0.449$). These findings suggest that integrating local wisdom within a nested learning structure supports the development of key science competencies, particularly conceptual knowledge and communication skills, through culturally meaningful learning. Therefore, the nested-local wisdom approach offers a contextually relevant and pedagogically grounded strategy for advancing sustainable science education.

Keywords: Communication skills; Concept maps; Conceptual knowledge; Local wisdom; Nested model.

Introduction

A crucial problem in science education, especially at the junior high school level, lies in students' perceptions of science as a cognitive difficulty, monotonous activities, and disconnected from their life realities (Anderhag et al., 2016; Shirazi, 2017; Taber et al., 2021). Echoing the view of Potvin & Hasni, (2014), concerns about the declining popularity of science among students have become a global focus contemporary science education literature. Learning that does not connect science with students' socio-cultural contexts tends to be regarded as meaningless

(Stuckey et al., 2013). This condition indicates the need for a transformation of the curriculum and pedagogy toward contextual and sustainable science learning, where scientific knowledge is meaningfully connected to students' social, cultural, and environmental realities (Coffie et al., 2025; Eilks & Hofstein, 2017). When the curriculum structure do not provide space for integrating personal experiences, authentic inquiry, or reflection on local value (Alifiyah et al., 2025), students lose the opportunity to develop a sense of ownership of science as an integral part of their lives (Clark et al., 2024). A transformative pedagogical approach enhances

How to Cite:

Asmar, A., Suryadarma, I. G. P., Yuliyanti, & Laruli, L. (2026). Nested-local Wisdom Model for Sustainable Science Education: Enhancing Students' Conceptual Knowledge and Communication Skills. *Jurnal Penelitian Pendidikan IPA*, 12(6), 164-176. <https://doi.org/10.29303/jppipa.v12i6.13865>

the quality of science teaching practices when integrating students' perspectives (Utha et al., 2023).

The need for transformation in science teaching is increasingly urgent, leading to curriculum design and pedagogical approaches that go beyond mere transmission of theory and facts (Eilks & Hofstein, 2017). This traditional approach often fails to address the relation and contextual dimensions that influence student engagement, resulting in passive learning and limited conceptual understanding (Coffie et al., 2025). Referencing the nested-integrated learning model developed by (Fogarty, 1991), which integrated several learning objectives across various domains within a single learning experience without rigidly separating disciplines, emphasizes a holistic and adaptive design in nested learning. Here, teachers dynamically adjust learning scenarios according to the cognitive and social condition of the students (Talanquer et al., 2024). The nested model approach promotes cross-disciplinary integration of science through contextual problem-solving activities that foster analytical and collaborative thinking skills among students (Habibah & Maryanto, 2020). Supporting this argument, Bahri et al., (2020) state that integrated nested learning provides substantive benefits because it connects school learning with real-life realities, not just understanding theoretical concept but also applying them in social and practical context. The integration of the nested model enables a layered learning structure, fostering strong connections between theoretical concepts and authentic learning experiences (Gitadewi et al., 2022).

It is important to emphasize at the outset that the terms local wisdom and indigenous knowledge are often used interchangeably to represent traditional knowledge systems that are internalized and practiced in the cultural life of communities (Mahaswa & Syaja, 2025). Various studies on the integration of local wisdom in pedagogical practices show significant results (Cahyaningsih et al., 2025; Lubis et al., 2022; Rahmasari & Kuswanto, 2023; Sulviana et al., 2025). Asmar & Suryadarma, (2021) state that local wisdom can be operationalized methodologically in learning design. According to Parmin & Trisnowati, (2024), the internalization of indigenous knowledge with global scientific standards has the potential to build an epistemological bridge between culture and science, creating a learning process that is more holistic, contextual, and meaningful for 21st-century generations. This perspective is further supported by findings from the community-based practices showing that local wisdom serves as a foundational framework in science and environmental education (Albar et al., 2025). In the context of sustainable science education, the integration of ethnoscience and Education for Sustainable

Development (ESD) has been shown to enhance environmental and scientific literacy, as well as foster students' awareness of sustainable issue (Marfiana et al., 2025; Purwianingsih et al., 2022). Additionally, learning designs that integrated local wisdom with sustainability-oriented approaches support the development of relevant competencies aligned with global challenges and the Sustainable Development Goals (SDGs) (Damayanti et al., 2024). Integration into education is not just about incorporating content, but also about changing the perspective on how we view "what is science?" (Zidny et al., 2020), serving as an epistemic bridge between empirical experience and formal science (Sotero et al., 2020).

Initial concepts held by students often serve as resistant cognitive structures, hindering the process of assimilation and accommodation of scientific concepts in effective science learning (Hewson & Hewson, 1984). The main difficulty in understanding scientific concepts is not solely due to limited information but also the way students organize and categorize knowledge within their conceptual frameworks (Chi, 2005). When students understand science concepts deeply, they do not just memorize facts, they "learn to see scientifically" (Abdel Rahman & Sommer, 2008). In the research description by Daniel et al., (2025), it is emphasized that conceptual knowledge does not develop optimally without students' epistemic engagement through the integration of the nature of science and scientific process skills. Learning is not just about achieving conceptual understanding. It is a cognitive and epistemological process that reinforces each other. Conceptual knowledge serves as a cognitive framework that enables students to understand "why" a procedure is performed, rather than merely "how" to carry it out (Beeler et al., 2024).

The practice of science teaching in the era of globalization is experiencing a revolution that requires more than just teaching procedural and empirical knowledge. The integration of communication training needs to be explicitly positioned as an essential component in the science curriculum, not merely as a complementary activity but as a core competency (Murphy, 2021; Shivni et al., 2021). According to Odell et al., (2023), communication is not just a tool for expression but also a tool for scientific thinking. The greatest challenge in science subjects lies in the abstract nature of its concepts, which requires a connector (communication) between ideas conceptually (Legvart et al., 2022), through communication skills that enable dialogue between the scientific community and the public (Daoust-Boisvert, 2022; Oliveira et al., 2023). Referring to the findings of Oliveira et al., (2023), it is shown that science communication skills are not

sufficiently trained from just the aspect of presentation techniques alone. Science education must provide space for students to reflect on the meaning and purpose of scientific communication. Communication skills are increasingly recognized as a central competency in science learning, as they support the development of critical thinking, conceptual understanding, and collaboration through activities such as discussion, scientific argumentation, and presentation (Afikah et al., 2022; Azmi et al., 2024; Pujiana et al., 2024)

Furthermore, this study is grounded in the need to reconstruct science learning paradigms to become more contextual, meaningful, and oriented toward sustainable science education. Science learning in Indonesia remains dominated by memorization of concept and has not fully fostered reflection and communication thinking skills in authentic contexts (Asmar & Suryadarma, 2021). Within interactive pedagogy, the nested model represents an intradisciplinary learning approach integrating three built-in competencies: thinking skills, social skills, and organizing skills (Fogarty). However, previous studies have primarily applied the nested model to cognitive domains without incorporating sociocultural and sustainability contexts. This study extends the nested model by integrating local wisdom as a culturally responsive and sustainability-oriented pedagogical framework, referred to as nested-local wisdom pedagogy.

In this study, thinking skills are represented by conceptual knowledge, reflecting students' ability to analyze and connect scientific concepts; social skills are represented by communication skills, indicating students' ability to articulate scientific ideas collaboratively; and organizing skills are represented by concept maps as supporting representations of students' cognitive organization. The layered structure of the nested model is integrated with local cultural dimensions the *Pinisi* boats, an intangible cultural heritage of the Konjo Tribe in South Sulawesi, as an epistemic learning context. This study therefore aims to examine whether science learning using a nested-based local wisdom approach significantly improves junior high school students' conceptual knowledge, communication skills, with concept maps serving as a supporting indicator, compared to conventional learning.

Method

Research Design

This study utilizes a quasi-experimental design featuring a non-equivalent control group model structure within a pretest-posttest framework. The

research design aligns with the research objectives to evaluate the effectiveness of nested based local wisdom (*Pinisi* boat) learning model in enhancing students' conceptual knowledge, communication skills, and concept maps. The quasi-experimental approach is chosen due to practical constraints in random assignment in the school environment. This situation necessitates that the separation of experimental and control group adapts to pre-existing classes (intact classroom setting). The research still allows for strong causal inferences, provided that baseline equivalence, strict procedural control, and consistent implementation of the intervention are maintained (Shandish et al., 2002).



Figure 1. Instructional structure of the model of nested based on local wisdom for sustainable science education

The learning intervention follows the nested based on local wisdom instructional framework, which is an instructional design that reconstructs local knowledge (*Pinisi* boat) into a scientific learning structure through tiered activities (Figure 1). The instructional design is intended to evaluate the causal effect of the treatment on the learning competency outcomes of the students. The experiment consists of four sequential sessions (meeting) conducted over two weeks. Each session is standardized through a learning guide to ensure a consistent level of replication across classes. Before the intervention begins, participants in both the experimental and control groups completed a pretest to assess their basic skills in three research indicators (conceptual knowledge, communication skills, concept maps). The pretest data were used to verify the initial equivalence between groups and were not included as dependent variables in the main Multivariate Analysis of Variance (MANOVA) analysis. Both groups were taught by the same teacher to control for teacher-effect bias. To minimize the risk of treatment diffusion, the teacher followed strictly differentiated instructional protocols for each group, supported by detailed lesson plans and monitoring procedures. The experimental group received instruction integrating local wisdom

contexts as a basic for science reasoning, whereas the control group was taught the same science content using a conventional approach aligned with the school curriculum without incorporating local wisdom elements. After the intervention, both groups completed a posttest using the same instruments to measure

learning outcomes, and these posttest scores were analyzed using MANOVA. The implementation stages of the nested based on local wisdom instructional framework are presented in Table 1.

Table 1. Syntax of Nested Instructional Based on Local Wisdom for Intervention in Experimental Classes on Biodiversity Material

Learning stage	Learning activities	Competencies developed	Integration of local wisdom
Contextual orientation	Learning begins by triggering a problem sourced from local cultural phenomenon (the Pinisi boat)	Thinking: initial schema; Social: spontaneous discussion; Organizing: documenting initial ideas through a concept-map sketch	Construction of ecological knowledge through the cultural practice of the “Pinisi boat” as an entry point
Multimodal exploration	Student explore video/practices with local figures related to the lesson material	Thinking: identifying local practice phenomena; Social: exploratory dialogue and sharing findings; Organizing: grouping phenomena based on similar characteristics	Translating local cultural (practice) into representations of scientific concepts
Nested task building	Students carry out nested task, namely a series of tiered activities that train three competency domains simultaneously	Thinking: understanding and constructing the core concepts of the lesson; Social: articulating scientific arguments verbally and in writing; Organizing: constructing visualization of culture-science relations based on exploration results	Arranging narratives and concept maps sourced form indigenous knowledge reconstructed into a scientific framework
Culture-science dialogue	Teachers and students enter a reflective phase to compare cultural perspectives and scientific arguments related to the phenomenon studied.	Thinking: connecting traditional concepts and modern concepts Social: argumentative dialogue and concept classification Organizing: revising concept structures after the dialogic process	Testing the alignment between local cultural practices and scientific knowledge
Knowledge reconstruction	Students reconstruct their understanding of scientific concepts by incorporating knowledge from local traditions and scientific analysis.	Thinking: concept consolidation and internalization of the lesson content Social: composing scientific narratives supporting the concept map Organizing: constructing complex concept maps with hierarchical and relational connections	Convergence between indigenous →conceptual understanding
Value affirmation and sustainable action	Learning is concluded by emphasizing local wisdom values relevant to science and formulating positive commitments (cultural and environmental contexts)	Thinking: generalizing scientific principles and concepts Social: scientific presentation and persuasion Organizing: finalization after feedback	Affirming local wisdom values in everyday life

The research data was collected by testing the influence of the nested based on local wisdom learning model on three dependent variables. The dependent

variables include conceptual knowledge, communication skills, and concept maps. The research population include all 7th grade students of SMPN 32

Bulukumba in the 2024/2025 academic year. The researcher selected two intact classes as research samples (total N = 62), with each sample (n = 31) for the experimental class and the control class. A cluster sampling approach was employed by selecting existing classes, and their equivalence was verified using pretest scores and academic records to ensure comparability between groups. This approach is consistent with a quasi-experimental design, where intact groups are used to maintain the natural classroom setting and support internal validity (Creswell & Guetterman, 2024)

The measurement instruments for the research variables were designed based on empirical studies in local wisdom-based science learning. Written essay tests were used to measure students' conceptual knowledge and partially assess communication skills, particularly in terms of clarity of concept delivery and scientific argumentation, as they capture students' ability to explain, elaborate, and justify scientific ideas in written form. To more comprehensively assess communication

skills, including collaborative communication, scientific presentation, and culturally situated scientific communication, performance-based assessments were employed through structured observation and presentation tasks using standardized rubrics.

In contrast, concept mapping tasks were used to evaluate students' ability to organize and structure relationships among scientific concepts. Inter-rater reliability was ensured through assessor agreement testing before the final scoring process to maintain consistency in evaluate essays, communication performance, and concept maps. All collected data were analyzed to examine differences in learning outcomes between the experimental and control groups after the intervention. The research was conducted following educational research ethics standards by obtaining consent for student participation before the intervention took place. Research instruments to evaluate of learning nested based on local wisdom are detailed in table 2, 3, and 4.

Table 2. Instrument Grid for Assessing Students' Communication Skills

Indicators	Operational behaviors
Clarity of concepts delivery	Articulates concepts using accurate scientific terminology
Scientific argumentation	Explains causal relationship within scientific phenomena
	Puts forward claims supported by scientific evidence
Collaborative communication	Analyzes and responds critically to peers' arguments
	Manages turn-taking and provides space for other group members
Scientific presentation	Constructs shared ideas coherently during group interactions
	Presents learning outcomes orally using a clear scientific structure
Culturally situated scientific communicatio	Employs visual representations to strengthen communication
	Connects science concepts with relevant local cultural contexts
	Demonstrates respect for cultural norms during scientific dialogue

Table 3. Instrument Grid for Assessing Students' Conceptual Knowledge

Indicators	Operational behaviors
Understanding of fundamental concepts	Accurately recognize and name fundamental scientific terms, principles, and entities relevant to the topic.
Conceptual relationships	Clearly articulate how scientific concepts relate, interact, and influence each other within a system.
Application of conceptual in contextual scenarios	Use scientific concepts correctly to interpret, analyze, or solve real-world or experimental problems.
Conceptual integration and structuring	Organize interconnected concepts into coherent frameworks such as concept maps, models, or structured verbal explanations.

Table 4. Instrument Grid for Assessing Students' Concept Maps

Indicators	Operational behaviors
Structural coherence	Concepts are organized hierarchically from most general to most specific.
Precision of conceptual relationships	Linking phrases correctly reflect causal, functional, comparative, or descriptive relationships.
Cross-subtopic concept connections	Cross-links accurately show relationships between different clusters of concepts.
Depth of visualization	The map reflects conceptual depth through inclusion of essential, non-redundant concepts.

Research instruments underwent validity and reliability testing prior to use. Construct validity was

analyzed though Aiken's V to assess the alignment of items with the theoretical construct. The validity results

indicate that the conceptual knowledge instrument received an Aiken’s V value of 0.88 the communication skills instrument received a validity index of 0.82, and the concept map instrument received a validity index of 0.86. All assessment results exceeded the eligibility threshold of ≥ 0.70 , indicating that the instrument is “very valid” and capable of representing the measured behavioral domain without contextual bias. Empirical reliability was calculated using Cronbach’s Alpha. The conceptual knowledge instrument achieved a reliability of $\alpha = 0.90$, the instrument of communication skills $\alpha = 0.84$, and the instrument of concept map $\alpha = 0.85$, with all results classified as “very high.” Validity values (Aiken’s V) ≥ 0.70 and Cronbach’s Alpha ≥ 0.70 are indicators that the instrument has internal consistency and equivalence suitable for experimental-based education (Aiken, 1985; Taber, 2018).

Research data were analyzed using MANOVA to examine the multivariate effects of the intervention on multiple learning outcomes. In addition, effect sizes were calculated using Partial Eta Squared (η^2) to estimate the proportion of variance explained by the intervention. Prior to analysis, the assumptions of MANOVA, including multivariate normality and homogeneity of variance-covariance matrices, were tested to ensure the validity of the statistical results. All analysis procedures were conducted using the Statistical Package for the Social Sciences (SPSS) version 22.

Result and Discussion

Emperical Verification through Statistical Testing

In this study, the researcher implemented a nested based on local wisdom approach and tasted its effectiveness through a quasi-experimental design in science learning. The research findings reveal that the experimental group students who received the nested based on local wisdom treatment intervention achieved higher results compared to the control group that applied conventional learning. This advantage is consistently observed across the three dependent variable of the study.

The descriptive statistics in Table 5 indicate that the pretest distribution of the experimental and control groups is closely comparable across all variables. The score ranges now show strong overlap, particularly in conceptual knowledge, where both groups share identical minimum values and closely aligned maximum value. The mean differences remain marginal, and the standard deviations are comparable, indicating similar variability in baseline performance. These patterns suggest no substantive initial differences between groups, supporting the assumption of baseline equivalence in this quasi-experimental design. Accordingly, the pretest data were used solely to confirm initial comparability and were not included in the main MANOVA, ensuring that subsequent differences are more plausibly attributed to the intervention.

Table 5. Descriptive Statistics of Pretest Scores Dependent Learning Variables

Deventent Variables	Group	N	Min	Max	Mean	SD
Conseptual knowledge	Experimental	31	30.00	55.00	40.22	6.82
	Control	31	30.00	52.50	40.76	6.64
Communication skills	Experimental	31	24.44	57.78	40.84	8.26
	Control	31	26.66	55.25	40.10	8.41
Concept mapping	Experimental	31	28.89	51.11	39.61	6.85
	Control	31	30.00	50.00	38.59	6.90

The statistical distribution in Table 6 indicates a significant advantage for the experimental intervention group across all dependent variables. This approach highlights the effectiveness of nested based on local wisdom learning in enhancing the multidimensional learning outcomes of students. In the variable of conceptual knowledge, the experimental group achieved a mean score of 76.82 compared to 59.59 in the control group (a difference of 17.23. points), with a lower standard deviation (6.27 vs. 8.95). These findings indicate a more homogeneous distribusi of students’ conceptual knowledge, rather than merely reflecting variability in performance. A similar increase is observed in communication skills, where the mean score of the experimental group reached 71.25, far surpassing

the control group’s 51.11 (a difference of 20.14). This finding represents the success of nested based on local wisdom learning in providing space for scientific dialogue, social interaction, and the construction of arguments to develop the ability to express ideas clearly, logically, and contextually. The most significant increase is seen in the concept map variable, with a mean score of 74.27 compared to 52.34 in the control group (a difference of 21.93 points). This finding indicates that this approach not only strengthens concept acquisition but also sharpens the competence in constructing and organizing knowledge systematically through the ability to connect core concept and sub-concepts within a meaningful cognitive structure. Generally, the consistency of excellence across variables shows that the

implementation of nested based on local wisdom learning offers a more holistic, relevant, and transformative science learning experience compared to conventional learning.

Referring to Figure 1, the results of the normality test confirm that both distributions, the experimental class and the control class, have significance values (Sig.) > 0.05 in both test, Kolmogorov-Smirnov (S) and Shapiro-Wilk (W). In the concept maps variable, the experimental class shows a residual value of W (31) = 0.960, p = 0.300, while the control class obtains a residual value of W (31) = 0.961, p = 0.317. The communication skills variable also demonstrates a similar trend, with a residual value of W (31) = 0.972, p = 0.576 for the experimental class and a residual value of W (31) = 0.961, p = 0.315 for the control class. In the conceptual knowledge variable, the experiment class achieves a residual value of W (31) = 0.965, p = 0.401, while the control class obtains a residual value of W (31) = 0.970, p = 0.531. Overall significance value above 0.05 indicate that the posttest data distributions for the three variables in both groups are normal.

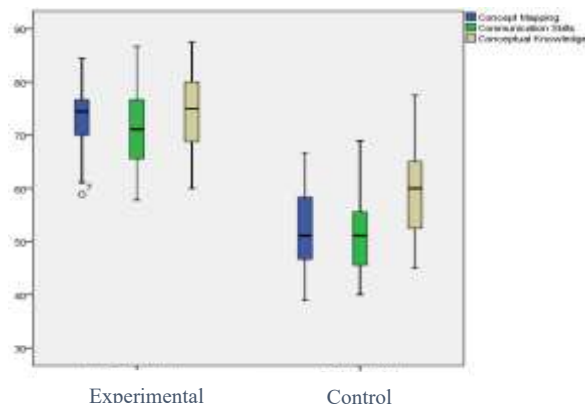


Figure 2. Normality test results for the study variables

Table 6. Descriptive Statistics of Posttest Scores Dependent Learning Variables

Devendent Variables	Group	N	Min	Max	Mean	SD
Conseptual knowledge	Experimental	31	62.50	87.50	76.82	6.27
	Control	31	45.00	77.50	59.59	8.95
Communication skills	Experimental	31	57.78	86.67	71.25	7.84
	Control	31	40.00	68.89	51.11	7.44
Concept mapping	Experimental	31	58.89	84.44	74.27	6.41
	Control	31	38.89	66.67	52.34	7.82

Table 7. Box’s M Test for Equality of Covariance Matrices

Statistic	Value
Box’s M	2.246
F	.354
df1	6
df2	26083.019
Sig.	.908

Referring to the Box’s Test results in Table 7, the value obtained was 2.246. (p = 0.908), which is above the significance value (p-value > 0.01). This result confirms that the covariance matrix between groups meets the assumptions of statistical equality strongly (homogeneity). The analysis of MANOVA can be performed without indication of assumption violations.

The statistical results in Tabel 8 show that the obtained Wilk’s Λ value of 0.212 confirms that a large proportion of multivariate variance in the combination of dependent variable can be explained by the class factor. The F value (3, 58) = 71.969, p < 0.001 confirms that the differences between groups are statistically significant at the multivariate level. Furthermore, the partial eta squared (η^2) value of 0.788 reflects a very large effect size, meaning that 78.8% of the variance in the combined dependent variable can be explained by the nested based on local wisdom learning model. Thus, the learning intervention provided has been shown to have a significant and meaningful multivariate impact on the learning performance profile of the students.

The results of the Test of Between-Subjects Effects in Table 9 confirm that the factor of class has a significant impact on the overall dependent variables (conceptual knowledge, communication skills, concept maps) that were tested. The concept map received an F value of (1, 60) = 128.815, p < 0.001, $\eta^2 = 0.682$. For the variable of communication skills, an F value of (1, 60) = 107.626, p < 0.001, with an effect size (η^2) of 0.642 was obtained.

An F value of (1, 60) = 48.882, $p < 0.001$, with an effect size (η^2) of 0.449 was obtained for conceptual knowledge. Overall, the nested based on local wisdom learning intervention produced a significant individual impact across all three domains of learning outcomes, as

indicated by consistently low p-value ($p < 0.001$) and large effect sizes (η^2). The impact of the nested based on local wisdom learning intervention is not only statistically significant but also substantively practical.

Table 8. Multivariate Test Results on the Effectiveness of the Nested Based Local Wisdom on Posttest Performance

Effect	Value	F	Hypothesis df	Error df	Sig.	Partial eta squared
Pillai's Trace	.788	71.845 ^b	3.000	58.000	.000	0.788
Wilks' Lambda	.212	71.969 ^b	3.000	58.000	.000	0.788
Hotelling's Trace	3.723	72.104 ^b	3.000	58.000	.000	0.788
Roy's Largest Root	3.723	72.256 ^b	3.000	58.000	.000	0.788

Table 9. Tests of Between-Subjects Effects Demonstrating the Impact of the Nested Based Local Wisdom on Learning Performance

Deventent variable		Type III sum of squares	df	Mean square	F	Sig.	Partial eta squared
Concept mapping	Group	6583.349	1	6583.349	128.815	0.000	0.682
	Error	3066.427	60	51.107			
Communication skills	Group	6288.917	1	6288.917	107.626	0.000	0.642
	Error	3505.983	60	58.433			
Conceptual knowledge	Group	3339.113	1	3339.113	48.822	0.000	0.449
	Error	4103.629	60	68.394			

The results of the Test of Between-Subjects Effects in Table 8 confirm that the factor of class has a significant impact on the overall dependent variables (conceptual knowledge, communication skills, concept maps) that were tested. The concept map received an F value of (1, 60) = 128.815, $p < 0.001$, $\eta^2 = 0.682$. For the variable of communication skills, an F value of (1, 60) = 107.626, $p < 0.001$, with an effect size (η^2) of 0.642 was obtained. An F value of (1, 60) = 48.882, $p < 0.001$, with an effect size (η^2) of 0.449 was obtained for conceptual knowledge. Overall, the nested based on local wisdom learning intervention produced a significant individual impact across all three domains of learning outcomes, as indicated by consistently low p-value ($p < 0.001$) and large effect sizes (η^2). The impact of the nested based on local wisdom learning intervention is not only statistically significant but also substantively practical.

students' academic performance. In line with the findings of Gitadewi et al., (2022), it is emphasized that the application of the nested learning model not only enhances students' conceptual understanding linearly but also encourages learning outcomes through cognitive activities. The study results by Habibah & Maryanto, (2020) state that the layered learning structure in the nested model creates vertical and horizontal integration among competencies, so the cognitive processes of students' do not occur in isolation but support each other. Nested learning creates a cognitive ecosystem and social interaction that strengthen the comprehensive transformation of students' learning achievement (Talanquer et al., 2024).

The effectiveness of Nested Based on Local Wisdom Learning (Pinisi Boat Context) on Domain's Learners' Competence

This research was conducted to evaluate the effectiveness of science learning that integrate the nested model and local wisdom (the Pinisi boat) on student learning outcomes in three competency domains (conceptual knowledge, communication skills, concept maps). The research findings based on empirical data provide strong evidence, emphasizing that the nested based on local wisdom learning intervention implemented not only increases test scores but also fosters deep cognitive and communication competencies among students. The nested based on local wisdom learning structure allows for simultaneous activation of

Practically, the integration of local culture (the Pinisi boat) serves as a starting point for learning to enhance the relevance, psychological attachment, and emotional involvement of students with abstract science material. In line with the finding of (Cross et al., 2020), it is stated that the integration of science learning makes students more cognitively and affectively engaged because they feel that science is an inseparable part of their lives. This perspective is also supported by studies on the Mentawai indigenous community, which demonstrate that local wisdom functions as an adaptive knowledge system in understanding and responding to natural phenomena, thereby strengthening the contextual relevance of science learning (Siregar et al., 2025). Consistent with this argument, the integration of cultural context in creative narratives significantly improves academic vocabulary and conceptual understanding of students in science (Stevenson &

Huffling, 2021; Zidny et al., 2020). Thus, cultural knowledge becomes a cognitive foundation that strengthens students' understanding of scientific concepts through connections that are more closely related to real-life realities.

The nested based on local wisdom learning intervention is not just about creating differences; it actually serves as the main catalyst in driving the transformation of student' learning outcomes. A significant improvement in concept map abilities indicates that the context of the local wisdom provides a strong conceptual foundation for students in organizing and connecting scientific concepts. Local wisdom serves as a cognitive anchor that helps students link cultural experiences with science material, thereby reinforcing the process of meaning-making. The research findings by (Rahmasari & Kuswanto, 2023) show that learning integrated with local wisdom (catapult) not only facilitates students' understanding of concepts but also allows for accurate mathematical and graphical representations. In line with this argument, (Makhrus et al., 2025) stated that the integration of cultural context and global sustainability issues generates constructive cognitive conflicts, prompting students to revisit misconceptions, construct scientific reasoning, and produce scientific arguments. (Andriyanto et al., 2025) found that culturally immersive learning integrated with local wisdom enhances students' emotional and cognitive engagement, allowing speaking skills to develop more naturally within an authentic cultural context. (Pangsuma et al., 2024) demonstrated that of the learning based on ESD module integrated with local wisdom (*Bugis*) significantly strengthens critical thinking and environmental literacy skills, interpreting sustainability issues through cultural values that resonate with students' realities.

The enhancement of conceptual knowledge reinforces the socio-cultural constructivism view that learning relevant to students' social experiences results in deeper understanding. In addition, the findings on the improvement of communication skills emphasize that culture-based learning not only builds understanding but also enhances students' ability to clearly, logically, and argumentatively convey scientific ideas. (Lubis et al., 2022) state that PBL oriented towards local wisdom and socio-scientific issues has been shown to enhance students' scientific thinking skills. The problem-solving process is carried out through relevant and meaningful socio-cultural contexts. In line with this argument, (Kamila et al., 2024) found that the integrated of local potential in science learning shows an increase in 21st-century skills and cultural awareness, where scientific concepts are connected through students' identities and social realities. Thus, the nested based on local wisdom

is not only statistically significant but also pedagogically transformational. This intervention strengthens students' cultural identities while simultaneously enhancing their science competencies across three domains.

Furthermore, the findings of this study provide strong evidence that the nested based on local wisdom model contributes substantively to the advancement of sustainable science education by repositioning cultural knowledge as an epistemic foundation rather than merely a contextual supplement. The significant improvements observed across learning domains indicate that embedding local wisdom within a structured instructional model facilitates not only conceptual understanding but also development of sustainability-oriented scientific literacy. This support the argument that science learning becomes more meaningful when it is grounded in learners' sociocultural realities, enabling students to interpret scientific concepts through culturally relevant frames of reference (Febrian et al., 2024; Sari et al., 2023; Zidny et al., 2020). Moreover, the integration of local wisdom inherently introduces values of environmental responsibility and sustainability, which are central to the principles of Education for Sustainable Development (Badiah et al., 2024; Nugroho et al., 2025; Wilujeng et al., 2019). In this sense, the nested-local wisdom approach function as a transformative pedagogical strategy that bridges the gap between formal scientific knowledge and lived cultural experience, thereby fostering students' capacity to engage critically with real-world sustainable issues. This argument is further strengthened by studies demonstrating the ESD-oriented and project-based learning approaches enhance systems thinking skills and sustainability awareness, enabling students to understand complex environmental relationships more holistically (Ekselsa et al., 2023). In addition, integrating ethnoscience and local ecological knowledge into science learning has been shown to align scientific concepts with students' cultural identities and environmental contexts, thereby increasing learning relevance and engagement (Amri et al., 2025; Santa et al., 2024). Therefore, this study argues that effective science learning should not be viewed solely in terms of cognitive gains, but also in its ability to culturally grounded and sustainability-conscious learners.

Conclusion

The nested-local wisdom learning model integrating the *Pinisi* boat context is associated with improved student performance across three measured domains-conceptual knowledge, communication skills,

and concept mapping. Multivariate analysis indicates a significant overall group difference (Wilks' $\lambda = 0.212$, $p < 0.001$) with a large effect size ($\eta^2 = 0.788$), suggesting that a substantial proportion of variance in the combined outcomes is explained by the intervention. These findings demonstrate that embedding local cultural knowledge within a structured nested framework not only supports cognitive and communicative development but also contributes to sustainable science education by fostering contextually meaningful and culturally grounded learning. However, given the quasi-experimental design and limited scope of variables, the results should be interpreted cautiously. Future research should incorporate broader sustainable indicators and more rigorous designs to further validate the role of nested-local wisdom pedagogy.

Acknowledgments

The researcher extends sincere appreciation to the experts, teachers, and coastal community elders whose insights, validation, and cultural contributions were essential in developing the nested learning model grounded in local wisdom. Gratitude is also extended to the partner schools and students for their active participation throughout the study, which enabled a robust process of data collection and model evaluation. Institutional support and constructive feedback from academic colleagues during the design, implementation, and assessment phases of this research are likewise deeply acknowledged.

Author Contributions

Conceptualization, A.A.; methodology, A.A. and S.I.G.P.; validation, W.I. and S.; formal analysis, A.A. and L.L.; investigation, A.A. and Y.; data curation, S.; writing—original draft preparation, A.A.; writing—review and editing, A.A., S.I.G.P., and Y.; All authors have read and agreed to the published version of the manuscript.

Funding

This research received no external funding and was fully supported by the authors' institutional resources.

Conflicts of Interest

The authors state that there are no potential conflicts of interest to disclose.

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