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Indigenous Knowledge as a Living Laboratory: Reconceptualizing Local Wisdom-Based Science Learning Strategies

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ABSTRACT

Modern science learning in the 21st century demands a paradigm shift from textbook-oriented teaching to a contextual approach grounded in real-world phenomena. However, the integration of local wisdom or Indigenous Knowledge (IK) into the formal curriculum is still often decorative due to the lack of a systematic operational framework in the classroom. This integrative literature review aims to map and synthesize 20 primary articles (ranging from 2016 to 2026) that examine ethnoscience, then reconstruct them into a Living Laboratory instructional strategy. Using qualitative thematic analysis, the data are categorized into three main dimensions: types of IK, representations of modern scientific concepts, and forms of reconstruction of the living laboratory framework. The results of the study successfully synthesized local wisdom into 6 main clusters, including: (1) traditional tool and game technology, (2) cultural heritage architecture, (3) agricultural and irrigation systems, (4) traditional textile industry, (5) local culinary processing, and (6) ecosystems and traditional medicine. The theoretical synthesis demonstrates a strong conceptual link that intuitive indigenous practices harbor valid empirical scientific principles (Physics, Chemistry, and Biology). The reconstruction of the "Living Laboratory" framework is operationalized through active strategies such as Project-Based Learning (PjBL), field experiments, and the STEAM approach. This research provides practical guidance for educators and curriculum developers to create culturally responsive learning tools, aligned with the principles of Culturally Responsive Teaching (CRT) and the concrete implementation of the Independent Curriculum.

Keywords: Indigenous Knowledge, Living Laboratory, Science Learning Strategies, Ethnoscience.

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INTRODUCTION

Mastering academic content in 21st-century education is not the only primary requirement for students; education must also focus on strengthening contextual and sustainable scientific literacy. A global paradigm shift is underway, moving from textbook-centered learning to more contextual, real-world learning, equipping students with 21st-century skills (Council et al., 2012; OECD, 2023). This aims to ensure that students are not merely memorizing formulas and theories from textbooks but also understand how science works to maintain ecosystem balance and solve everyday problems.

However, in practice, science education in schools is often trapped in an overly rigid, Western-centric approach that ignores local cultural realities (Aikenhead, 2006). Science is often presented as separate from local values with which students are already familiar, resulting in students experiencing cultural border-crossing or feeling unfamiliar with the material learned in their own schools (Snively

& Corsiglia, 2001). This gap leads to the environment's enormous potential as a learning medium being neglected and even abandoned by future generations, who consider it outdated. However, data show that the failure to connect science to local realities reduces students' motivation to learn about global environmental issues (Putrayasa et al., 2026). Every indigenous community possesses a knowledge system that has been tested for centuries in interacting with nature to survive and build civilization. This aligns with the main principle of the Independent Curriculum, which states that learning must be tailored to the students' environmental conditions (Efendi et al., 2023).

Indigenous Knowledge (IK) is a body of scientific practices developed over generations by residents as part of cultural heritage, and in this article, it is viewed as a living laboratory. Indigenous practices, such as traditional agricultural systems, forest conservation, food processing, craft making, and the construction of traditional houses, contain empirically applied principles of biology, chemistry, and physics. (Anwar, 2025). Conceptualizing indigenous environments as living laboratories acknowledges that scientific experiments and observations occur not only in enclosed spaces with modern, unfamiliar equipment but also in the harmonious interaction between communities and their ecosystems. This IK-based living laboratory concept offers a more inclusive and dynamic classroom management strategy, in which the surrounding environment is transformed into a concrete space for scientific experimentation. This contextualizes learning, providing a more in-depth and realistic learning experience.

Despite the enormous potential of local wisdom, the integration of Indigenous Knowledge into the formal science curriculum still faces challenges due to the lack of a systematic conceptual framework, making it difficult for teachers to understand and implement (Lestari, 2025). Much previous research has discussed ethnoscience, but the majority is limited to identifying the scientific content of specific cultures without formulating it into a comprehensive instructional strategy in the classroom. Some studies even simply mention the term ethnoscience without specifying the types of activities and how it is implemented in learning. As a result, indigenous wisdom often becomes merely an add-on or decorative element, rather than the core of students' scientific discovery processes. This is where the urgency of this research lies: is there a research gap regarding how to integrate Indigenous Knowledge theoretically and practically into a structured project-based learning model? Without a solid conceptual framework, efforts to decolonize the science curriculum at the national and international levels will continue to fail in the classroom.

Therefore, this literature review-based research is necessary to synthesize various previous research ideas and findings on ethnoscience and position them within the mapping of modern learning strategies. By reconceptualizing living laboratory-based science learning, this research offers an alternative and critical perspective on culturally responsive curriculum management. Specifically, this article aims to map how indigenous knowledge can be deconstructed and restructured into a robust model for science learning, while also providing a theoretical foundation for developing a curriculum that is more inclusive, relevant, and respectful of local cultural identities.

METHOD

This research was designed as an integrative literature review. This design was chosen because it aimed to build a new conceptual framework and reconceptualize learning strategies through a comprehensive literature synthesis from various previous empirical studies (Snyder, 2019; Toronto & Remington, 2020). The procedure for implementing this literature review was adopted from a modified systematic review framework through four main stages: (1) identification, (2) screening, (3) eligibility, and (4) data synthesis (Page et al., 2021).

The literature search was conducted electronically by accessing three major reputable databases: Google Scholar, Sinta (Ristekdikti), and Scopus (Adawiah et al., 2026). The publication dates of the analyzed articles were limited to the period between 2016 and 2026. This limitation aims to ensure that the synthesized research ideas or findings represent the latest developments in 21st-century science curricula (Gough et al., 2017). The keywords used in the search process were arranged using

Boolean operators (AND and OR) as follows: "Indigenous knowledge" OR "Local wisdom" AND "Living laboratory" AND "Science learning strategies" OR "Ethnoscience."

Data obtained from 20 selected articles were analyzed using qualitative thematic analysis to identify recurring conceptual patterns (Braun & Clarke, 2025). The analysis steps included:

1) Data Reduction
   Extracting essential data from each article, including author name, year of publication, type of local wisdom studied, scientific concepts, and science learning models used in living laboratories.
2) Coding and Categorization:
   Grouping the data thematically into three main dimensions: the dimension of indigenous knowledge types, consisting of traditional tool/game technology, architecture, agriculture, textile industry, culinary and food processing, and environmental conservation; the dimension of representation of modern scientific concepts contained in each indigenous practice; and the dimension of living laboratory activity forms by coding their instructional reconceptualization.
3) Theoretical Synthesis:
   Comparing findings across researchers to identify conceptual gaps and synthesize them into recommendations for a robust reconceptualization of new learning strategies.

RESULT AND DISCUSSION

Based on data analysis of 20 selected primary articles, it was found that indigenous knowledge in Indonesia has broad relevance across all basic science groups (Physics, Chemistry, and Biology). The theoretical analysis process showed that traditional knowledge, previously considered intuitive and passed down from generation to generation, contains empirical scientific principles that can be validated using modern science. Therefore, there is no conflict between the scientific knowledge of the community that has been built up through generations and the modern scientific knowledge contained in textbooks (Riantika & Sholikah, 2025). In fact, indigenous knowledge of the Indonesian people can enrich students' science learning resources, while at the same time, efforts to preserve and introduce culture to the younger generation through integration into learning in schools (Kamila et al., 2024).

To avoid biased fragmentation of the material and to present a comprehensive reconceptualization, the 20 articles were synthesized into six main clusters of local wisdom from various regions in Indonesia. Each cluster was not only mapped based on its scientific concept representation but also further deconstructed into concrete instructional strategies to transform traditional environments into living laboratories for students. The results of this thematic analysis and synthesis are comprehensively summarized in Table 1 below.

Table 1. Synthesis Matrix of Ethnoscience and Living Laboratory Framework Reconstruction

No.	IK Type (Indigenous Knowledge)	Representation of Modern Science Concepts	Living Laboratory Framework Reconstruction
1.	Tool Technology & Traditionals game:	Force, Mechanics & Kinematics:	Contextual Mechanics Experiments & Physics Modeling:
	- Mechanism of traditional rice pestle/lesung (Husin & Billik, 2019) - Mechanism of the Sigale-Gale puppet (Wilujeng et al., 2025)	Leverage principles, frictional force, muscular force, Newton's laws of motion, momentum, equilibrium, motion, acceleration, Boyle's	Students conduct empirical experiments to analyze the mechanical lever system of traditional pestles, model the principles of force equilibrium in traditional puppet

No.	IK Type (Indigenous Knowledge)	Representation of Modern Science Concepts	Living Laboratory Framework Reconstruction
	- Kebabengan and Englek traditional games (Rosa et al., 2025) - Operational mechanism of the Submarine at the Surabaya Submarine Monument (Solihin et al., 2024)	law, and Bernoulli's principle.	movements, measure force and kinematic motion principles during traditional games on the field, and analyze applications of fluid dynamics within submarine operational mechanisms.
2.	Architecture & Cultural Heritage Construction:	Equilibrium & Fluids:	Architectural Design Analysis via Project-Based Learning (PjBL):
	- Nail-less wooden dowel system of the Malige Buton Traditional House (Tumanggor et al., 2026) - Building structure of the Sasak Lombok Traditional House (Wahyudiati & Fitriani, 2021)	Rigid body equilibrium, center of mass, load force distribution, and fluid mechanics in natural ventilation systems.	Working in groups, students construct miniature frames of traditional houses to test the efficiency of natural ventilation and evaluate structural strength against external load force distributions.
3.	Agricultural, Calendrical, & Irrigation Systems: - The Pranata Mangsa Javanese Calendar calendrical system (Pamungkas et al., 2017) - Construction of traditional bamboo water channels/ irrigation (Rahmi & Sari, 2025)	Astronomy and Hydrodynamics: Climate/weather cycles, astronomy, water capillarity, water flow rate, and fluid pressure.	Guided Inquiry & Empirical Data Analysis: Students analyze the accuracy of seasonal predictions based on community traditional calendar patterns and observe bamboo irrigation systems to measure water capillarity phenomena concretely.
4.	Traditional Craft & Textile Industries:	Matter and Its Changes:	STEAM-Oriented Project-Based Laboratory:
	-Manufacturing process of Batik Bakaran Pati (Damayanti et al., 2017) -Utilization of bio-dyes in Batik Tulis Ciwaringi (Tresnawati, 2018) - Fabric dyeing of Sesek Sasak Lombok (Wahyudiati & Fitriani, 2021) - Exploration of Kajang sarong fabric dyeing (Allo & Fadly, 2026) -Manufacturing process of	Organic chemical reactions, natural dyes, material properties, physical changes, color fixation, mixtures, and solutions.	Students design fabric dyeing experiments by varying types of fixators, analyze the solution concentration of natural dyes derived from surrounding plants, and explore their artistic or philosophical values.

No.	IK Type (Indigenous Knowledge)	Representation of Modern Science Concepts	Living Laboratory Framework Reconstruction
	Tapis Lampung crafts (Rosa et al., 2025)		
5.	Culinary, Food Processing, & Biotechnology:	Microbiology and Thermodynamics:	Environmental Biochemistry & Thermodynamics Practicum**:**
	-Fermentation of Lemea Rejang Lebong Bengkulu (Sari et al., 2025) -Processing of Durian Tempoyak and Jambi Palm Sugar (Suri et al., 2023) -Processing of Pisang Epe Maros culinary (Basri & Akhmad, 2022) -Traditional fish salting process of Katibung Lampung (Syamilah, 2024) -Traditional salt making ("Sia") in Lombok (Wahyudiati & Fitriani, 2021)	Conventional biotechnology, anaerobic respiration in fermentation, temperature and heat, heat transfer, crystallization, evaporation, and changes in states of matter.	Students observe microorganisms or bacteria during local food fermentation processes, measure heat transfer rates during food processing, and test evaporation efficiency in salt crystallization
6.	Ecosystems, Conservation, & Traditional Medicine:	Ecology & Morphology:	Phenomenological Field Study (Ethnopedagogy):
	-Coastal ecosystem and tidal observations of MIS Kou (Umasugi & Patty, 2025) -Conservation practices of the Lembung Pamekasan Mangrove Ecotourism (Agustintias et al., 2026) -Utilization of traditional medicinal plants in Semarang (Sumarni et al., 2022)	Ecosystem equilibrium, interaction of living organisms, coastal plant adaptation, medicinal plant morphology, and environmental conservation.	Students explore mangrove forest or coastal ecosystems, analyze the impact of customary laws (hukum adat) on conservation and nature preservation, and conduct direct observations on the characteristics and morphology of traditional medicinal plants utilized by local communities.

Based on the data presented in Table 1, it is clear that there is a strong conceptual relationship between indigenous knowledge and modern scientific concepts (Fatimah, 2023). Mapping these 20 primary articles demonstrates that local wisdom in Indonesia is not merely a static cultural product left behind by time, but rather a form of intuitive science that has long been practiced by the community from generation to generation, even before the term modern science was introduced (Rahman, 2026).

The strength of this research's theoretical synthesis lies in the living laboratory framework reconstruction column in Table 1 above, which serves as an instructional recommendation. Through this framework, a variety of ethnoscience phenomena that were initially abstract to students, such as the mechanical lever system in a mortar or the biochemical reactions in a local fermentation process, can be integrated into highly applicable instructional activities, such as Project-Based Learning (PjBL) and field experiments (Ramadhani & Zainil, 2025).

This paradigm shift from textbook-oriented teaching to living laboratory exploration offers a concrete solution for developing a science curriculum that is not only globally oriented but also deeply rooted in local values (Ismail et al., 2024). With this approach, students can experience the content they are learning as contextual, intimate, and real-world. Thus, science is viewed not merely as abstract, textual material found in textbooks, but as knowledge relevant to everyday life (Bella et al., 2025).

Theoretically, integrating local wisdom through this living laboratory framework aligns with the principles of Culturally Responsive Teaching (CRT) and constructivist learning theory. (Choirrunisa & Maryati, 2025; Tamam & Fikriyah, 2026). When students explore scientific concepts through familiar cultural objects, such as the structure of a traditional house or the Subak irrigation system, they are not actually building knowledge from scratch but rather linking new information to the cognitive structures (prior knowledge) they already possess from their social environment. This cultural bridging process not only facilitates the retention of abstract concepts but also fosters a positive cultural identity among students as they study modern science. (Septina, 2025).

Instructional implementations such as Project-Based Learning (PjBL) within this framework act as operational platforms that transform local knowledge into active scientific skills (Munawwarah et al., 2025). For example, in the textile or food-processing industry cluster, students are not merely observing but are challenged to design independent experimental projects, such as varying the types of natural fixatives used in batik or measuring the thermal efficiency of local culinary production. Through the PjBL approach, from determining fundamental questions to creating real products, students are trained to hone Higher Order Thinking Skills (HOTS), problem-solving abilities, and teamwork, which are key components of 21st-century skills. (Masyithah & Hariyono, 2025).

However, the success of reconstructing a living laboratory in the classroom depends heavily on the teacher's readiness as an instructional facilitator. (Dairu et al., 2025). Teachers are required to possess culturally responsive Pedagogical Content Knowledge (PCK), enabling them to guide discussions without discrediting the community's indigenous knowledge or modern scientific principles. (Fakhriyah et al., 2025). Therefore, the matrix presented in Table 1 above can be recommended as an initial guide for educators, curriculum developers, and textbook authors to develop project-based Student Worksheets (LKPD) that are integrative, contextual, and responsive to local wisdom across regions. Thus, the principles of the Indonesian Independent Curriculum can also be realized in learning. (Pritasari & Khoirunisa, 2026).

CONCLUSION

This research successfully addresses the challenge of the lack of a systematic conceptual framework for integrating local wisdom into the formal science curriculum by reconstructing a living laboratory strategy. Based on a theoretical synthesis of 20 articles, a strong conceptual relationship was found: intuitive traditional practices in Indonesia do not conflict with modern science but rather contain valid empirical principles within the Physics, Chemistry, and Biology clusters. The community's indigenous knowledge was successfully mapped into six main clusters: tool technology and traditional game, cultural heritage architecture, agricultural and irrigation systems, traditional textile industry, local culinary processing, and ecosystem conservation and traditional medicinal plants. Through this deconstruction, several concrete instructional recommendations are provided to transform traditional environments into inclusive, dynamic spaces for scientific experimentation. The living laboratory framework can be implemented through project-based learning (PjBL) models, field experiments, guided inquiry, and the STEAM approach. The implementation of these active strategies successfully transforms the initially abstract phenomenon of ethnoscience into a tangible, empirical scientific activity for students. Consequently, this conceptual framework not only bridges cultural boundaries and improves students' cognitive retention based on the principles of Culturally Responsive Teaching (CRT) but also provides practical implications in the form of theoretical guidance for teachers and curriculum developers in developing contextual learning tools, while simultaneously realizing the main principles of the Independent Curriculum in the classroom.

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