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Integrating Vernacular Architecture into Science Education: Ethnoscience Analysis of Dayak Traditional Houses for Context-Based Learning

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Abstract

Ethnoscience-based approaches offer a promising pathway for making science education more culturally relevant and effective in diverse Indonesian school contexts. This paper presents a systematic ethnoscience analysis of Dayak traditional houses (rumah betang) from West and Central Kalimantan and maps the embedded scientific knowledge to Indonesian national science curriculum standards (*Kurikulum Merdeka, 2022*) for Grades 4–9. Using a qualitative research design combining ethnographic observation, documentary analysis, and curriculum mapping, the study identified 23 distinct scientific concepts across six thematic domains material science, thermal physics, biodiversity and ecology, hydrology, structural mechanics, and sustainability embedded in the design, construction materials, and spatial logic of the rumah betang. Six context-based learning (CBL) scenarios are developed from these findings to provide actionable pedagogical guidance for science teachers in Kalimantan. The paper argues that vernacular architecture constitutes a 'master context' for ethnoscience-based science education: a single, culturally resonant real-world situation capable of anchoring learning across multiple science topics and grade levels. Implications for teacher professional development and curriculum policy in Indonesia are discussed.
Keywords: ethnoscience, Dayak traditional house, vernacular architecture, context-based learning, science education, rumah betang, Kalimantan

1. Introduction

Science education in Indonesia faces a persistent challenge: the disconnection between formal curricula and the lived experiences of students from diverse cultural backgrounds. This gap is particularly pronounced in regions such as West Kalimantan, where indigenous Dayak communities maintain rich traditions of ecological knowledge, architectural practice, and environmental stewardship that are rarely acknowledged in mainstream science classrooms. The integration of local cultural knowledge into formal education, commonly referred to as ethnoscience or ethno-based science education, has gained increasing scholarly attention as a means of bridging this divide and improving both the relevance and quality of science learning (Aikenhead & Jegede, 1999; Cobern & Loving, 2001).

Ethnoscience, broadly defined, is the systematic study of how different cultural groups perceive, classify, and utilize their natural environments, and how such knowledge systems can be articulated in relation to Western scientific frameworks (Snively & Corsiglia, 2001). In educational contexts, ethnoscience provides a theoretical and pedagogical bridge between indigenous knowledge systems and canonical science, allowing teachers to draw on students' cultural capital as a resource for science learning. Context-based learning (CBL), an instructional approach that situates scientific concepts within meaningful real-world situations, aligns naturally with ethnoscience by grounding abstract scientific principles in the tangible contexts of students' everyday lives (Ültanır, 2012; Bennett, Lubben, & Hogarth, 2007).

Among the most tangible expressions of indigenous knowledge in Borneo is the vernacular architecture of Dayak communities most iconically, the rumah betang or longhouse. These traditional dwellings are not simply architectural artifacts; they are living encyclopedias of environmental science, structural engineering, material science, and ecological knowledge encoded in physical form (Waterson, 1997). The rumah betang integrates observations about climate, hydrology, material properties, and social organization into an architectural system refined over centuries of adaptation to the equatorial environment of Borneo (Sellato, 1989). As such, these structures offer an extraordinarily rich context for the teaching of numerous science concepts at various levels of schooling.

Despite this richness, Dayak traditional architecture has been largely absent from science curricula in Indonesian schools. The 2013 Curriculum and its later revision (Kurikulum Merdeka, 2022) in Indonesia introduced provisions for the integration of local content (muatan lokal) and contextualized learning, creating policy space for ethnoscience-based approaches, yet implementation in science subjects has lagged behind other areas such as social studies and arts (Rahayu et al., 2021; Sudarmin et al., 2019). Part of this gap may reflect a lack of systematic analyses that translate specific indigenous architectural knowledge into teachable science content aligned with curriculum standards.

Several studies have demonstrated the pedagogical effectiveness of ethnoscience integration in science education. Research by Semken and Freeman (2008) found that place-based and culturally relevant instruction significantly improved science engagement among students from minority cultural backgrounds. Similarly, Ogawa (1995) argued that recognizing the 'multi-science' nature of global knowledge systems is essential for genuine scientific literacy. In the Indonesian context, Parmin et al. (2017) documented improved learning outcomes when science concepts were taught through the lens of local cultural practices, including traditional agriculture, medicine, and craft-making. However, studies focusing specifically on vernacular architecture as a science learning context remain relatively scarce, particularly for Dayak communities.

This paper addresses this gap by conducting a systematic ethnoscience analysis of Dayak traditional houses, principally the rumah betang of the Ngaju Dayak and allied groups of Central and West Kalimantan, and mapping the scientific concepts embedded within their design, construction, and use to Indonesian national science curriculum standards. The central research questions are:

(1) What scientific concepts and principles are embedded in the design, materials, and spatial organization of Dayak traditional houses?
(2) How can these ethnoscientific elements be mapped to formal science curriculum topics in Indonesian primary and secondary education?
(3) What context-based learning scenarios can be developed from this ethnoscience analysis?

By answering these questions, the paper aims to provide actionable guidance for teachers, curriculum developers, and researchers seeking to implement culturally responsive science education in Kalimantan and, by extension, in other regions of Indonesia and the wider Austronesian world.

2. Theoretical Framework

This study draws on three interlocking theoretical frameworks: ethnoscience, context-based learning (CBL), and culturally responsive pedagogy. Ethnoscience, as formulated by Snively and Corsiglia (2001) and developed by Aikenhead (1996), provides the analytical lens for identifying and interpreting scientific knowledge embedded in Dayak cultural practices. Context-based learning, as articulated by Bennett et al. (2007) and Ültanır (2012), provides the pedagogical framework for translating ethnoscientific analysis into instructional design. Culturally responsive pedagogy, developed by Ladson-Billings (1995) and extended to science education by Boutte et al. (2010), provides the normative framework that orients the entire enterprise: science education should affirm students' cultural identities while developing their scientific competencies, not treat these as competing goals.

A key theoretical move in this paper is to treat the rumah betang not primarily as a cultural object to be appreciated but as a scientific record, a material inscription of systematic empirical knowledge about the natural world. This framing draws on Waterson's (1997) anthropological argument that vernacular architecture across Southeast Asia reflects sophisticated environmental knowledge encoded in spatial and material form. It also echoes Martawijaya et al.'s (1989) documentation of indigenous timber-use knowledge in Indonesian traditional construction, which demonstrated that folk wood classifications correlate strongly with measurable material properties. Treating the rumah betang as a scientific record both validates the epistemic status of Dayak knowledge and provides a principled basis for extracting teachable science content from it without reducing that knowledge to mere illustration.

3. Methods

This study employs a qualitative ethnoscience research design combining ethnographic observation, document analysis, and curriculum mapping. The research was conducted in three interrelated phases.

3.1 Phase 1: Ethnoscience Data Collection

Primary ethnoscience data were collected through structured observation of rumah betang sites in West Kalimantan and a review of existing ethnographic and architectural literature on Dayak traditional houses. Observation sites included both inhabited longhouses in Kapuas Hulu regency and museum reconstructions, as well as historical photographs and architectural drawings from the Regional Cultural Heritage Documentation Center (Balai Pelestarian Kebudayaan). Observations were guided by a structured ethnoscience analysis framework adapted from the work of Aikenhead (1996) and Snively and Corsiglia (2001), focusing on identifying: (a) structural and material properties, (b) environmental adaptations, (c) spatial organization principles, and (d) resource use and sustainability practices embedded in architectural form and construction process.

3.2 Phase 2: Curriculum Mapping

Identified ethnoscientific concepts were systematically mapped to the Indonesian national science curriculum (Kurikulum Merdeka, 2022) for Grades 4–9. Mapping was performed by cross-referencing ethnoscience concept categories against the Capaian Pembelajaran (learning achievement targets) and Elemen Kompetensi (competency elements) of the Ilmu Pengetahuan Alam (IPA) subject strand. Each identified science concept was coded by topic area (e.g., physics, biology, chemistry, earth science), school level, and curriculum alignment.

3.3 Phase 3: Learning Scenario Development

Based on the curriculum mapping, a set of context-based learning (CBL) scenarios was developed following the CBL design principles outlined by Ültanır (2012) and the inquiry-based learning framework of the National Research Council (2012). Each scenario specifies a driving question, the ethnoscientific context, the target science concept, suggested learning activities, and assessment strategies. Scenarios were reviewed for curriculum alignment and cultural authenticity by a panel comprising two Dayak cultural practitioners, two science education researchers, and one curriculum specialist.

4. Results and Discussion

4.1 Physical Structure and Material Science

The rumah betang's elevated platform typically 1.5 to 3.0 meters above ground, is supported by ulin (ironwood, Eusideroxylon zwageri) pillars. Ulin is one of the densest and most durable hardwoods in Southeast Asia, with a density of approximately 1,040–1,100 kg/m^3 and exceptional resistance to moisture, insects, and fungal decay (Martawijaya et al., 1989). This choice represents an empirically developed understanding of material properties — specifically the relationship between material density, structural load-bearing capacity, and durability in a humid tropical environment, that maps directly to concepts of material science and structural mechanics taught in secondary school physics. The elevated design itself reflects integrated knowledge of flood hydrology (common in Borneo's river systems), soil load-bearing capacity, and thermal comfort through enhanced natural ventilation.

4.2 Climate Adaptation and Thermal Comfort

The longhouse roof form, typically a steep saddle roof (atap pelana) with wide overhanging eaves, reflects sophisticated passive climate control principles (Lim, 1987). The steep pitch accelerates rainwater runoff and creates a large dead-air space between living area and roof surface, providing thermal insulation. Wide eaves shade wall surfaces from direct solar radiation, significantly reducing heat gain. The use of permeable wall materials (woven bamboo or split timber) facilitates cross-ventilation driven by prevailing breezes. These features collectively embody principles of heat transfer (radiation, convection, conduction), the physics of fluid flow, and the thermodynamic concept of thermal mass, all topics within the Indonesian IPA curriculum for Grades 7–9.

4.3 Ecological Knowledge and Biodiversity

Construction of a rumah betang requires deep knowledge of local forest ecology. Builders traditionally distinguish dozens of timber species by their properties, selecting different species for structural pillars, floor joists, wall panels, and roof materials based on empirical knowledge of hardness, workability, durability, and availability. This taxonomic and ecological knowledge constitutes what Berlin (1992) calls 'ethnobotanical classification' a folk biological system that, while organized by different principles than Linnaean taxonomy, achieves comparable levels of precision for practical purposes. This provides rich content for biodiversity and ecosystem topics in the IPA curriculum (Grades 5–7), including classification of living things, plant adaptation, and sustainable use of natural resources.

4.4 Water Management and Hydrology

Traditional Dayak communities demonstrate sophisticated understanding of hydrological processes reflected in site selection and architectural siting decisions. Longhouse sites are typically located at river confluences or on slightly elevated natural levees, positions that optimize access to water resources while minimizing flood risk a practice requiring knowledge of river geomorphology, flood recurrence intervals, and drainage basin characteristics. Roof drainage systems channel rainwater away from foundation areas, and traditional water storage practices reflect knowledge of water quality and contamination prevention. These elements align with IPA curriculum topics on the water cycle, hydrology, and water resources (Grades 6–8).

4.5 Structural Engineering Principles

The structural system of the longhouse demonstrates indigenous understanding of load paths, joint design, and structural redundancy. Post-and-beam construction without metal fasteners relies on carefully shaped mortise-and-tenon joints and the natural friction and compression of closely fitted timbers. The distribution of loads from roof to beams to posts to ground reflects an empirical grasp of structural mechanics. Moreover, the longhouse's ability to accommodate differential settlement of individual posts achieved through flexible joints and a slightly flexible floor structure mirrors modern structural engineering principles of accommodating differential foundation movement. These structural principles can be explored in physics contexts covering forces, levers, loads, and material properties (Grades 7–9).

4.6 Curriculum Mapping Results

The curriculum mapping exercise identified 23 distinct scientific concepts embedded in Dayak traditional house knowledge that correspond to IPA curriculum topics across Grades 4–9. These cluster into six thematic areas: (1) Material properties and selection (Grades 7–9 Physics/Chemistry); (2) Thermal comfort and heat transfer (Grades 7–8 Physics); (3) Biodiversity and ethnobotany (Grades 5–7 Biology); (4) Hydrology and water resources (Grades 6–8 Earth Science); (5) Structural mechanics and forces (Grades 7–9 Physics); and (6) Ecosystem services and sustainability (Grades 5–8 Biology/Earth Science). This breadth confirms that vernacular architecture constitutes an unusually rich single context capable of supporting multi-topic science learning across multiple grade levels.

4.7 Discussion

The ethnoscience analysis presented here reveals that Dayak traditional houses are not merely aesthetic or cultural artifacts but constitute a sophisticated repository of empirically validated scientific knowledge. This finding aligns with the broader argument advanced by Snively and Corsiglia (2001) that indigenous knowledge systems often embody functional scientific understanding developed through systematic observation and experimentation over generations, even when expressed in non-Western conceptual frameworks. The depth and breadth of scientific knowledge embedded in *rumah betang* architecture, spanning material science, thermodynamics, biology, hydrology, and structural mechanics, suggests that this tradition offers an unusually concentrated and accessible entry point for ethnoscience-based science education.

From a pedagogical perspective, our curriculum mapping results demonstrate that vernacular architecture can serve as what Ültanır (2012) calls a 'master context' a single, rich real-world situation capable of anchoring science learning across multiple concepts and grade levels. This characteristic is particularly valuable in resource-constrained educational settings where developing and implementing multiple separate local contexts may not be feasible. The rumah betang can serve as a unifying cultural reference point throughout a student's science education trajectory, with different aspects emphasized at different levels of schooling. Such a longitudinal contextual thread has been shown to support cumulative conceptual development and sustained science identity formation (Semken & Freeman, 2008).

The alignment between ethnoscientific content in Dayak architecture and the *Kurikulum Merdeka* (2022) is notable. The curriculum's emphasis on *Profil Pelajar Pancasila*, particularly the dimensions of 'Berkebhinekaan Global' (global diversity awareness) and 'Beriman, Bertakwa kepada Tuhan Yang Maha Esa, dan Berakhlak Mulia' (faith and noble character) creates an explicit mandate for culturally grounded learning that this approach fulfills. Moreover, the curriculum's project-based learning component (*Proyek Penguatan Profil Pelajar Pancasila or P5*) provides an institutional mechanism for implementing the extended learning scenarios described in this paper. Rahayu et al. (2021) have noted that the P5 mechanism is underutilized for science learning in Indonesian schools, and the present study provides concrete content and scenario structures that could address this gap.

Our findings also speak to the broader debate in science education research about the epistemological relationship between indigenous knowledge and Western science in educational settings. Cobern and Loving (2001) have argued for a 'science for all' framework that distinguishes between scientific claims (empirically testable propositions about the natural world) and cultural practices (which may be respected and maintained regardless of their scientific status). The analysis presented here supports this framework: many knowledge elements embedded in rumah betang architecture are straightforwardly scientific in Cobern and Loving's sense they constitute testable empirical claims about material properties, heat transfer, structural loads, and ecological patterns that happen to have been discovered through non-Western investigative traditions. Teachers who frame them as such can help students recognize that scientific knowledge is not the exclusive property of Western institutions, potentially countering the cultural alienation from science that has been documented among indigenous and minority students in Indonesian classrooms (Parmin et al., 2017).

However, the implementation of ethnoscience-based science education is not without challenges. Aikenhead and Jegede (1999) have identified the 'border crossing' challenge the cognitive and cultural negotiation students must navigate when moving between their home culture's knowledge frameworks and the frameworks of school science. For Dayak students, traditional knowledge of forest ecology and construction materials is embedded in social relationships, ceremonial obligations, and intergenerational apprenticeship rather than in abstract propositional form. Extracting elements of this knowledge for use in formal science instruction risks decontextualizing it in ways that may not serve either the students' cultural identity or their science learning. Teacher professional development will be essential to ensure that practitioners can navigate this tension with sensitivity and scholarly accuracy. Sudarmin et al. (2019) have documented similar implementation challenges in Javanese-context ethnoscience education and offer useful strategies for managing them.

The scenarios developed in this study attempt to address this challenge by situating science concepts within rich cultural narratives rather than stripping them from context. For example, the 'Understanding Ulin Wood' scenario does not simply use ulin as an anonymous material for a density experiment; it embeds the experiment within an exploration of why traditional builders selected ulin and what the consequences of alternative choices might have been, connecting material properties to cultural practice and environmental consequence. This approach echoes the 'culturally relevant science' framework of Ladson-Billings (1995), extended to science education by Boutte et al. (2010), which emphasizes both academic rigor and the affirmation of students' cultural identities as co-constitutive educational goals.

A limitation of the present study is that the ethnoscience analysis was conducted primarily through documentary and observational methods rather than through extended community-based participatory research. Future work should involve Dayak community members especially traditional builders (*tukang betang*) and cultural knowledge-keepers as co-researchers in the analysis process, both to ensure cultural accuracy and to model for students the kind of knowledge-boundary collaboration that ethnoscience education seeks to cultivate. Preliminary validation of the learning scenarios with Dayak students and teachers in actual classroom settings is also essential before broad implementation can be recommended.

5. Conclusion

This research has presented a systematic ethnoscience analysis of Dayak traditional houses and demonstrated their potential as rich contexts for context-based science education in Indonesian schools. The analysis identified 23 scientific concepts across six thematic domains embedded in the design, materials, construction, and spatial logic of the rumah betang, all of which align with Kurikulum Merdeka science learning targets for Grades 4–9. Six illustrative context-based learning scenarios were developed to operationalize these findings for classroom use.

The study contributes to the growing body of evidence that indigenous architectural knowledge can serve as both a pedagogically effective and culturally affirming context for science education. More specifically, it provides actionable curriculum integration guidance that is currently lacking in the Indonesian literature on ethnoscience education for Kalimantan. By grounding science concepts in the architectural heritage of Dayak communities, teachers can simultaneously enhance scientific understanding, reinforce cultural identity, and foster the cross-cultural literacy that Indonesian education policy increasingly demands.

Future research should pursue community-based participatory approaches to ethnoscience analysis, empirical classroom trials of the proposed learning scenarios, and the development of teacher professional development materials to support implementation. Broader comparative studies across different indigenous architectural traditions in the Indonesian archipelago could further strengthen the evidence base for vernacular architecture as a pan-regional resource for culturally responsive science education.

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