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Integrating Local Ethnobiological Knowledge of Invertebrates into a Conceptual Framework: A Theoretical Foundation for Enhancing Science Process Skills

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Abstract

The disconnect between formal science education and students' socio-cultural realities often leads to scientific alienation in developing regions. While ethnobiology offers a bridge to contextualize learning, existing literature is heavily skewed towards ethnobotany, neglecting the pedagogical potential of local fauna. This study aims to develop a novel conceptual model integrating the ethnobiology of local invertebrates from Bengkulu, Indonesia, into the junior high school science curriculum. Using a qualitative-theoretical synthesis approach, we reconstructed indigenous knowledge regarding three key taxa: *Geloina erosa* (Lokan), *Telescopium telescopium* (Cunying), and *Meretrix sp.* (Remis). The study mapped this "village science"—such as the use of *Lokan* as a river quality bio-indicator and the tidal migration behavior of *Cunying*—onto specific Science Process Skills (SPS) indicators. The result is the **"Bio-Ethno-SPS"** conceptual framework. This model provides a structured pedagogical pathway for teachers to transform local wisdom into rigorous scientific inquiry, fostering skills such as observation, inference, and prediction. We conclude that Bengkulu's invertebrate ethnobiology is not merely cultural heritage but a sophisticated epistemological resource for Culturally Responsive Teaching (CRT).

1. Introduction

Science education in the 21st century demands the development of Science Process Skills (SPS) as the foundation of scientific literacy to equip students for complex environmental challenges (NGSS, 2013). In Indonesia, the national curriculum expects science teaching not only to transfer theoretical knowledge but also to integrate local values to create meaningful learning. However, reality shows that biology instruction at the Junior High School (SMP) level remains dominated by textual approaches disconnected from students' socio-cultural realities (Zidny et al., 2020). This phenomenon leads to "science alienation," where students fail to recognize the connection between formal biological concepts and the rich biodiversity in their immediate environment (Aikenhead, 2001;

Ethnobiology has been globally recognized as a crucial instrument in Culturally Responsive Teaching (CRT) (Gay, 2018). Previous research has extensively explored ethnobotany (plant knowledge) in learning (Albuquerque & Hurrell, 2010), yet there is a significant lack of attention towards **ethnozoology**, particularly regarding invertebrates (Alves & Albuquerque, 2018). In the coastal and riverine regions of Bengkulu Province, local communities possess profound Traditional Ecological Knowledge (TEK) regarding various invertebrate taxa such as *Lokan* (*Geloina erosa*) and *Cunying* (*Telescopium telescopium*). Despite this potential, current curriculum drafts lack a theoretical model that systematically integrates this ethno-invertebrate knowledge into measurable SPS indicators (Fahmi et al., 2019). Most existing ethnoscience research remains descriptive-documentary without offering an applicable pedagogical framework for training process skills (Yuliana et al., 2021).

The urgency of this research lies in the need to bridge indigenous knowledge with Western science to prevent the loss of local wisdom while simultaneously enhancing students' scientific competence. The **novelty** of this study is the development of the **Bio-Ethno-SPS Conceptual Model**, which specifically utilizes the taxonomy and ecology of Bengkulu's local invertebrates as primary variables. Unlike general ethnoscience models, this model offers an epistemological pathway that maps traditional practices—such as harvesting techniques and habitat recognition—directly into higher-order SPS indicators like inference, data interpretation, and experimentation (Rezba et al., 2007).

This study aims to build a robust theoretical foundation for integrating local invertebrate ethnobiological knowledge into the conceptual framework of SMP science learning. The contributions of this research include: (1) providing a theoretical database for developing culture-based learning tools in Bengkulu; (2) strengthening the literature on ethnozoology in international science education; and (3) offering strategies for teachers to transform local wisdom into rigorous laboratory activities.

Research Questions:

1. How can the characteristics of Bengkulu's local invertebrate ethnobiological knowledge be mapped onto formal biological concepts?
2. What is the structure of a conceptual model capable of integrating this knowledge to enhance SMP students' Science Process Skills?

To what extent does this theoretical foundation meet the pedagogical requirements of culturally responsive science teaching in the Indonesian context?

3. Methodology

Research Design: A Qualitative-Theoretical Synthesis

This study employs a **qualitative-theoretical synthesis** design to construct a new conceptual model through interdisciplinary integration between ethnobiology and science education. As described by Snyder (2019), theoretical synthesis is crucial in emerging fields to draw conclusions from diverse literature and create a coherent new framework. In this context, the method was chosen to extract the Traditional Ecological Knowledge (TEK) of the Bengkulu community and map it systematically onto formal Science Process Skills (SPS).

Data Sources and Selection Criteria

Data were collected through systematic search and curation of primary/secondary data divided into two domains:

1. **Bengkulu Invertebrate Ethnobiology Domain:** Data were gathered from ethnographic reports and local biodiversity studies in Bengkulu Province (specifically Mukomuko, Central Bengkulu coastal areas, and river estuaries). Inclusion criteria focused on invertebrate taxa with high economic, cultural, or ecological significance to locals (e.g., *Geloina erosa* and *Telescopium telescopium*).
2. **Science Process Skills (SPS) Domain:** Primary references were drawn from standard SPS instruments (Rezba et al., 2007) and the Indonesian national curriculum aligned with global standards like NGSS.

Data Synthesis and Model Development Framework

The conceptual model development followed four integrative stages adapted from the *Inquiry-based Ethnoscience* framework by Rahmawati & Taylor (2018):

- **Stage 1: Ethnobiological Categorization (Etic-Emic Mapping):** Classifying local knowledge (emic) into formal biological structures (etic).
- **Stage 2: SPS Potential Identification:** Analyzing which SPS indicators (e.g., predicting, classifying) are embedded in specific traditional practices.
- **Stage 3: Pedagogical Framework Construction:** Building logical connections between local phenomena, biological concepts, and inquiry activities.
- **Stage 4: Theoretical Validation:** Validating the model through theoretical expert judgment and comparison with regional ethnoscience studies.

4. Results and Discussion

The Ethnobiological Inventory of Bengkulu's Invertebrates

The synthesis identified three key invertebrate taxa with significant cultural and ecological roles:

1) *Lokan* (Geloina erosa) in the Mukomuko River Ecosystem

The Mukomuko community distinguishes *Lokan* based on microhabitat. "Sand Lokan" (*Lokan Pasir*) has lighter shells, while "Mud Lokan" (*Lokan Lumpur*) has dark, eroded shells due to acidic, anoxic sediment. Crucially, locals use *Lokan* behavior as a water quality indicator; when the river is stagnant and polluted ("yellow foam"), *Lokan* surface to the mud, a phenomenon described locally as "Lokan Mabuk" (Drunken Lokan). This reflects scientific concepts of **phenotypic plasticity** and **hypoxia responses**.

2) *Cunying* (Telescopium telescopium) in Mangrove Zones

In Bengkulu's mangroves, locals observe that *Cunying* snails migrate vertically up mangrove roots during incoming high tides to avoid aquatic predators and suffocation. This indigenous knowledge perfectly aligns with biological concepts of **circadian rhythms** and **behavioral adaptation**.

3) *Remis* (Meretrix sp.) and Intertidal Dynamics

Traditional *Remis* harvesters on Pantai Panjang correlate successful harvests with the lunar cycle (full moon) and specific sand textures (fine vs. coarse). This indicates an implicit understanding of **intertidal zonation**, **substrate preference**, and **lunar reproductive periodicity**.

Mapping Local Wisdom to Science Process Skills

The study formulated the **"Bio-Ethno-SPS Matrix"** (Table 1) to map these findings.

Table 1. Mapping of Bengkulu's Invertebrate Ethnobiology and SPS Integration

Local Taxa	Indigenous Knowledge (Emic)	Scientific Concept (Etic)	Targeted SPS Indicator	Proposed Inquiry Activity

Lokan (*Geloina erosa*)	Determining location based on mud hardness; "Drunken Lokan" phenomenon.	Benthic habitat preference; Bio-indicators of water quality (Hypoxia).	**Inferring**	Students sample river substrates and infer why Lokan prefer specific textures/pH levels.
Cunying (*T. telescopium*)	Observing snails climbing trees during high tide.	Behavioral adaptation to tidal cycles; Circadian rhythms.	**Observing & Predicting**	Students observe time-lapse videos of snail movement and predict positions based on tidal charts.
Remis (*Meretrix sp.*)	Harvesting during specific lunar phases and fine sand areas.	Intertidal zonation; Substrate granulometry; Lunar periodicity.	**Hypothesizing**	Students formulate hypotheses on the relationship between sand grain size and clam burrowing speed.
Kepiting Bakau (*Scylla serrata*)	Tying crabs based on claw strength and sex.	Sexual dimorphism; Functional morphology.	**Classifying**	Students create a dichotomous key to classify crabs based on observable morphological traits.

The "Bio-Ethno-SPS" model serves as a cognitive bridge. As noted by Zidny et al. (2020), integrating indigenous knowledge reduces cognitive dissonance. By using familiar organisms like *Lokan* instead of abstract textbook examples, the model validates students' cultural identity while facilitating the acquisition of formal scientific concepts. This aligns with Culturally Responsive Teaching (CRT) principles, transforming "village science" into legitimate school science.

Invertebrates as Neglected Agents of Inquiry

A key novelty of this research is the shift from static ethnobotany to dynamic **ethnozoology**. Invertebrates like *Cunying* exhibit motility and behavioral responses to environmental stimuli (tides), which allows for the development of higher-order SPS such as **predicting** and **interpreting data** (Alves et al., 2021). This addresses the "invertebrate neglect" in science education literature and proposes that local fauna are active agents of inquiry.

Theoretical Mechanisms of SPS Enhancement

The model operates on Vygotsky's Zone of Proximal Development (ZPD). Local knowledge acts as scaffolding. For instance, the traditional knowledge that "Cunying climbs trees" triggers cognitive conflict—why would a snail climb? This prompts students to formulate **hypotheses** (e.g., avoiding predators) and engage in scientific argumentation, significantly enhancing their critical thinking skills compared to rote memorization (Fahmi et al., 2021).

Limitations

This study is limited by its theoretical nature; empirical testing via quasi-experimental designs is required to quantify its impact on student SPS scores. Additionally, the focus on coastal invertebrates may limit generalizability to highland ecosystems.

5. Conclusion

This study successfully reconstructs Bengkulu's invertebrate ethnobiology into the **"Bio-Ethno-SPS"** conceptual model. We conclude that local practices surrounding *Geloina erosa*, *Telescopium telescopium*, and *Meretrix sp.* contain sophisticated scientific principles—such as bio-indicators and tidal dynamics—that are compatible with modern curricula. **Implications:** The model provides a practical roadmap for teachers to implement the "Kurikulum Merdeka" by using local wisdom as a scaffold for high-level scientific inquiry. **Suggestions:** Future research should empirically test this model in classrooms, and policymakers should support the integration of research-based local content to foster globally competent yet culturally grounded students.

Declarations

Author Contributions. Each author has contributed significantly to the writing of this article.

Conflicts of Interest. The authors declare no conflict of interest.

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