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MORALITY BEFORE KNOWLEDGE

# Transformation of scientific knowledge into local knowledge: An analysis of the Mangupa-Upa tradition in the context of ESD-based education policy

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## ABSTRACT

**Background:** The Mangupa-Upa tradition is part of the traditional ceremonies of the Batak Mandailing people, rich in cultural values, spirituality, and ecological symbolism. Amid global challenges such as environmental degradation and the crisis of cultural identity, an educational approach that integrates local knowledge is becoming increasingly relevant. This study aims to reconstruct elements of the Mangupa-Upa tradition into contextual biology learning resources that align with the direction of the Independent Curriculum and the principles of Education for Sustainable Development (ESD). **Methods:** The method used is a systematic literature review of various primary sources, including journal articles, scientific books, policy documents, and local cultural texts. The analysis was conducted thematically with a descriptive qualitative approach. **Findings:** The results of the study indicate that pangupa materials, such as betel, fish from seven rivers, old goats, and banana leaves, have symbolic meanings that can be reconstructed into scientific concepts in biology, such as biodiversity, the digestive system, the excretory system, plant and animal morphology, and the locomotion system. This integration of local knowledge supports the ethnopedagogical and ESD approaches, by instilling cultural values, environmental conservation, and strengthening local identity in the learning process. Furthermore, the reconstruction results indicate that a single local tradition can generate various biology learning topics relevant to the learning outcomes of phases E and F in the Independent Curriculum. **Conclusion:** The implications of this research suggest that transforming scientific knowledge into local forms such as Mangupa-Upa can be an effective pedagogical strategy to bridge the epistemological gap in formal education. This tradition serves not only as a cultural heritage but also as a transformative learning medium that strengthens students' scientific understanding in a contextual, participatory, and sustainable manner. **Novelty/Originality of this article:** The novelty of this study lies in reconstructing the Mangupa-Upa tradition into contextual biology learning resources aligned with the Independent Curriculum and ESD, demonstrating how a single local tradition generates multiple scientific learning themes.

**KEYWORDS:** education for sustainable development; local wisdom; biology education.

## 1. Introduction

Transforming scientific knowledge into local knowledge is a strategic approach to designing contextual, relevant, and sustainable education, particularly amidst global challenges such as environmental degradation, the cultural identity crisis, and socioeconomic inequality. In this context, education is no longer sufficient simply to transmit knowledge; it must also build ecological and social awareness through the integration of local cultural values as part of a meaningful learning process. One framework

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supporting this transformation is Education for Sustainable Development, which combines environmental, social, and economic dimensions to encourage students to think critically, act ethically, and actively contribute to sustainable development. ESD has also proven effective in equipping students with 21st-century skills, such as systematic and solution-oriented thinking. Fathurohman et al. (2023) integrating ESD into science education can improve the quality of learning through a contextual, interdisciplinary approach based on real-world experiences.

Integrating local wisdom into biology learning broadens the context of the teaching material while strengthening students' character and environmental literacy. Research by Pangsuma et al. (2024) showed that an ESD-based learning module incorporating Bugis local wisdom significantly improved critical thinking skills and environmental literacy through a problem-based approach. These findings reinforce the idea that incorporating local values into ESD-based learning modules can deepen students' understanding of sustainability and environmental change issues, while simultaneously developing higher-order thinking skills.

In Indonesia's multicultural context, the Mangupa-Upa tradition of the Batak Mandailing people in the Southern Tapanuli region is a concrete example of local wisdom rich in ecological and social values. This ceremony involves the symbolic presentation of plant and animal foods, such as betel, fish from seven rivers, an old goat, and banana leaves, each of which carries philosophical and spiritual meaning. Through an ethnopedagogical approach, these elements can be reconstructed into scientific concepts in biology learning, such as biodiversity, the digestive system, plant and animal morphology, and locomotion (Abdurrahman et al., 2020). However, in formal education practice, the transformation of science into local knowledge still faces methodological and policy challenges. Most curricula do not fully accommodate culture-based approaches, and teachers often lack the resources to develop contextualized learning modulesA study suggests that integrating local knowledge into science education can strengthen students' environmental literacy and cultural identity, as well as pave the way for community-based sustainable development (Rasmawan et al., 2025; Purwasih et al., 2025).

These findings align with Aikenhead & Michell (2011), who emphasized that integrating indigenous knowledge into science education requires a paradigm shift in curriculum design and teacher training, as conventional science epistemologies tend to marginalize local perspectives. Bang & Medin (2010) also highlighted that science education that ignores cultural context risks alienating learners and reinforcing non-inclusive epistemological hierarchies. Ronnebeck et al. (2023) in their systematic observation showed that teachers face significant challenges in implementing inquiry-based science education that accommodates local knowledge, primarily due to limited resources and institutional support. Meanwhile, Van Eijck & Roth (2007) suggested that science curricula should pivot to incorporate community-based knowledge systems to foster environmental literacy and social relevance.

Thus, mainstreaming local knowledge such as Mangupa-Upa in science education not only enriches learning content but also strengthens students' connection to their social and ecological environment. To achieve this, educational policies are needed that support teacher training, the development of contextual learning resources, and curriculum design that is inclusive of epistemological diversity. Therefore, analyzing the Mangupa-Upa tradition within the framework of ESD-based educational policy is crucial to demonstrate how local wisdom can be utilized as a learning medium that not only enriches scientific understanding but also strengthens cultural identity and sustainability values. This study aims to examine the transformation of elements of the Mangupa-Upa tradition into biology learning materials that align with the direction of the Independent Curriculum and ESD principles. Using a descriptive qualitative approach and secondary data analysis from conceptual literature, cultural studies, and policy documents, this study is expected to contribute to the development of an educational model based on local culture and oriented towards sustainability.

## 2. Methods

Systematic Literature Review (SLR) is a structured and rigorous method for synthesizing data from diverse sources such as journal articles, books, and policy documents, often combined with qualitative approaches to provide comprehensive insights (Snyder, 2019; Xiao & Watson, 2019). This approach is used to explore knowledge from various perspectives, which is then compiled into an in-depth thematic synthesis. The analysis was carried out thematically through four main stages: identification of elements of the Mangupa-Upa tradition, categorization of ecological and social meanings, mapping of relevant biological concepts, and integration of the results into a learning framework based on Education for Sustainable Development which is in line with the direction of the Independent Curriculum.

### *2.1 Identification of elements of the Mangupa-Upa tradition*

The first phase involved identifying the elements of the Mangupa-Upa tradition through literature reviews, documentation, and interviews with indigenous communities. The elements examined included ceremonial symbols and objects, the sequence of rituals, and the accompanying cultural values. This step aimed to provide a comprehensive overview of the tradition's structure as a foundation for subsequent analysis. Additionally, the identification process highlights the historical and social context underpinning the tradition, including its origins, changes in form and meaning over time, and its role in reinforcing the community's cultural identity. Thus, the study focuses not only on physical and symbolic aspects but also on the social dynamics that keep the Mangupa-Upa tradition relevant to this day.

This process is reinforced by the results of interviews with traditional elders and the indigenous Batak Mandailing community in Padangsidimpuan City. The interviews yielded information regarding the procedures for conducting wedding ceremonies, the types of dishes served, and the biodiversity utilized in the Indahan Tupporobu feast. These dishes reflect local knowledge of plant and animal species, including the parts of plants used, such as rhizomes, stems, leaves, and fruits. The data was then classified based on botanical families, local names, and scientific names, thereby illustrating the connection between the tradition and the community's ecological and biological knowledge.

### *2.2 Categorization of ecological and social meanings*

At this stage, the meanings embedded in the Mangupa-Upa tradition are categorized into two main dimensions: ecological and social. The ecological dimension encompasses the tradition's connection to nature, the utilization of resources, and conservation principles. Meanwhile, the social dimension emphasizes the values of solidarity, respect, and togetherness reflected in traditional ceremonies. A thematic approach is employed so that each element of the tradition can be mapped according to its ecological and social contexts.

This classification of meanings becomes increasingly clear through the traditional dish Indahan Tupporobu. The utilization of biodiversity such as plants from the *Zingiberaceae, Arecaceae, Alliaceae*, and *Poaceae* families demonstrates the community's knowledge in processing food ingredients while also using plants as traditional medicine. On the other hand, the symbolic arrangement of the dishes reveals profound social values: white rice as a symbol of prosperity, river fish as a symbol of sustenance, and a buffalo head as a symbol of strength and wisdom. Thus, this categorization affirms that the Mangupa-Upa tradition functions not only as a cultural ritual but also as a means of educating about the values of sustainability and social solidarity.

### *2.3 Mapping of relevant biological concepts*

The third stage involves mapping the results of the identification and categorization onto relevant biological concepts. The use of plants and animals in traditional dishes is linked to ecological concepts (human-environment interactions), biodiversity and systematics (classification of plants based on botanical families), as well as physiology and health (the use of ginger, turmeric, and galangal rhizomes as traditional medicine). This mapping demonstrates that the Mangupa-Upa tradition can serve as a tool for contextual biology education rooted in local wisdom.

### *2.4 Integration of the results into a learning framework based on education for sustainable development which is in line with the direction of the independent curriculum*

The final stage involves integrating the analysis results into a learning framework based on Education for Sustainable Development. The integration process includes developing learning themes that link the Mangupa-Upa tradition with biological concepts, designing contextual learning strategies in line with the Merdeka Curriculum, and emphasizing the values of sustainability and local wisdom. These values are then linked to relevant biology topics, such as ecology, biodiversity, and plant physiology, so that the Indahan Tupporobu dish can serve as a concrete example in the learning process.

With this approach, the research produced a learning model that is not only relevant and contextual but also supports sustainable development goals. The resulting ESD-based learning framework is expected to foster students' awareness of the importance of protecting the environment, preserving culture, and understanding the connection between science and daily life. Furthermore, integrating the Mangupa-Upa tradition into biology lessons can reinforce the initiative to strengthen the Pancasila student profile, particularly in the dimensions of cooperation, critical thinking, and faith and devotion to God Almighty. By using local traditions as a learning resource, students not only gain academic knowledge but also internalize the cultural and spiritual values that form part of the nation's identity. This makes learning more meaningful, grounded, and oriented toward sustainability.

## 3. Results and Discussion

### *3.1 Reconstruction of the Mangupa-upa tradition as a medium for learning biology*

The Mangupa-Upa tradition is part of the Angkola community's traditional communication, rich with spiritual, social, and ecological symbolism. As a form of cultural expression, this tradition serves not only as a ritual but also as a medium for conveying the values of life and community identity (Amri, 2018). In an educational context, the integration of local traditions such as Mangupa has great potential to strengthen students' cultural identity and ecological awareness, particularly through ethnopedagogical approaches and the Development of Education for Sustainable Development (Pane, 2022). Betel (*Piper betle*), as a symbol of customary law and unity, scientifically contains antiseptic compounds such as eugenol and kavibetol, relevant to the topic of plant diversity and the immune system. Fish from seven rivers reflect genetic diversity and ecological adaptation, which can be linked to the life cycle and conservation of freshwater species. Old goat meat symbolizes strength and authority, scientifically rich in protein and phosphorus, relevant to the locomotor system and muscle formation. Banana leaves used as a base for dishes have a high antioxidant content and a unique morphological structure, which can be linked to the topic of plant morphology.

Research by Vilmala et al. (2025) shows that the PjBL-ESD learning model significantly improves critical thinking skills and understanding of local wisdom values. This demonstrates that the integration of science and local culture can strengthen students' competencies in addressing sustainability issues contextually. The reconstruction results show that a single local tradition like Mangupa-Upa can generate a variety of biology

learning topics. These topics include biodiversity, the digestive and excretory systems, the locomotor system, and plant and animal morphology. This demonstrates that indigenous knowledge can be transformed into scientific knowledge that is contextual, meaningful, and relevant to the continuing education curriculum.

These coping biodiversity.

Table 1. Results of reconstruction of original knowledge into scientific knowledge in biology learning

| Names of plants and animals | Original science | Scientific science | Biology material |
|---|---|---|---|
| Burangir – Betel leaf (*Piper betle*) | The meaning is that the bride and groom must behave according to applicable laws and not deviate from customs and regulations. The burangir elements have an extreme aroma and flavor. Anyone can attest that by chewing each burangir element separately, they will experience a very strong, extreme flavor. Therefore, traditional burangir symbolizes the elements of *Dalihan Na Tolu,* capable of creating a strong spirit of unity. This occurs because extremes meet in a strong and harmonious togetherness. | The betel plant (*Piper betle*) contains bioactive compounds such as eugenol, hydroxychavicol, chavicol, allylpyrocatechol, and chavibetol, which exhibit strong antiseptic and antimicrobial properties. These natural compounds are safe, inexpensive, biodegradable, and widely available, making *Piper betle* a valuable alternative antiseptic (Jadhav et al., 2023). | Plant diversity |
| Pira manuk – Chicken eggs (*Gallus gallus domesticus*) | The meaning is that the body and soul are united and inseparable, which means healthy, strong and resilient. | Chicken eggs are widely accessible and provide essential nutrients such as protein, fat, and minerals, making them a valuable food product. Their nutritional composition includes high-quality protein and lipids, with variations depending on breed and production system (Réhault-Godbert et al., 2019; Ruxton et al., 2010; Mulewu et al., 2026). Eggs contain high-quality protein because they contain complete essential amino acids so that eggs are used as a benchmark in determining the protein quality of various food ingredients (Indrawan, 2012). | Digestive system |

| Names of plants and animals | Original science | Scientific science | Biology material |
|---|---|---|---|
| Sirana ancim – Salt (*Sodium chloride*) | The meaning contained in *Sira na ancim* in this traditional mangupa ceremony is that the taste buds of the bride and groom become sensitive, provide good fortune and can enjoy pleasure in their life. | Studies in Indonesia show that the quality of edible salt varies depending on production methods, with geomembrane processing producing salt that meets national standards for NaCl and iodine content (Muslimah et al., 2024; Amah et al., 2022). | Human sensory system |
| Manuk pogang – Roasted chicken (*Gallus gallus domesticus*) | The meaning is to have many children and the bitterness of their blood means that in their lives they will not experience the death of children. | Chicken meat is widely recognized as a valuable source of high-quality animal protein, with breast meat containing approximately 21% protein and very low fat content, while native breeds such as Kadaknath provide even richer amino acid profiles (Bajraktarova et al., 2025; Haunshi et al., 2022). The highest protein value in chicken is one of the nutritional components of meat. The Effect of Feeding Different Protein Sources on Carcass Yield and Protein Content in Local Crossbred Chicken Meat (Pratiwi et al., 2017). By consuming chicken that is high in protein is associated with original science that in pregnant women the fetus in the bride is healthy and grows well. | digestive system (balanced nutritional diet) |
| Ihan sahat – Goldfish (*Cyprinus carpio* L.) | It means a prosperous, lucky and dignified life. | Goldfish (*Carassius auratus*) exhibit remarkable adaptability to diverse aquatic environments. They can tolerate wide ranges of temperature and salinity, making them resilient to environmental changes and human handling processes such as storage and transportation (Claus et al., 2025; Lawson & Alake, 2011). With the life cycle of fish as explained above, it is understood that the life of the bride and groom is in line with the fish, where goldfish can live well and can quickly adapt to life after marriage. | Fish life cycle, freshwater fish conservation. |
| Ihan sayur – Fish in curry (*species* | The meaning is to live long, always healthy and happy. | Freshwater fish are widely recognized as important sources of omega-3 | Animal digestive |

| Names of plants and animals | Original science | Scientific science | Biology material |
|---|---|---|---|
| *varies*) | | unsaturated fatty acids that contribute to human health. Dailey et al. (2015) demonstrated that fish and their microbiota play a crucial role in producing these essential fatty acids, while Calder (2015) emphasized their clinical relevance in reducing inflammation and supporting overall health. Consuming omega-3 in fish is very influential in helping maintain heart health by lowering blood pressure and reducing the risk of sudden death, heart attacks, abnormal heart rhythms, and strokes and can also help healthy brain function and the development of vision and nerves in babies during pregnancy, if consuming fish will potentially be healthy and if healthy life will be happy and have a long life. | system and anatomy |
| Ihan na pitu sunge – Fish from seven rivers (*species varies*) | The symbol is a request for seven generations to be without danger, long life and many descendants. | Fish that come from seven rivers symbolize seven healthy descendants by consuming fish from the seven rivers.<br>Fish not only contains omega-3s, but also protein, which is essential for the body, especially during growth and development during the first thousand days of life, starting from when the fetus is in the womb. Fish also contains minerals, approximately equal in quantity to those found in milk, such as calcium and phosphorus. Consuming fish from the seven rivers can lead to numerous offspring, as each fish caught from the seven rivers has a different nutritional value and can provide a source of wealth for up to seven generations. | Fish life cycle |
| Hambeng ni simaradang – Old goat (*Capra aegagrus hircus*) | It signifies the hope that one's dignity and charisma will continue to increase as one ages. Consuming hambeng is | The first benefit of goat meat is that it provides a substantial source of energy for daily activities. Its calorie, fat, and protein content will keep the body fit while | Muscular system: muscles, bones and joints |

| Names of plants and animals | Original science | Scientific science | Biology material |
|---|---|---|---|
| | understood to signify a long and healthy life into old age. Scientific evidence indicates that hambeng meat is rich in protein, which is essential for muscle growth and development. | consuming this meat. Goat meat contains one of the highest levels of protein compared to other meats. Protein is known to be essential for muscle formation and growth. 100 grams of goat meat contains 272 mg of phosphorus, or 27% of the daily requirement. This nutrient is one of the nutrients that can maintain bone strength and health. | |
| Padi – Rice (*Oryza sativa* L.) | This means that your livelihood will be made easier, your income will be cheaper and you will become richer. | Rice is a staple food for Indonesians, as rice is consumed in almost every region of the country. Rice contains carbohydrates (76.40-7.64%) and water (12.67-14.52%), making it a primary source of energy that is quickly and easily absorbed by the body because it can be digested into glucose (Poedjiadi, 2007). | Biodiversity |
| Tolu bulung tip – Three banana leaves (*Musa* spp.) | The meaning of the prayer is to obtain a good and long life. | Banana plant leaves are elongated lanceolate, the leaves have long stalks, ranging from 30 – 40 cm, these leaf stalks are quite hard and strong and contain a lot of water Cahyono, (2009). Banana leaves have a high antioxidant content, and the shape of the leaves. These leaves are full of plant compounds such as epigallocatechin gallate, or EGCG (found in green tea), and other powerful antioxidants. | Plant morphology and biodiversity |
| Weeds – Wild plants (*various species*) | The meaning is to be forgotten in kinship life<br>Behaving in a shared destiny. The way that weeds grow strong, even when destroyed by fire, will continue to grow together because their roots are very strong and will grow back. This is similar to how native science says that behaving in a | Morphology of cogongrass, Cogongrass is classified as a malignant weed, its reproductive capacity is very high, it reproduces vegetatively and generatively, is able to grow on various types of soil, and is fire resistant, even though the top part is burned, the rhizome or roots in the soil are ready to grow back (Rukmana, 1999). | Plant morphology |

| Names of plants and animals | Original science | Scientific science | Biology material |
|---|---|---|---|
| | shared destiny between family members, husband and wife. | | |
| Bulung torop – Jackfruit leaf (*Artocarpus elasticus* Reinw.) | The meaning is that the person being offered is strong within their family and kinship. The morphology of the torop tree suggests that it must emulate the tree's strength and live for many years, just as sibling relationships must avoid any quarrels that could destroy the family. | The torop tree, also known as benda or bendha, is a monoecious, medium-sized plant, reaching a height of 45–65 meters. Its trunk diameter ranges from 1.2–2 meters, with a branch-free lower trunk that can reach up to 30 meters. | Biodiversity and plant morphology |
| Bulung ni haruaya – Haruaya leaf (*Ficus benjamina*) | The meaning is that the person who is given the gift will become a person of authority, strong, and resilient in life. The morphology of the banyan tree suggests that its sturdy nature is worthy of emulation, and therefore, the community interprets it as a symbol of family resilience against any challenges. | This plant can grow up to 20–25 meters, with upright stems, sympodial branching, and hanging aerial roots. The leaves are simple, oval, pinnate-veined, and green, while the fruits are small berries that turn from green to red and black when ripe. These morphological characteristics are consistent with descriptions of *Ficus benjamina* in Indonesian botanical studies (Baskoro et al., 2022; Wibowo et al., 2021). | Plant morphology |
| Hulung kuling ni horbo – Buffalo skin (*Bubalus bubalis*) | This means being sensitive so that you know how painful you feel when someone else hurts you. | The skin consists of sensory nerves that function as the sense of touch. The skin contains 64% water, 33% protein, 2% fat, 0.5% minerals and other compounds such as 0.05% pigment, histologically animal skin can be divided into three layers, namely: (1) the epidermis layer (2) the corium layer consisting of collagen fiber tissue, (3) the subcutaneous layer, (Nurwantoro, 2003). | Animal morphological characteristics and excretion. |
| Sapot bone ni horbo – Buffalo leg (*Bubalus bubalis*) | This means that what you forget is always thorough, careful in every action. Easy steps to visit relatives. | The foot, which is part of the lower limbs, helps with walking, climbing, running, and other activities. The human foot consists of the femur, tibia, and fibula. | Animal locomotor system |

| Names of plants and animals | Original science | Scientific science | Biology material |
|---|---|---|---|
| Mata ni horbo – Buffalo eye (*Bubalus bubalis*) | The meaning is that responsive behavior in the lives of indigenous peoples, don't be careless, everything you see should be considered carefully in your heart. | As an additional structure of the eye, various accessory structures are known, consisting of eyebrows, eyelids, eyelashes, conjunctiva, lacrimal apparatus, and extrinsic eye muscles (Seeley et al., 2006). The eye is one of the body parts that has an important role in human life, such as good vision by consuming buffalo eyes from healthy eyes, we can see and can store many memories in the journey of life through the eyes. | Animal organ systems |
| Pinggol ni horbo – Buffalo ear (*Bubalus bubalis*) | The meaning is to always be sensitive when hearing sad news and always waiting for good news and always wanting to hear and seek information about people who bring good news. | The ear is one of the human organs that functions as hearing, through sound. | Animal organ systems |
| Ate-ate ni horbo – Buffalo heart (*Bubalus bubalis*) | The meaning of what is seen must be tested for its truth by considering it in the heart. | As an organ capable of cleansing the blood of chemicals or metabolites harmful to the body, beef liver is a food rich in iron. 100 grams of beef liver contains at least 7 mg of iron. The high iron content in beef liver makes it an excellent food for preventing and treating anemia. | Animal internal organ and circulatory systems |
| Aliang-aling ni horbo – Buffalo offal (*Bubalus bubalis*) | This means that every action must be preceded by careful consideration, filtering out what is good and what is bad | The digestive system of ruminants consists of four main parts: the mouth, stomach, small intestine, and hind digestive tract. The stomach of ruminants consists of four parts: the rumen, reticulum, omasum, and abomasum. | Animal internal organ systems and digestive systems |

(Parsadaan, 1993)

Table 1 presents the results of the reconstruction of elements of the Mangupa-Upa tradition into scientific concepts relevant to biology learning. Each pangupa material used in traditional ceremonies has a symbolic meaning that can be transformed into a science-based learning topic. For example, betel (*Piper betle*), which traditionally symbolizes law and unity, scientifically contains antiseptic compounds relevant to the topic of plant diversity and the immune system. Chicken eggs, interpreted as a symbol of the unity of body and soul, are associated with the digestive system and have high nutritional value, supporting learning about nutrition and metabolism. Furthermore, fish from the seven

rivers reflect genetic diversity and ecological adaptation, which can be integrated into the life cycle and conservation of freshwater species. Old goat meat, a symbol of strength and authority, contains protein and phosphorus relevant to the locomotor system and muscle formation. Banana leaves, reeds, and banyan trees, each of which have philosophical meanings in social and spiritual contexts, can be linked to plant morphology and biodiversity.

This reconstruction demonstrates that the Mangupa-Upa tradition not only holds cultural value but also holds rich pedagogical potential for Education for Sustainable Development-based biology learning. By linking symbolic meanings to scientific concepts, students can understand biology material contextually, while simultaneously building ecological awareness and cultural identity. This approach aligns with the principles of ethnopedagogy and project-based learning, which have been shown to be effective in enhancing critical thinking skills and environmental literacy (Vilmala et al., 2025). Of the 22 pangupa elements reconstructed in Table 1, 10 are derived from plants and 12 from animals. This proportion shows that although the Mangupa-Upa tradition is rich in animal symbolism, plant elements still play an important role in conveying ecological, spiritual, and social values. Plants such as betel, banana leaves, reeds, and banyan trees serve not only as physical materials, but also as representations of the philosophy of life, health, and death.

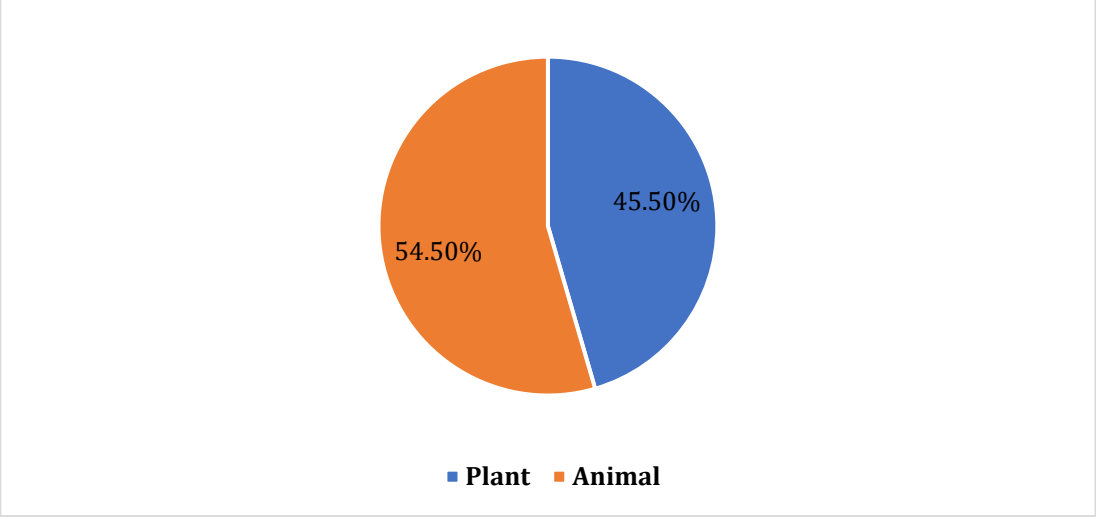


Fig. 1. Pie chart showing the proportions of plant and animal elements in the Mangupa-Upa tradition

The proportion of plant elements (54.50%) and animal elements (45.50%) in the Mangupa-Upa tradition reflects a balance between ecological symbolism and socio-cultural values. Plants such as betel and banana leaves are often associated with progeny, lineage, and social harmony, while animals such as goats and fish symbolize strength, courage, and resilience. This symbolism aligns with Posey's (1999) study, which emphasized that indigenous communities use biological representations as a medium for communicating ecological and spiritual values in their cultural practices. Furthermore, research by Berkes (2012) shows that traditional ecological knowledge (TEK) is often manifested through rituals and symbols that integrate understandings of biodiversity and the ecological functions of local species. Therefore, the proportion of biological elements in Mangupa-Upa not only reflects cultural heritage but also serves as a contextual and transformative means of ecological education.

This aligns with the view of Toledo & Barrera-Bassols (2008), who stated that indigenous communities develop ecological worldview cosmovisions that integrate biological elements into their value systems and cultural practices. In an educational context, this representation can serve as an entry point for building culturally based ecological literacy and strengthening students' connection to their environment. Furthermore, UNESCO (2017) emphasizes that ecological symbolism in local cultural

practices can be utilized as a learning resource within the Education for Sustainable Development framework, as it embodies the values of sustainability, interdependence, and social responsibility. Therefore, the proportion of biological elements in Mangupa-Upa is not merely ethnographic data, but also a reflection of local knowledge systems that can be transformed into contextual and transformative pedagogical approaches.

### *3.2 Integration with the independent curriculum and ESD approach*

The integration of the Mangupa-Upa tradition into the Independent Curriculum can be achieved through the Education for Sustainable Development approach, which emphasizes sustainability values, environmental ethics, and social participation. These cultural elements align with learning outcomes in phases E and F, including biodiversity, organ systems, life cycles, and local species adaptations (Demssie et al., 2020; Druker-Ibáñez & Cáceres-Jensen, 2022). This approach enables students to understand biological concepts through the context of local culture, while encouraging active involvement in environmental conservation and strengthening community values. The Independent Curriculum encourages locally context-based learning and strengthens students' character through a cross-disciplinary approach (Ministry of Education, Culture, Research, and Technology, 2022). A systematic study by Fathurohman et al. (2023) showed that the STEM-ESD approach can improve students' self-efficacy, environmental literacy, and sustainability awareness. These findings support the idea that integrating the Mangupa-Upa tradition as a local context in biology learning can strengthen sustainability competencies and increase the curriculum's relevance to real-world issues facing the community.

Table 2. Relationship between Mangupa local wisdom and the meredeka curriculum

| No. | Learning outcomes learning objectives | Learning objectives |
|---|---|---|
| 1. | At the end of phase E, students have the ability to create solutions to problems based on local, national or global issues related to understanding the diversity of living things and their roles, viruses and their roles, biological technology innovation, ecosystem components and interactions between components and environmental changes. | Students can identify Biodiversity.<br>Students can understand the benefits and basis of classification of living things.<br>Students can explain the role/benefits of plant diversity in the surrounding environment for dishes used during the Mangupa-Upa traditional ceremony. |
| 2. | At the end of phase F, students will have the ability to describe cell structures and the bioprocesses that occur, such as membrane transport and cell division; analyze the relationship between organ structures in organ systems and their functions, as well as abnormalities or disorders that arise in these organ systems; understand the function of enzymes and recognize the metabolic processes that occur in the body; and have the ability to apply the concepts of inheritance, growth and development, evaluate new ideas about evolution, and innovation in biological technology. | Students can learn about the structure of organs in animals |

Based on the reconstruction results in Table 1, it can be concluded that a single local tradition can generate a variety of biology learning topics. For example, the biodiversity of burangir plants in the Mangupa-Upa event includes not only one species, but various varieties that can be studied scientifically. The topic of animal life cycles can be related to fish from seven rivers, which traditionally symbolize offspring and continuity, while scientifically reflecting the adaptation and life cycle of freshwater species. The topic of the digestive and excretory systems can also be drawn from the symbolic meaning of pangupa

materials such as chicken eggs, buffalo offal, and salt, which in a cultural context are interpreted as health and balance of life, and in a scientific context are related to the function of body organs and metabolism. The relationship between elements of the Mangupa-Upa tradition and learning outcomes in the Independent Curriculum is summarized in Table 2 above. This research shows that the integration of local knowledge in sustainability transformation remains minimal, despite its significant potential to enrich understanding of systemic change. Similar conclusions are drawn by Demssie et al. (2020) and Tom et al. (2019), who emphasize that indigenous knowledge is essential for fostering sustainability competencies and systemic transformation. Therefore, transforming scientific knowledge into local forms such as Mangupa-Upa is a strategic step to bridge the epistemological gap in ESD-based education, while simultaneously strengthening the curriculum's relevance to students' cultural and ecological contexts.

### *3.3 Implications for education policy*

The integration of local wisdom, such as Mangupa-Upa, aligns with national policy directions that emphasize the importance of culture- and environment-based education. The Education for Sustainable Development policy document from National Development Planning Agency emphasizes that mainstreaming local culture in education is a key strategy for achieving the Sustainable Development Goals (SDGs), particularly in the areas of quality education and environmental conservation (National Development Planning Agency, 2020). However, implementation at the school level still faces challenges, including limited teacher resources and a lack of culture-based teaching modules. Therefore, policy support is needed to encourage teacher training and the development of contextual learning resources. These findings align with various international studies that emphasize the importance of integrating local knowledge into science education as a strategy for building environmental literacy and strengthening students' cultural identities. Kopbossyn & Ismail (2025) demonstrated that a culture-based approach can increase the relevance of learning and student engagement in sustainability issues. ESD is not simply the transfer of knowledge, but rather the transformation of values and sustainable life practices through contextual and inclusive education.

A study by Han & Huang (2025) emphasized that integrating ESD into international curricula is a strategic step in supporting the 2030 Education Agenda. They suggested that education policies should accommodate local contexts and cultures as part of sustainable curriculum design. Meanwhile, Van den Berg & Verster (2023) developed an ESD-based transdisciplinary learning framework that positions local knowledge as the foundation for collaborative and reflective learning in higher education. Other studies by Rönnebeck et al. (2023) support the development of community-based and inquiry-based science curricula that accommodate local contexts as part of a sustainable pedagogical strategy. Research by Pangsuma et al. (2024) also confirms that local wisdom-based education is an effective approach to supporting the SDGs agenda through learning that is relevant to students' social and cultural environments.

In sustainability transformations, local knowledge-based approaches are often marginalized by the dominance of Western epistemology. However, according to Lam et al. (2020), local and indigenous knowledge plays a crucial role in shaping a more pluralistic and contextual understanding of socio-ecological change. They emphasize that Indigenous and Local Knowledge (ILK) can broaden perspectives on transformation in a more inclusive and equitable manner, particularly in the context of environmental education and conservation. Vilmala et al. (2025) demonstrated that the implementation of Project-Based Learning based on Education for Sustainable Development (PjBL-ESD) is an effective instructional innovation. This model not only enhances students' critical thinking skills but also strengthens their appreciation of local wisdom values, making it highly relevant to advancing sustainability-oriented education in higher education. Meanwhile, Fathurohman et al. (2023) recommended that ESD-based learning be implemented at all levels of education to support the achievement of the 2030 SDGs, particularly in the context of

quality education. This reinforces the urgency of mainstreaming local wisdom, such as Mangupa-Upa, into national education policy.

## 4. Conclusions

This study confirms that the Mangupa-Upa tradition of the Batak Mandailing community has great potential to be reconstructed as a contextual, transformative, and sustainable source of biology learning. Through an ethnopedagogical approach and the Education for Sustainable Development framework, cultural elements such as food can be scientifically linked to biological concepts, such as biodiversity, the digestive system, the excretory system, plant and animal morphology, and the locomotion system. The integration of the Mangupa-Upa tradition into the Independent Curriculum has proven relevant to the learning outcomes of phases E and F, and has strengthened students' environmental literacy, cultural identity, and critical thinking skills. This reconstruction not only enriches open materials but also bridges the epistemological gap between local knowledge and formal science in Indonesian education.

The policy implications of these findings demonstrate the need to mainstream local wisdom in curriculum design and the development of culture-based teaching modules. Synergy between the government, historians, and local communities is key to realizing inclusive, relevant, and poverty-focused education. Thus, Mangupa-Upa serves not only as a cultural heritage but also as a pedagogical medium supporting the SDGs agenda and the transformation of community-based science education.

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## Author Contribution

The author contributed to the conception, design, data analysis, interpretation of results, and writing of the manuscript, and approved the final version for publication.

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The author declares no conflict of interest.

### Declaration of Generative AI Use

During the preparation of this work, the author used OpenAI's ChatGPT and Grammarly to assist in improving grammar, clarity, and academic tone of the manuscript. After using this tool, the author reviewed and edited the content as needed and took full responsibility for

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## Open Access



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