

Building Students' Ecological Literacy through Sustainable Development-Oriented Science Learning: Integrating Biological Concepts with Madurese Local Wisdom

Submitted 22 April 2026, Revised 10 July 2026, Accepted 25 July 2026

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Abstract

The study was conducted with three main objectives: (1) building students' ecological literacy through the implementation of science learning oriented towards sustainable development, (2) introducing Madurese local wisdom to students, and (3) identifying biological concepts contained in the local wisdom. This study used a literature review and it be obtained through observation and then analyzed using Miles & Huberman's analysis techniques. The discussion show that this study proves the success of building students' ecological literacy through the integration of sustainable development-oriented science learning with biological concepts inherent in Madurese local wisdom. The study is strengthened by the results of previous studies. This article focused on the containment and linking of biological concepts with materials used in Madurese local wisdom in the context of gettas. The findings indicate that integration with the Madurese cultural context can support improvements in students' ecological literacy and strengthen contextual, relevant science learning in the local environment.

Keywords: Biological Concept, Ecological Literacy, Sustainable Development

INTRODUCTION

Currently, sustainable development is the main basis for building a better future for future generations. However, until now, sustainable development still faces many challenges (Halkos & Gkampoura, 2021). One of the biggest challenges is the low public awareness of the environment (Boermans et al., 2024). Sustainable development aims to protect ecosystems, improve waste management, and mitigate air pollution (Zhou et al., 2024). Therefore, increasing public environmental awareness is essential to achieving sustainable development goals (Achir & Sumirat, 2025).

The challenges of achieving sustainable development in Indonesia are becoming increasingly complex because each region has distinct characteristics, abundant natural resources, yet is vulnerable to uncontrolled exploitation. Sustainable development is a comprehensive approach that seeks to meet the needs of the present generation without harming future generations (Zhou et al., 2024). In Indonesia, sustainable development still faces several obstacles such as difficulties in coordination between the parties involved (Ashok et al., 2026), limited funds, and low public awareness (Boermans et al., 2024). Nevertheless, Indonesia's rich natural resources and vast geographical (Ashok et al., 2026), thus providing significant opportunities to take advantage of technological advances (Hariyani et al., 2025) and international assistance in supporting sustainable development policies (Ramadhani et al., 2024).

One of the major challenges in implementing sustainable development policies in Indonesia is environmental degradation, particularly from excessive deforestation. Another significant challenge is the unequal level of development across regions (Yeung, 2026). To address these issues, the government has implemented several policies, their implementation has been ineffective due to weak law enforcement, limited coordination between the central and regional governments, and conflicts of interest with the private sector (Yasa et al., 2025). Opportunities to encourage sustainable development include using environmentally friendly technologies, such as renewable energy, energy efficiency, and waste treatment, to reduce negative environmental impacts (Kumar et al., 2022).

There are 17 sustainable development goals, namely ending poverty, ending hunger, ensuring healthy living, ensuring quality education, achieving equality between men and women, ensuring access to clean water, ensuring clean and sustainable energy, encouraging sustainable economic growth, and building strong infrastructure, reducing inequality, creating sustainable cities and communities, ensuring sustainable ways of consumption and production, fighting climate change, conserving marine resources, preserving terrestrial ecosystems, promoting peaceful and just societies, and strengthening and developing global cooperation for sustainable development (Boermans et al., 2024). Strategies that can be carried out to implement sustainable development include it in education (Faizah et al., 2026). The Sustainable Development Goals in Education explicitly recognize the need for education for sustainable development and global citizenship (Amin et al., 2026).

Education plays an important role in achieving sustainable development by shaping individuals' knowledge, attitudes, and behaviors in line with sustainability principles. Educational institutions are expected to actively contribute to the implementation of sustainable development initiatives (Ankareddy et al., 2025). Within the educational context, schools play a crucial role, second only to the family in fostering students' character and values, thereby helping to develop responsible individuals who are committed to the principles of sustainable development (Sakti et al., 2024). Students will be given an understanding related to consciousness, which refers to a person's ability to relate abilities and values and consider an event based on their observational and experiential knowledge (Ramsey et al., 2021). As is the case in science education, it is studied to see the surrounding environment realistically (Andriani et al., 2025). Students in science learning will be given an understanding of the surrounding environment, such as how to take care of it (Abdullah, 2024), how to maintain, how to preserve, and things that should not happen, which are adjusted to the principles of sustainable development.

As agents of change, young people must develop a strong awareness of the importance of environmental protection. The science teachers play a crucial role in the teaching and learning process by fostering students' environmental awareness and encouraging environmentally responsible attitudes (Basheer et al., 2026). Science teachers can improve students' understanding of environmental issues (van de Wetering et al., 2022) by encouraging them to take care of the environment. This can be done by linking environmental topics to their daily lives and inviting students to participate in various efforts that have a positive impact (Raditya et al., 2025). Environmentally friendly activities are small lifestyle changes that can have a big impact in the future (Richter et al., 2024).

Efforts to overcome challenges in sustainable development include increasing ecological literacy in science education. A healthy ecosystem requires good ecological literacy (Pouresmaieli et al., 2024), but students' environmental awareness is still relatively low (Wang, 2024). Literacy is a person's ability to understand and utilize information while reading or writing. Nowadays, society is increasingly dependent on the environment due to population growth and technological developments (Pang et al., 2024). However, unsustainable human activities have created a variety of environmental problems (Huo & Peng, 2023). Students, as the younger generation, have an important role in preserving the environment (Sentosa et al., 2024). The active involvement of students in various environmental activities can increase awareness of the importance of protecting the environment (Wang, 2024). Therefore, every student must build ecological literacy. Ecological literacy is the knowledge and understanding of human relationships with the environment (Pouresmaieli et al., 2024). Ecological literacy can measure a person's knowledge of ecological systems, a sense of concern for the environment, and actions to reduce negative impacts on environmental problems (Arif & Changxiao, 2022).

Ecological literacy can be applied in local wisdom. Using ecological literacy based on local wisdom is an effective way to form a generation that cares about the environment and is able to support ecological preservation in a sustainable manner (Ziraluo & Zebua, 2026). Local wisdom is the inheritance owned by a community, in the form of practical, socio-political, and qualitative knowledge in daily life (Agung et al., 2024). Ecological literacy is a type of literacy that focuses on understanding the relationship between humans and the environment to support sustainable development (Pouresmaieli et al., 2024). By applying ecological literacy based on local wisdom, students can better understand the impact of human activities on the environment and become more responsible in conserving natural resources (Ziraluo & Zebua, 2026).

Ecological literacy grounded in local wisdom is highly effective, especially in the context of the Madurese. By applying ecological literacy through Madurese culture, students not only enrich their understanding of the relationship between humans and the environment, but also form a generation with strong character who can care for the environment sustainably. Examples of Madurese local wisdom in the culinary field (Wijaya & Rozie, 2023), such as traditional *gettas* snacks from Sumenep, are appropriate topics for instilling ecological literacy. *Gettas* are made from glutinous rice flour and coconut, which reflects the community's understanding of food independence and local produce (Faruq et al., 2024). The ecological connection is evident because *gettas* are a food that must be served in the Nyadar ritual, a thanksgiving ceremony for salt farmers (Hidayatin et al., 2024). In this ritual, *gettas* are not only food, but also a symbol of gratitude for the natural cycles that help the salt production process (Faruq et al., 2024). The integration of local wisdom in the context of *gettas* is linked to the concept of biology (Ziraluo & Zebua, 2026).

The research was conducted with the aim of first building students' ecological literacy through the implementation of science learning oriented towards sustainable development. Second, introducing local Madurese wisdom to students. Third, identify the biological concepts contained in the local wisdom.

DISCUSSION

This article discusses how to build ecological literacy based on Madurese local wisdom in the context of *gettas*. The problem analysis was prepared through a literature review by digging up information from various literature related to ecological literacy and biological concepts contained in *gettas*. The literature used comes from Google Scholar and Google Books. In the first stage is to identify relevant articles, the second is to search for articles on the determined topic, and the third is to analyze and synthesize the selected articles. The data analysis technique used in this study is based on the model of Miles and Huberman (Miles et al., 2023). The interactive model from Miles & Huberman is a qualitative data analysis approach that treats data analysis as an interactive, continuous cycle. The following diagram of the interactive analysis from Miles & Huberman can be seen in Figure 1.

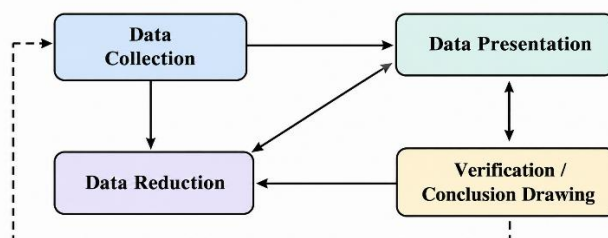


Figure 1. Miles and Huberman Model Diagram

Miles and Huberman's qualitative data analysis model includes reduction, presentation, and drawing conclusions, which are very important in research that integrates the concept of science biology with Madurese local wisdom to build ecological literacy oriented to sustainable development (SDGs). This model allows researchers to reduce observational data and field interviews into information about the local wisdom of gettas. The stage of presenting the findings in the form of information contained in the materials of gettas associated with biological concepts. Stage of drawing verified conclusions regarding how effective such integration is in improving students' ecological understanding, attitudes, and behaviors.

The results of field research on the typical food of Madurese gettas were then processed by the researcher, based on the concept of biology in junior high school. The results presented by the researcher are in the form of tables and figures. The results of the research include a discussion of the biological concepts explored for each of the materials used in making gettas, as shown in Table 1.

Table 1. Results of Biology Concepts Associated with Madurese Local Wisdom Gettas Context

No.	Supporting Photos	Science Concept
1.	Glutinous rice flour 	Classification of Living Beings (Class VII) Living things can grow and develop like glutinous rice from seeds in the soil to become tall glutinous rice plants and ready to harvest. Taxonomy of rice grain: <i>Oryza sativa</i> L. Kingdom: <i>Plantae</i> Divisi: <i>Spermatophyta</i> Kelas: <i>Monocotyledoneae</i> Order: <i>Poales</i> Famili: <i>Gramineae/Poaceae</i> Genus: <i>Oryza</i> Species: <i>Oryza sativa</i> L. Structure and Function of the Body of Living Beings (Class VIII) Glutinous rice flour is a source of carbohydrates. The function of carbohydrates provides energy to the body. Carbohydrates also serve as the basic ingredients for several parts of the body's cells. About 50% of the daily calories you eat should come from carbohydrates. Consuming carbohydrates excessively is also not good because it can result in high blood sugar in the body which can trigger disease. Glutinous rice flour belongs to complex Carbohydrates where it can create a long-lasting source of energy. Growth and Development (class IX) - When glutinous rice increases high, growth is called primary growth. Primary growth is related to the primary meristem cells in plants. Meristem cells are cells that actively divide, so when the seeds find suitable conditions, the growth process begins. - External factors that affect glutinous rice are sunlight, water, soil, humidity, temperature and nutrients

No.	Supporting Photos	Science Concept
		Human Coordination, Reproduction, and Homeostatic System (class IX) Glutinous rice flour has a carbohydrate content. When consuming foods that contain carbohydrates, glucose levels in the blood increase. This high sugar level will stimulate the release of the hormone insulin from the pancreas. Insulin will increase the permeability of cell membranes in cells, so that glucose can enter the cell. Cells use glucose as a source of energy and specifically muscle cells, glucose is converted into glycogen.
2.	Grated coconut 	Classification of Living Beings (Class VII) - Living things can grow and develop like a coconut tree from seeds in the ground to become tall and fruitful coconut trees to be ready for harvest. Coconut trees need solar energy for their growth process. - Taxonomy of the coconut tree: <i>Cocos nucifera</i> Kingdom: <i>Plantae</i> Subkingdom: <i>Tracheobionta</i> Super divisi: <i>Spermatophyta</i> Divisi: <i>Magnoliophyta</i> Class: <i>Liliopsida</i> Subkelas: <i>Arecidae</i> Ordo: <i>Arecales</i> Famili: <i>Arecaceae</i> Genus: <i>Cocos</i> Species: <i>Cocos nucifera</i> L. Structure and Function of the Body of Living Beings (Class VIII) Grated coconut is included in saturated fats. Fat serves to protect the organs of the human body from impact and shock. Fat also functions as an
No.	Supporting Photos	Science Concept
		Insulator to retain body heat, help maintain healthy skin and hair and form membrane cells in the body of living beings. Foods that contain fat, if consumed excessively, can cause cholesterol.
		Growth and Development (Class IX) - When the coconut tree grows taller, growth is called primary growth. Primary growth is related to the primary meristem cells in plants. Meristem cells are cells that actively divide, so when the seed finds suitable conditions, the growth process begins.
		
		- External factors that affect coconut trees are sunlight, water, soil, humidity, temperature and nutrients.
3.	Brown sugar	Classification of Living Beings (Class VII)

No.	Supporting Photos	Science Concept
		- Living things can grow and develop like a palm tree from seeds in the ground to become tall and fruitful palm trees to be ready for harvest. Palm trees need solar energy for their growth process. - Taxonomy of palm trees: <i>Arenga pinnata</i> Merr. Kingdom: <i>Plantae</i> Division: <i>Magnoliophyta</i> Class: <i>Liliopsida</i> Ordo: <i>Arecales</i>Famili: <i>Areaceae</i> Genus: <i>Arenga</i> Species: <i>Arenga pinnata</i> Merr. Substances and Their Changes (Class VII) When brown sugar is mixed with other ingredients, it is then in the mixer. Brown sugar does not turn into other substances, only bentuknya yang berubah dari padat Being a solution is called a physical change.
No.	Supporting Photos	Science Concept
		- In the manufacturing process, brown sugar undergoes a change in form from liquid to solid. - In the process of making sugar gettas, it undergoes a physical change from solid to liquid Structure and Function of the Body of Living Beings (Class VIII) - Sugar is often referred to as simple carbohydrates where when you consume sugar your body will feel energized. Glucose is an example of sugar which is a source of energy needed by body cells. Sugar content has an important role as a source of energy in humans. Sugar has many types such as brown sugar. - The natural sweetener is palm sugar. Natural sweeteners come from natural sources such as palm trees. Growth and Development (class IX) - When the palm tree grows taller, growth is called primary growth. Primary growth is related to the primary meristem cells in plants. Meristem cells are cells that actively divide, so when the seed finds suitable conditions, the growth process begins. - External factors that affect palm trees are sunlight, water, soil, humidity, temperature and nutrients
4.	Sugar 	Classification of Living Beings (class VII) - Living things can grow and develop like a sugarcane tree from seeds in the ground to become tall sugarcane trees. Sugarcane trees need solar energy for their growth process. - Taxonomy of the Sugarcane tree: <i>Saccharum officinarum</i> L. Kingdom: <i>Plantae</i> Divided: <i>Tracheophyta</i> Class: <i>Liliopsida</i> Order: <i>Poales</i> Famili: <i>Poaceae</i> Genus: <i>Saccharum</i> Species: <i>Saccharum officinarum</i>
No.	Supporting Photos	Science Concept

No.	Supporting Photos	Science Concept
		- Granulated sugar is often referred to as a simple carbohydrate, and when you consume sugar, your body will feel energized. Glucose is an example of a sugar, which is a source of energy for body cells. - The natural sweetener is granulated sugar. Natural sweeteners come from natural sources such as sugarcane plants. - Sugar is included in preservatives that are often added to food to extend the shelf life of food and prevent spoilage. Growth and Development (Class IX) - When the sugarcane plant grows taller, growth is called primary growth. Primary growth is associated with the primary meristem in plants. Meristem cells actively divide, so when the seed encounters suitable conditions, growth begins - External factors that affect sugarcane crops are sunlight, water, soil, humidity, temperature, and nutrients.
5.	Egg whites 	Classification of Living Beings (Class VII) - Living things can grow and develop like chickens from eggs to large chickens and lay eggs. - Taxonomy of laying hens: <i>Gallus gallus domesticus</i> Kingdom: <i>Animalia</i> Filum: <i>Chordata</i> Kelas: <i>Aves</i> Ordo: <i>Galliformes</i> Famili: <i>Phasianidae</i> Genus: <i>Gallus</i> Spesies: <i>Gallus gallus domesticus</i> Structure and Function of the Body of Living Beings (Class VIII) Egg whites are a source of protein. Cells until DNA is formed from proteins. Protein functions to build the body and form body structures. Proteins are formed from units called amino acids. Egg whites are digested by the enzyme pepsin in the stomach and trypsin in the small intestine into amino acids. Cell Recognition (Class VIII) A cell, if simply analogous to egg white, in the liquid and thick part of the egg white, is analogous to cytoplasm. Cytoplasm is the fluid inside the cell that fills the space and becomes a place for the cell's Organelles. The same is true for egg whites, which are the place for the yolk or organelles of the cell.
6.	Salt 	Structure and Function of the Body of Living Beings (Class VIII) Salt is included in preservatives used as a salting agent that is often added to food to extend the shelf life and prevent spoilage.
7.	Cooking oil	Classification of Living Beings (Class VII) - Living things can grow and develop, like oil palm trees, from seeds in the ground to become tall and fruitful palm trees to be ready for harvest. Oil palm trees need solar energy for their growth process. - Taxonomy of palm trees: <i>Elaeis guineensis</i>

No.	Supporting Photos	Science Concept
		Kingdom: <i>Plantae</i> Divisi: <i>Tracheophyta</i> Kelas: <i>Magnoliopsida</i> Ordo: <i>Arecales</i> Famili: <i>Arecaceae</i> Genus: <i>Elaeis</i> Species: <i>Elaeis guineensis</i> Jacq. Structure and Function of the Body of Living Beings (Class VIII) Cooking oil is a saturated fat. If consumed in excess, cholesterol can raise levels and harm the body. Heart disease and type 2 diabetes are examples of diseases caused by excessive consumption of foods that contain saturated fat. Growth and Development (Class IX) When the oil palm tree grows taller, growth is called primary growth. Primary growth is associated with the primary meristem in plants. Meristem cells actively divide, so when the seed encounters suitable conditions, growth begins.
8.	Water	Structure and Function of the Body of Living Beings (Class VIII) Water is the most important nutrient because 70% of our body is made up of water. Water helps regulate the body's normal temperature and aids in the removal of metabolic waste. To keep our organs functioning properly, we should, under normal circumstances, consume 2 liters of water per day.

Natural Science learning that integrates Madurese's local wisdom has significant potential to improve students' ecological literacy. Ecological literacy has the potential to build critical awareness and eco-friendly behavior among students (Nada & Listiana, 2024). Ecological literacy is essential to internalize awareness of the importance of preserving and preserving the environment, which is not just knowledge but includes the ability of individuals to understand, apply, and actively participate in environmental issues (Pouresmaieli et al., 2024). This critical awareness then encourages students to take tangible action in their daily lives, such as reducing energy consumption, using resources efficiently, supporting environmentally friendly practices, and participating in environmental conservation and protection efforts (Miterianifa & Mawarni, 2024).

Natural Sciences learning has an important role and a close relationship in overcoming the challenges of sustainable development. The essence of science learning is to instill a deep understanding of nature, the environment, and the wealth of natural resources that must be maintained and preserved. By building ecological literacy, students are expected to have a critical awareness of the impact of human activities, which will ultimately encourage them to actively contribute to environmental conservation efforts, both through environmentally

friendly technological innovations, responsible decision-making, and the adoption of daily behaviors that support sustainability (Purnamasari & Hanifah, 2021).

Making traditional Madurese snacks such as *gettas* made mainly from glutinous rice flour and grated coconut. Madurese traditional snacks in the context of *gettas* are a real example of the integration of local wisdom with the principles of sustainable development (Suryandari et al., 2023). The process of making *gettas* traditionally reflects the value of sustainability because it utilizes natural materials that are sourced from nature and can be renewed from the surrounding environment (Suryandari et al., 2025). The *gettas* processing process tends not to waste energy, and produces an environmentally friendly process because it is minimal even without producing hazardous waste that damages the ecosystem, so that it is in line with efforts to preserve natural resources and the environment (Kumar et al., 2023).

Madurese local wisdom snacks are integrated into the biological concept of the *gettas* context. *Gettas* were studied and analyzed in association with the concept of junior high school/MTS biology. By Classification, the main ingredients used in *gettas*, such as glutinous rice flour and grated coconut, belong to the Plantae plant group. Glutinous rice flour is made from glutinous rice seeds that are processed into a starch rich in carbohydrates. The concept of growth can be associated with the cultivation of glutinous rice and coconuts, which progress through growth stages until they are ready for harvest. *Gettas*, when consumed, involve the human body's systems, especially the digestive system, where complex carbohydrates from glutinous rice are broken down into simple substances used as energy sources.

This article uses local wisdom in the form of *gettas* snacks as science learning materials that reflect cultural values, ecological meaning, and a close relationship with the life of the Madurese people. Culture in the Sumenep area is famous for its *nyadar* traditional ceremonies, which aim to be a form of gratitude for the abundant gifts of nature (Wafirah et al., 2024). In the ceremony, *gettas* snacks must be present. Ecologically, the manufacture of *gettas* supports sustainable development by using naturally occurring ingredients, such as glutinous rice flour, coconut, sugar, salt, and water. The process of making *gettas* does not produce hazardous waste (Afifah, 2026). *Gettas* have a very close relationship in everyday life, thus allowing students to connect biological concepts with real experiences (Faruq et al., 2024). Ecological literacy based on Madurese's local wisdom is an effort to overcome challenges in sustainable development by increasing awareness of the importance of protecting the environment (Pouresmaieli et al., 2024).

The findings indicate that sustainable development-oriented science learning, integrating biological concepts with Madurese local wisdom, contributes positively to students' ecological literacy. Students demonstrated improved understanding of ecological principles, stronger environmental awareness, and greater willingness to participate in environmentally responsible behaviors (van de Wetering et al., 2022). These findings suggest that contextual science learning grounded in local culture provides meaningful learning experiences that enable students to connect scientific knowledge with environmental issues encountered in their daily lives.

The integration of Madurese local wisdom also strengthened students' appreciation of the reciprocal relationship between humans and nature. Various traditional practices in Madurese communities embody principles of environmental conservation, sustainable resource utilization, and collective responsibility for maintaining ecosystem balance (Fitrian et al., 2026; Sofa & Mistianah, 2026). When these cultural values are incorporated into biology learning, students recognize that scientific knowledge and indigenous knowledge are complementary rather than contradictory (Yerukie et al., 2025). This integration enriches students' perspectives by demonstrating that environmental sustainability has long been embedded within local cultural traditions.

Overall, this study demonstrates that sustainable development-oriented science learning integrating biological concepts with Madurese local wisdom represents an effective pedagogical approach for fostering ecological literacy. The combination of scientific knowledge, cultural values, and authentic environmental experiences enables students to develop ecological understanding, environmental responsibility, and sustainability competencies that are increasingly important in addressing contemporary environmental challenges.

CONCLUSION

This study shows that integrating Natural Sciences learning oriented towards sustainable development with the local wisdom of the Madurese, especially through the context of traditional gettas snacks, is effective in improving students' ecological literacy. With this approach, students not only understand concepts such as body structure and function, coordination systems, and metabolism, but also relate them to sustainable daily living practices.

Madurese local wisdom serves as a relevant and contextual medium in shaping values of environmental conservation, independence, and gratitude for nature. The eco-friendly process of making gettas reflects the principle of sustainability because it uses natural materials that are readily available and do not generate hazardous waste.

The application of ecological literacy grounded in local wisdom in science learning not only strengthens students' understanding of science but also fosters a character who cares about the environment, in line with *the Sustainable Development Goals* (SDGs). Education that integrates local culture can be an effective strategy for increasing the younger generation's ecological awareness and supporting sustainable development.

ACKNOWLEDGEMENT

The author would like to express his great gratitude to the University of Trunodjoyo Madura, especially the Science Education Study Program, Faculty of Teacher Training and Education, for providing moral support and facilities during the preparation of this article. Thank you. We also express our gratitude to the research supervisors who have provided input, suggestions, and motivation throughout the research and writing process of this article. The author did not forget to thank the sellers of Madurese typical food who have helped provide good information, from the explanation of gettas food to the origin of gettas. The results of these interviews were very helpful in preparing this article. Hopefully, the results of this research can make a positive contribution to the development of science learning oriented towards sustainable development and the preservation of local culture.

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