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Integration of Ethnoscience in Science Learning: An Ethnoscience Study on the Palm Sugar Production Process

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Abstract

This study explores the integration of ethnoscience into science education through the traditional process of palm sugar production in Mekarsari Village, Lombok, West Nusa Tenggara. Utilizing an exploratory research design, qualitative data were collected, and document analysis to examine the intersection between indigenous knowledge and scientific principles. The findings reveal that palm sugar production embodies fundamental scientific concepts. The study highlights how local farmers' expertise in tree selection, sap extraction, and sustainable processing methods aligns with modern scientific understanding. Furthermore, integrating palm sugar production into science curricula enhances students' competencies by fostering critical thinking, problem-solving, collaboration, and environmental awareness. Ethnoscience-based education also promotes character development, reinforcing values such as teamwork, responsibility, and respect for cultural heritage. Additionally, the study underscores the potential of this approach in equipping students with essential 21st-century skills, bridging traditional wisdom with contemporary scientific inquiry. By incorporating ethnoscience into formal education, this study demonstrates its effectiveness in creating a contextualized, interdisciplinary learning environment that respects both indigenous knowledge and modern scientific principles. The research concludes that integrating local wisdom into science education fosters sustainability, scientific literacy, and cultural appreciation, preparing students to navigate complex global challenges while preserving traditional knowledge systems.

Keywords: Ethnoscience; palm sugar production; science education; indigenous knowledge; sustainable learning.

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INTRODUCTION

Ethnoscience is a field of study that examines the indigenous knowledge systems existing within specific cultural groups. It encompasses the ways in which these communities interpret and interact with their natural environment, integrating traditional practices and beliefs into a systematic body of knowledge (Suryani et al., 2022; Verawati et al., 2022; Wirama, 2023). Ethnoscience does not merely serve as a collection of cultural artifacts but represents a structured approach to understanding the intricate relationships between people and their environment. This knowledge is often transmitted through oral traditions and practical applications in agriculture, medicine, and craftsmanship. By integrating ethnoscience into formal education, particularly in science learning, students can develop a contextual understanding of scientific principles by connecting them to their local cultural practices (Nisa', 2024; Primadianningsih et al., 2023; Hasibuan, 2023).

The term "ethnoscience" originates from the Greek word "ethnos," meaning "nation" or "people," and the Latin word "scientia," meaning "knowledge." This concept refers to the knowledge held by specific ethnic groups, encompassing ecological insights, agricultural techniques, medicinal applications of plants, and cultural traditions that have been preserved across generations (Wirama, 2023; Prayogi et al., 2022). Ethnoscientific knowledge is essential in understanding sustainability, as it often includes environmental practices refined through centuries of experience. For instance, indigenous salt-making techniques, agricultural pest management, and herbal medicine illustrate the scientific accuracy embedded in traditional knowledge systems (Pratama & Jumadi, 2023; Sari, 2024). By incorporating ethnoscience into education, these practices can serve as valuable teaching materials, allowing students to relate scientific concepts to real-world applications and cultural heritage.

The integration of ethnoscience into science curricula presents numerous benefits for students. First, it enables them to perceive science not as a distant or abstract discipline but as something closely related to their daily lives and cultural background. Second, it fosters critical thinking by encouraging students to compare and analyze traditional knowledge with modern scientific concepts. Third, it enhances student engagement by making science education more contextualized and relevant (Hidayanti & Wulandari, 2023; Wardani, 2023). Such an approach is crucial in bridging the gap between indigenous knowledge and formal scientific education, ensuring that traditional knowledge systems are acknowledged and respected in modern scientific discourse. This perspective is particularly valuable in fields like environmental conservation, where indigenous knowledge has contributed significantly to sustainable resource management (Rist & Dahdouh-Guebas, 2006; Thornton & Scheer, 2012).

One of the most effective methods for integrating ethnoscience into education is by using culturally relevant teaching materials and learning models. For example, employing local traditional games or storytelling as a medium for science instruction allows students to grasp abstract scientific concepts in a familiar cultural context. Studies have shown that this approach improves students' motivation and comprehension of scientific principles (Supiyati, 2024; Zelviana, 2023). Furthermore, the use of project-based learning (PBL) models that incorporate ethnoscientific themes promotes hands-on experiences and collaborative problem-solving, reinforcing students' ability to apply scientific concepts to practical situations (Astuti et al., 2022; Handayani et al., 2018; Rioux & Smith, 2019). These methods have proven to be effective in fostering scientific literacy while preserving the cultural identity of learners.

Another key strategy in ethnoscience-based education is the promotion of collaborative learning between students, educators, and local knowledge holders. By facilitating interactions with indigenous practitioners, such as traditional healers, farmers, or artisans, students can gain firsthand insights into the scientific validity of ethnoscientific practices (Fonua, 2018; Hasibuan, 2023). This collaboration not only enriches students' learning experiences but also empowers indigenous communities by recognizing their contributions to scientific knowledge (Munawarah, 2024; Cocks et al., 2012). Additionally, advancements in digital learning tools, such as e-modules, interactive learning platforms, and digital comics, provide innovative ways to document and disseminate ethnoscientific knowledge, making it more accessible to students in various educational settings (Wati et al., 2021; Dewi et al., 2021; Jin, 2021; Wibowo, 2022).

The traditional process of palm sugar production in Desa Mekarsari offers an exemplary case for the integration of ethnoscience into science education. Palm sugar, derived from the sap of the sugar palm tree (*Arenga pinnata*), is produced through a series of chemical and physical transformations, including sap extraction, fermentation, evaporation, and crystallization. These processes correspond to scientific concepts such as phase transitions, enzymatic reactions, and heat transfer, making palm sugar production a valuable context for science instruction (Rahayu, 2023; Asiyah et al., 2023). By engaging students in hands-on activities related to palm sugar making, educators can bridge the gap between traditional knowledge and modern scientific understanding, reinforcing students' grasp of fundamental scientific principles (Nisa', 2024).

The incorporation of ethnoscience-based learning, particularly through real-world examples such as palm sugar production, has been shown to improve students' scientific literacy and critical thinking skills. Research indicates that ethnoscience-oriented project-based learning enhances students' ability to analyze and apply scientific concepts in real-life scenarios, fostering a deeper appreciation for both science and cultural heritage (Nursamsu & Rachmatsyah, 2021; Budiarti et al., 2022). Furthermore, palm sugar production provides a platform for interdisciplinary learning, combining elements of chemistry, biology, and environmental science with cultural studies. For instance, students can explore the ecological significance of *Arenga pinnata* cultivation and its role in sustainable agriculture, thereby fostering an awareness of environmental conservation and local resource management (Sudarmin et al., 2023).

Beyond enhancing scientific understanding, integrating ethnoscience in education strengthens students' sense of identity and cultural pride. Engaging in collaborative projects related to palm sugar production encourages teamwork, communication skills, and social responsibility (P et al., 2023; Prasetyo, 2023). Additionally, by emphasizing the cultural significance of traditional industries, students develop an appreciation for local heritage while gaining insights into the socio-economic aspects of traditional food production. This holistic educational approach not only enriches students' academic experience but also contributes to the preservation of indigenous knowledge systems (Fasasi, 2017).

The relevance of ethnoscience-based education extends beyond the classroom, aligning with global efforts to promote culturally responsive pedagogy and sustainable development. Recognizing and valuing local knowledge systems contributes to a more inclusive and holistic understanding of science, where diverse perspectives are acknowledged and respected (Hasibuan, 2023; Harjono, 2025). This approach prepares students to engage in scientific inquiry with cultural awareness, an essential skill in an increasingly interconnected world (Anattri, 2024). By integrating ethnoscience into the curriculum, educators can create learning environments that are both scientifically rigorous and culturally meaningful, ensuring that students develop a well-rounded understanding of science that is relevant to their lives and communities.

Despite its numerous benefits, the integration of ethnoscience into formal science education remains a challenge due to the predominance of Western scientific paradigms in standardized curricula. Many educational systems continue to prioritize theoretical and abstract scientific knowledge over practical, community-based learning experiences. This gap can result in a lack of student engagement and reduced relevance of science education for learners from indigenous or rural backgrounds. Addressing this issue requires educational policymakers and institutions to recognize the value of ethnoscience and actively incorporate it into national curricula (Mutasa, 2015; Rist & Dahdouh-Guebas, 2006).

The study of palm sugar production in Desa Mekarsari serves as an important model for ethnoscience integration in science education. It provides a concrete example of how local knowledge can be used to illustrate scientific concepts while preserving cultural traditions. By designing curricula that incorporate ethnoscientific knowledge, educators can ensure that science education remains relevant, engaging, and inclusive for diverse student populations. Furthermore, continued research on the effectiveness of ethnoscience-based learning strategies is essential for refining and expanding their application in educational settings.

The integration of ethnoscience in science education presents a valuable opportunity to enhance students' understanding of scientific principles through the lens of local knowledge systems. The case of palm sugar production highlights the potential of ethnoscience to make science learning more contextualized, engaging, and culturally relevant. By embracing ethnoscience as a legitimate and valuable component of science education, educators can bridge the gap between traditional knowledge and modern scientific discourse, ultimately fostering a more holistic and inclusive approach to learning.

Study Objectives

The present study aims to elucidate and analyze how the process of palm sugar production in Mekarsari Village, Lombok, West Nusa Tenggara, can be effectively integrated as a learning resource within ethnoscience-based science education. Specifically, the study seeks to achieve the following objectives:

1. To identify and examine the local wisdom embedded in the traditional process of palm sugar production.
2. To analyze the process of palm sugar production within the context of both indigenous knowledge and scientific principles.
3. To explore the relationship between local wisdom in palm sugar production and students' competencies in science learning.
4. To investigate the character values reflected in students' learning experiences through the study of palm sugar production.
5. To assess the relevance of ethnoscience-based science education in addressing the competencies required for 21st-century learning.

METHODS

This study employs an exploratory research design to examine the integration of palm sugar production in Mekarsari Village as a learning resource in ethnoscience-based science education. Exploratory research is appropriate for investigating phenomena that have not been extensively studied, allowing for a deeper understanding of the local wisdom embedded in palm sugar production and its relevance to science education. The study focuses on describing traditional knowledge and practices, analyzing their scientific relevance, and evaluating their potential application in formal science learning. A qualitative approach was utilized to capture the intricate details of the knowledge systems and pedagogical implications associated with palm sugar production.

Data collection was conducted through multiple methods, including in-depth interviews, participant observation, and document analysis. Interviews were carried out with local palm sugar producers, community elders, and educators to gain insights into the traditional knowledge surrounding palm sugar production. These interviews aimed to uncover the processes involved, the scientific principles embedded in local practices, and the cultural values transmitted through this activity. Participant observation allowed researchers to directly engage with the production process, documenting each stage of transformation from sap extraction to crystallization. Additionally, relevant documents, such as local manuscripts, educational policies, and prior research on ethnoscience, were analyzed to provide contextual support for the study.

The data were analyzed using a thematic analysis approach, which involved identifying key themes related to ethnoscience, education, and scientific concepts within the palm sugar production process. Thematic analysis enabled the categorization of findings into core aspects, such as indigenous knowledge, scientific relevance, student competencies, character values, and 21st-century education demands. Coding techniques were employed to systematically organize the data, ensuring that emerging themes accurately reflected both traditional wisdom and its applicability to modern science education. The findings were then interpreted within the framework of ethnoscience education to explore potential curriculum integration.

To ensure the credibility and reliability of the findings, triangulation was applied by cross-referencing data obtained from different sources and methods. Comparing interview responses with observations and document analysis helped validate the accuracy of the information gathered. Member checking was also conducted by sharing preliminary findings with local knowledge holders and educators to confirm the authenticity of interpretations. Additionally, reflexivity was maintained throughout the research process, with researchers critically reflecting on their biases and positionality to ensure a culturally sensitive and unbiased analysis.

Ethical considerations were strictly adhered to, particularly in obtaining informed consent from all participants. The study ensured that the knowledge shared by the local community was respected and appropriately represented, maintaining ethical research principles in working with indigenous and rural communities. Participants were fully informed about the research objectives, and their contributions were anonymized to protect their identities. By following ethical research practices, this study not only contributes to academic discourse but also upholds the dignity and intellectual property of the local community, fostering mutual respect and knowledge exchange between researchers and indigenous knowledge holders.

RESULTS AND DISCUSSION

The findings of this study provide a comprehensive analysis of how the traditional process of palm sugar production in Mekarsari Village can be effectively integrated as a learning resource within ethnoscience-based science education. The results reveal that palm sugar production is not merely an economic activity but a cultural practice embedded with indigenous knowledge that aligns with various scientific principles, such as thermodynamics, chemical reactions, and phase transitions. Through in-depth interviews and participant observation, it was found that local artisans possess a wealth of empirical knowledge regarding the techniques and environmental factors influencing sugar production, demonstrating a deep understanding of natural processes that have been refined through generations.

Furthermore, the thematic analysis indicates that the integration of this traditional practice into science learning enhances students’ comprehension of fundamental scientific concepts while simultaneously preserving local wisdom and cultural heritage. The relationship between indigenous knowledge and formal science education was further explored through its impact on students' competencies, character development, and alignment with 21st-century learning objectives. By embedding ethnoscience into the curriculum, students are encouraged to develop critical thinking, problem-solving skills, and cultural appreciation, fostering a more holistic and contextualized approach to science education. Additionally, the findings highlight that an ethnoscience-based learning model promotes student engagement by making scientific concepts more relatable and meaningful through real-world applications. Discussions with educators also emphasize the need for collaborative efforts between schools and local communities to facilitate experiential learning, ensuring that students gain firsthand exposure to traditional knowledge systems. The results further indicate that the values embedded in palm sugar production, such as patience, discipline, and environmental stewardship, contribute to character-building in students, reinforcing the importance of integrating cultural heritage into education. This section will discuss these findings in detail, elaborating on the scientific concepts embedded in the palm sugar production process, the pedagogical implications of ethnoscience integration, and its potential role in fostering sustainable education that respects both modern scientific inquiry and indigenous wisdom.

Indigenous knowledge in palm sugar production

The indigenous knowledge embedded in the process of tapping and processing palm sap reflects the deep understanding that local communities have of their natural environment. This knowledge encompasses techniques for sap extraction, recognition of optimal tree maturity, sustainable harvesting practices, and the utilization of various products derived from sap. As noted in the *Journal of Food and Nutrition Research*, the sap extracted from trees such as *Arenga pinnata Merr* and coconut can be processed into products such as jaggery, granulated sugar, syrup, and fermented beverages like toddy. These processes indicate a profound comprehension of tree physiology, sustainable extraction methods, and sap refinement to ensure high-quality product yields. This expertise exemplifies the harmonious relationship between local communities and their surrounding environment, where traditional practices are adapted to optimize resource use while preserving ecological balance (Kurniawan et al., 2018). Table 1 provides a detailed overview of the indigenous knowledge present in the palm sugar production process.

Table 1. Overview of the indigenous knowledge present in the palm sugar production process.

No	Stages	Indigenous knowledge
1	Identifying Tree Maturity	Local farmers possess an intrinsic understanding of the ideal age for palm tree tapping. They determine maturity by cutting one of the palm's fronds to assess its readiness. Young or overly mature trees do not yield high-quality sap, and the ability to assess the right timing demonstrates the depth of traditional ecological knowledge passed down through generations.
2	Tapping Techniquez	The sap extraction process follows meticulous, time-tested techniques. Before tapping, farmers strike the palm's flower stalk from the base to the tip, repeating this process biweekly to facilitate sap flow. Once the flower stalk matures and emits a distinct aroma, it is cut and wrapped in *ijuk* (palm fiber) for a day. Farmers then inspect the stalk to determine if sufficient sap has been collected. If the flow is optimal, the *ijuk* covering is removed, and a plastic container or bamboo receptacle is attached to collect the sap.
3	Utilization of Traditional Tools	The tools used in palm sap collection remain simple yet effective. Farmers use bamboo ladders tied to the palm tree to reach the stalk, specially designed tapping knives, and containers made from bamboo, clay, or repurposed plastic jugs to store the sap. The cooking process also relies on traditional methods, where sap is boiled in large iron woks over wood-fired stoves, and stirred using bamboo or wooden paddles. For molding the final palm sugar product, farmers cut bamboo segments into approximately 15 cm sections, which serve as natural molds.
4	Tapping Schedule	Palm sap extraction follows a strict schedule, typically conducted in the early morning and late afternoon. These specific timeframes optimize sap quality and yield,

No	Stages	Indigenous knowledge
		reflecting the farmers' understanding of the biological rhythms of the tree. This practice showcases the synchronization between human activities and the natural cycles of the environment.
5	Recognizing Sap Quality	Experienced palm sugar producers can assess sap quality through sensory observations. By simply looking at, smelling, or tasting the sap, they can determine its freshness and suitability for sugar production. This ability to discern subtle differences in sap characteristics exemplifies the refined expertise that has been cultivated over generations.
6	Sustainable Practices	Sustainability is a fundamental aspect of palm sap harvesting. Local farmers implement rotational tapping methods to prevent over-exploitation of trees and ensure long-term productivity. Additionally, they adhere to unwritten ecological guidelines, such as planting new palm trees to replace aging ones, ensuring the continuity of the tradition and the preservation of local biodiversity.
7	Cultural and Ritual Aspects	In certain communities, palm sap tapping and sugar production are intertwined with cultural traditions and rituals. These may include prayers or ceremonies performed before or after tapping, symbolizing gratitude and respect for nature. Such rituals reinforce the spiritual and communal aspects of traditional knowledge, illustrating how environmental stewardship is deeply embedded within cultural practices.
8	The Sap Boiling Process	Once collected, the sap undergoes filtration to remove impurities before being boiled in large woks over wood-fired stoves. During this process, the sap gradually thickens and darkens in color. A crucial step involves adding grated coconut, coconut oil, candlenut, or sugar to regulate foam formation and enhance the sugar's texture and flavor. This traditional technique showcases the intricate knowledge of chemical changes occurring during the heating process.
9	Sugar Molding Process	The final step in palm sugar production involves pouring the thickened syrup into pre-soaked bamboo molds. The bamboo molds, having been soaked in water beforehand, prevent the sugar from sticking and facilitate easy removal once it solidifies. This method, passed down through generations, highlights the efficiency of indigenous knowledge in utilizing natural materials for food processing.

The wealth of knowledge demonstrated in these practices underscores the scientific accuracy embedded within indigenous wisdom. By integrating these processes into science education, students can develop a more profound appreciation of both traditional knowledge and formal scientific principles. Furthermore, this knowledge transfer fosters environmental awareness, cultural preservation, and sustainability in learning, aligning with the broader objectives of ethnoscience-based education.

The relationship between indigenous knowledge and scientific knowledge in palm sugar production

According to Nurrubi et al. (2022), local wisdom contains indigenous knowledge that can be transformed or reconstructed into scientific knowledge. This knowledge serves as a valuable resource for science education, providing a more relevant and in-depth context for learning. In the palm sugar production process, the indigenous knowledge possessed by local communities merges with scientific principles, demonstrating an interplay between tradition and modern scientific understanding. Local knowledge encompasses an in-depth comprehension of the sugar palm tree's life cycle, tapping techniques, and traditional methods of processing sap into sugar. Meanwhile, scientific aspects include an understanding of fermentation, evaporation, and the chemical reactions involved in transforming sap into sugar. The integration of these two types of knowledge creates an efficient and sustainable process while preserving cultural heritage and enhancing scientific literacy. Table 2 shows the integration of indigenous knowledge into scientific knowledge in the palm sugar production process.

Table 2. Ethnoscience in palm sugar production

No	Production stage	Indigenous knowledge	Scientific knowledge
1	Flower Stalk Tapping Preparation	In traditional practice, farmers strike the palm's flower stalk before tapping to facilitate sap flow.	Scientifically, this technique influences the internal tissues of the stalk, breaking down cell structures and enhancing sap secretion (Harahap et al., 2021).
2	Tapping at Specific Times of the Day	Farmers tap the palm tree in the morning and evening to obtain the highest quality sap.	Scientifically, lower temperatures during these times reduce microbial activity that could cause premature fermentation. Additionally, during these hours, internal tree pressure is generally higher, allowing sap to flow more smoothly (Wijiastuti, 2019).
3	Immediate Processing of Fresh Sap	Local wisdom dictates that fresh sap must be cooked immediately to preserve its quality.	From a scientific perspective, this prevents fermentation, a natural process in which microorganisms such as yeast and bacteria convert sugars into alcohol or acids. Fresh palm sap has a high sucrose content (13-17%), a clear appearance, a fragrant aroma, and a pH level of 6.0 to 7.0. Preventing fermentation ensures that the sap retains its original chemical composition, making it an ideal raw material for further processing (Sukmana et al., 2022).

No	Production stage	Indigenous knowledge	Scientific knowledge
4	Filtration of Tapped Sap	Before boiling, the sap undergoes filtration to remove impurities.	This process aligns with the scientific principle of separation, specifically filtration, which involves removing solid particles from a liquid or gas mixture based on differences in physical properties.
5	Boiling Process	Make the sap thick and change color.	The transformation of palm sap into sugar involves several scientific processes: • Heat Transfer (Convection): As the sap is heated, thermal energy transfers from the fire to the liquid. • Evaporation: As water in the sap evaporates, the sugar concentration increases, causing the mixture to thicken. • Crystallization: Once sufficient water has evaporated, the high sugar concentration leads to crystallization, forming solid sugar. • Caramelization: The breakdown of sucrose and other sugars through heat produces a distinct brown color and rich flavor. This involves complex chemical changes, such as the formation of new compounds that alter the taste and texture of the final product. • Chemical Transformation: Caramelization triggers noticeable changes in temperature, color, aroma, and texture, leading to the formation of solid palm sugar from liquid sap (Widiastuti et al., 2023).
6	Addition of Coconut Gratings, Candlenut, or Oil	During the boiling process, local producers add grated coconut, candlenut, or oil when excessive foaming occurs	Scientifically, these substances act as anti-foaming agents, preventing foam from interfering with the evaporation and sugar concentration process. This ensures controlled heating and minimizes liquid overflow (Offshore Technology, 2021).
7	Soaking Bamboo Molds in Water	Before molding the palm sugar, bamboo molds are soaked in	From a scientific standpoint, soaking bamboo creates a moisture barrier, reducing adhesion between the sugar

No	Production stage	Indigenous knowledge	Scientific knowledge
		water. This traditional practice prevents the sugar from sticking to the mold.	and the mold, thereby making demolding easier. This process is based on the principles of surface interaction between a moist surface and a cooling sugar solution (Chen et al., 2023).
8	Molding and Solidification of Palm Sugar	The final step involves pouring the thickened sugar solution into bamboo molds, where it solidifies.	Scientifically, this represents the solidification process—a phase transition from liquid to solid—resulting from the evaporation of water and subsequent cooling of the sugar concentrate (Chen et al., 2023).

The process of palm sugar production is closely related to fundamental scientific concepts taught in school curricula. The different stages of production—such as sap tapping, heating, and crystallization—can be integrated into science lessons, helping teachers create contextualized learning experiences. By aligning traditional knowledge with science education, students can grasp complex scientific concepts more effectively through real-world applications, making learning more engaging and meaningful. Ethnoscience-based learning not only enriches scientific understanding but also fosters cultural appreciation and sustainability awareness, preparing students for 21st-century education challenges.

The relationship between ethnoscience in palm sugar production and science curriculum learning outcomes in Indonesia

In science education, two key elements—scientific understanding and process skills (inquiry)—are essential for the practical application of science in daily life. These elements apply to four main content areas: living organisms, matter and its properties, energy and its transformations, and Earth and space. The integration of theoretical knowledge with practical skills in science education is critical for fostering students' ability to connect classroom learning with real-world phenomena (Kemendikbudristek, 2022). Table 3 illustrates how the ethnoscience of palm sugar production aligns with the learning outcomes of the Indonesian science curriculum.

Table 3. Alignment of ethnoscience in palm sugar production with Indonesia's science curriculum learning outcomes

No	Learning outcomes	Grade	Science comprehension
1	Students are able to classify living organisms and objects based on observed characteristics, identify the properties and characteristics of substances, distinguish between physical and chemical changes, and separate simple mixtures.	VII	Explain the taxonomy of *Arenga pinnata Merr.*, from kingdom to species.
		VII	Describe the states of matter and their changes, including the particle theory in liquids, solids, and gases.
		VIII	Differentiate between physical and chemical changes based on their characteristics.

No	Learning outcomes	Grade	Science comprehension
		VIII	Explain simple separation techniques, including filtration, evaporation, and crystallization.
2	Students are able to measure temperature changes caused by heat energy transfer and distinguish between thermal insulators and conductors.	VIII	Explain and apply the process of heat transfer in the stages of boiling palm sap.
		VIII	Describe the cooking wok used for boiling sap as an example of a heat conductor, while the wooden stirrer and bamboo sugar molds serve as examples of heat insulators.

Table 3 highlights how the learning outcomes outlined in the Indonesian science curriculum can be achieved through the scientific concepts embedded in palm sugar production. Moreover, the process skills element—including observation, questioning and predicting, planning and conducting investigations, processing and analyzing data, evaluating, and reflecting—can be maximized through project-based learning. Since palm sugar production is a hands-on activity that requires direct engagement, students can develop inquiry-based learning skills, fostering critical thinking and problem-solving abilities. By integrating ethnoscience into the curriculum, educators can provide a contextual and experiential approach to science learning, making it more relevant and engaging for students.

Ethnoscience in palm sugar production and character values (Pancasila Student Profile)

Studying the process of palm sugar production as part of science education enables students to develop a deeper appreciation for the traditions of their local community and recognize the significance of their parents' livelihoods as palm sugar farmers. This practice has been passed down through generations, serving as both a source of local wisdom and economic sustenance. By understanding the traditional knowledge embedded in palm sugar production, students are encouraged to develop positive character values in learning, aligning with the *Profil Pelajar Pancasila* (Pancasila Student Profile). This integration illustrates how science education can be connected with cultural awareness and local traditions to foster well-rounded character development. Three key dimensions of *Profil Pelajar Pancasila* are highlighted in the palm sugar production process, as presented in Table 4.

Table 4. Character values (*Pancasila Student Profile*) in palm sugar production

Character values	Element	Values Reflected
Religious and Moral Integrity	Element: Ethical attitude towards nature. Sub-element: environmental stewardship	• Discussions on the historical and cultural significance of palm sugar production in Mekarsari Village. • Use of eco-friendly materials and tools in the production process. • Emphasis on maintaining cleanliness in the workspace after production, reinforcing the importance of environmental balance.

Character values	Element	Values Reflected
Cooperation and Teamwork	Element: Collaboration Sub-element: Working together	• Students engage in group tasks such as sap collection, boiling, molding, timekeeping, documentation, and report writing, fostering teamwork and shared responsibility.
Critical Thinking	Element: Acquiring and processing information and ideas Sub-element: Identifying, clarifying, and analyzing information and ideas	• Analysis of the chemical processes involved in caramelization. • Understanding the factors that influence the quality of palm sugar. • Recording observations throughout the production process to develop analytical skills.

Integrating the palm sugar production process into science education provides students with an opportunity to learn beyond scientific content. Through this experiential learning approach, students gain not only scientific knowledge but also social values and character-building experiences that can be applied in everyday life. By fostering environmental awareness, teamwork, and critical thinking, this learning model strengthens students' ability to connect science education with real-world cultural and ethical considerations.

Ethnoscience in palm sugar production to support 21st-century learning skills

Integrating ethnoscience into modern education highlights how traditional knowledge and practices can enhance essential 21st-century skills among students. This approach encourages learners to develop competencies such as communication, collaboration, critical thinking, and creativity, which are crucial for adapting to the demands of the modern world. By engaging in hands-on learning experiences, students gain a deeper understanding of scientific concepts while simultaneously honing their problem-solving and teamwork abilities. The ethnoscience of palm sugar production serves as an effective educational tool to bridge traditional wisdom with contemporary learning objectives. Table 5 presents the 21st-century skills fostered through the ethnoscience of palm sugar production and their practical implementation.

Table 5. The 21st-century skills fostered through the ethnoscience of palm sugar production and their practical implementation

No	Skills	Implementation
1	Communication	Students are encouraged to articulate their ideas, ask questions, and engage in discussions throughout the palm sugar-making project. By sharing observations and explaining each production step, they develop confidence in expressing scientific concepts and collaborating effectively with peers.
2	Collaboration	Working in teams fosters responsibility and teamwork, as students are assigned specific roles in the production process, such as sap collection, boiling, molding, and documenting findings. This cooperative approach helps them develop interpersonal skills while working toward a shared goal.
3	Ritical thinking	Throughout the project, students analyze and solve problems that arise during production, such as identifying factors that

No	Skills	Implementation
		influence the quality of palm sugar. Engaging in discussions to evaluate these issues enhances their ability to think critically and make informed decisions.
4	Creativity	Students are encouraged to experiment with new methods or recipes in palm sugar production. This may include adding unique flavors, modifying ingredient compositions, or developing techniques to improve shelf life at room temperature. Such experimentation fosters innovation and problem-solving abilities.

By integrating ethnoscience into science education, students not only gain a deeper appreciation for local knowledge but also develop practical skills that are essential in today's dynamic learning environment. This approach ensures that traditional practices remain relevant while equipping students with the tools needed to navigate modern scientific and technological advancements.

The findings of this study highlight the intricate relationship between indigenous knowledge and scientific principles in the traditional process of palm sugar production. The results indicate that palm sugar production is not merely an economic activity but an integral part of local wisdom that has been refined over generations. Through in-depth interviews and participant observation, it was found that artisans in Mekarsari Village possess deep empirical knowledge about tree selection, sap extraction techniques, and the environmental conditions necessary for high-quality palm sugar production. These insights align with biological and chemical principles, such as the physiology of *Arenga pinnata*, thermodynamics in the boiling process, and crystallization in sugar solidification. The results further emphasize the pedagogical potential of integrating ethnoscience-based learning into the curriculum, as it provides students with a contextualized approach to scientific concepts while preserving cultural heritage.

A key aspect of ethnoscience in palm sugar production is its methodological rigor in selecting and processing raw materials. The study found that local farmers determine the optimal age for tapping palm trees by assessing the physical characteristics of the plant. Scientifically, this practice ensures that the sugar content in the sap is at its highest concentration, which directly impacts the efficiency of sugar crystallization. Additionally, the timing of sap collection—typically in the early morning and late afternoon—is rooted in both indigenous wisdom and scientific reasoning. Lower temperatures during these periods reduce microbial activity, preventing premature fermentation of the sap. These findings support prior studies that highlight the fusion of indigenous knowledge and scientific methods in sustainable resource management (Harahap et al., 2021; Wijiastuti, 2019).

The integration of palm sugar production into science education also demonstrates its impact on student competencies. The study found that incorporating hands-on learning experiences, such as sap extraction, filtration, and boiling, enhances students' understanding of scientific concepts. Engaging in real-world applications of separation techniques (e.g., filtration and evaporation) and chemical transformations (e.g., caramelization and crystallization) allows students to develop problem-solving and critical-thinking skills. Moreover, discussions on sustainability and ecological balance encourage students to analyze the long-term environmental impact of traditional practices. This aligns with previous research that underscores the importance of experiential learning in improving scientific literacy and fostering deeper engagement in science education (Kencana, 2023; Syahidah, 2023).

Beyond cognitive learning, the study revealed that ethnoscience-based education plays a significant role in character building. Students participating in palm sugar production projects demonstrated increased collaboration, responsibility, and environmental awareness. The structured nature of production—requiring teamwork in collecting sap, monitoring the cooking process, and documenting observations—encouraged students to develop communication and leadership skills. Additionally, the cultural values embedded in the process, such as respect for nature and traditional rituals associated with sugar production, provided an opportunity for students to reflect on ethical and moral principles. These findings align with previous studies emphasizing the role of ethnoscience in promoting character education, particularly within the framework of *Profil Pelajar Pancasila* (Utami et al., 2018).

The relevance of ethnoscience-based education in 21st-century learning is also evident in the study. The integration of palm sugar production into science curricula provides a platform for students to develop essential 21st-century skills, including critical thinking, creativity, collaboration, and communication. By encouraging students to explore alternative production methods—such as experimenting with different sugar formulations or evaluating the efficiency of traditional versus modern processing techniques—science education becomes more dynamic and innovative. The results further suggest that integrating local wisdom into formal education fosters a sense of identity and cultural pride while simultaneously equipping students with scientific knowledge applicable to global challenges (Baka, 2024; Aisyah & Khotimah, 2023).

The study underscores the value of incorporating ethnoscience in science education through palm sugar production. The findings demonstrate that traditional knowledge not only aligns with scientific principles but also enriches the learning experience by promoting environmental sustainability, social responsibility, and cultural appreciation. Future research should explore the long-term impact of ethnoscience-based education on students' scientific competencies and career choices. Additionally, collaborations between educational institutions and local communities should be strengthened to ensure the continuity and relevance of indigenous knowledge in modern science education. By adopting a holistic approach that bridges tradition and innovation, educators can create a meaningful and impactful learning environment that prepares students for the complexities of the 21st century.

The integration of ethnoscience into science education carries significant pedagogical implications, particularly in enhancing contextual learning and student engagement. By incorporating indigenous knowledge into the curriculum, educators provide students with a more relatable and meaningful learning experience, bridging the gap between abstract scientific concepts and real-world applications. This approach fosters inquiry-based learning, where students actively engage in hands-on experiences such as palm sugar production, encouraging critical thinking, problem-solving, and collaboration. Furthermore, ethnoscience-based learning supports differentiated instruction, accommodating diverse learning styles by allowing students to explore science through cultural narratives, traditional practices, and experiential activities. This method aligns with constructivist learning theories, which emphasize knowledge construction through personal experiences and social interactions, making science education more inclusive and accessible.

Beyond its impact on pedagogy, ethnoscience integration plays a crucial role in fostering sustainable education that respects both modern scientific inquiry and indigenous wisdom. By validating traditional knowledge systems alongside formal scientific methods, this approach promotes a more holistic understanding of environmental sustainability, resource management, and biodiversity conservation. For example, traditional practices in palm sugar production, such as rotational tapping and the use of biodegradable materials, reflect sustainable agricultural techniques that align with contemporary ecological principles. Teaching these practices in science education not only preserves cultural heritage but also cultivates environmental responsibility among students, preparing them to address global sustainability challenges. Moreover, this integration fosters cross-disciplinary learning, linking science with ethics, history, and local economic development, thereby producing well-rounded individuals capable of making informed decisions in an increasingly complex world.

CONCLUSION

The integration of ethnoscience into science education, as demonstrated through the study of palm sugar production in Mekarsari Village, offers a meaningful approach to contextualized learning that bridges indigenous knowledge and modern scientific inquiry. The findings highlight that traditional practices align with fundamental scientific concepts, including physics, chemistry, biology, and environmental science, reinforcing students' understanding of heat transfer, phase changes, and material properties through real-world applications. This approach fosters critical thinking, collaboration, and problem-solving skills while enhancing students' engagement with science. Additionally, ethnoscience-based learning promotes cultural preservation, character development, and environmental sustainability, ensuring that education remains relevant to both local and global challenges. By incorporating traditional wisdom into formal education, educators can create an inclusive, interdisciplinary, and experiential learning environment that prepares students for the complexities of the 21st century while respecting and preserving valuable indigenous knowledge systems.

RECOMMENDATION

The findings of this study highlight the importance of integrating ethnoscience into science education to enhance students' understanding of scientific concepts while preserving indigenous knowledge. It is recommended that educators develop curriculum materials that incorporate traditional practices, such as palm sugar production, to create a more contextualized and engaging learning experience. Collaboration between schools, local communities, and policymakers should be strengthened to support the documentation and dissemination of indigenous knowledge in science education. Additionally, further research should explore the long-term impact of ethnoscience-based learning on students' scientific competencies, environmental awareness, and career aspirations. Educational institutions should also invest in teacher training programs that equip educators with the skills needed to implement ethnoscience-based pedagogies effectively. By fostering an inclusive learning environment that bridges traditional wisdom with modern scientific inquiry, science education can contribute to sustainable development and cultural preservation while preparing students for the demands of the 21st century.

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