ETHNOSCIENCE INTEGRATION BASED ON LOCAL WISDOM OF KUDUS IN SCIENCE LEARNING TO IMPROVE STUDENTS' SCIENCE LITERACY

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ABSTRACT

Science learning in Islamic schools requires contextual and meaningful approaches to enhance students' scientific literacy. One relevant approach is ethnoscience, which integrates scientific concepts with local wisdom. This study aims to examine the ethnoscience values contained in the local wisdom of Menara Kudus and their relevance for integration into science learning in Islamic schools to improve students' scientific literacy. This research employed a descriptive qualitative approach using observation, in-depth interviews with cultural informants, and documentation as data collection techniques. The results indicate that Menara Kudus contains various ethnoscience values encompassing physical, chemical, environmental, and socio-cultural aspects. Physical and chemical aspects are reflected in the use of red brick materials, traditional construction techniques without modern cement, and principles of force, balance, and structural stability. Environmental aspects are evident in the building's adaptation to the tropical climate, while socio-cultural aspects are represented by the value of tolerance taught

by Sunan Kudus. These findings demonstrate that Menara Kudus has significant potential as a contextual and holistic ethnoscience-based science learning resource. Integrating these values into science learning in Islamic schools is expected to enhance students' scientific literacy while simultaneously strengthening character education.

Keywords: *Ethnoscience, Local Wisdom, Scientific Literacy, Kudus Tower, Science Learning*

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INTRODUCTION

Natural Science subject learning in Islamic school in the 21st century demands an approach that develops students' scientific thinking skills, scientific process skills, and scientific literacy. Scientific literacy is a core competency because it helps students understand natural phenomena, evaluate scientific information, and make evidence-based decisions in everyday life. In an era of globalization and rapid technological development, scientific literacy also plays a crucial role in equipping students to address various scientific and technological issues, such as climate change, energy utilization, environmental health, and the development of science-based technologies that are increasingly relevant to society (Science, 2021).

However, national and international assessments show that Indonesian students' scientific literacy levels remain relatively low compared to those of other countries. This low level of scientific literacy indicates that science learning has not fully developed students' ability to connect scientific concepts to real-world contexts. One of the main causes of this is a learning process that is still textbook-oriented, emphasizes memorization of concepts, and provides little opportunity for students to explore, observe, and reason scientifically based on their environment and culture. As a

result, science learning becomes less meaningful and less relevant to students' life experiences (Kharis, 2020).

This situation is still frequently encountered in science learning in Islamic school. Although Islamic school excel in instilling religious values and character, science learning often fails to integrate local potential, which is closely related to students' lives. Yet, the characteristics of Islamic school, closely tied to the social and cultural life of the surrounding community, are crucial for developing contextual and meaningful science learning. Integrating science, religious values, and local culture is urgently needed to ensure that science learning in Islamic school can develop students who are not only academically competent but also demonstrate a concern for the environment and local wisdom (Azzaki et al., 2021).

In line with the demands of the Independent Curriculum, science learning is directed at developing 21st-century competencies, such as critical thinking, creativity, collaboration, and communication, as well as fostering student profiles with character and roots in national culture. This curriculum encourages teachers to provide contextual learning, based on real-life experiences, and relevant to students' environments. Therefore, utilizing local wisdom as a resource for science learning is a strategy that aligns with the direction of curriculum policy and the needs of students in Islamic school (Of et al., 2016).

Various studies have shown that an ethnoscience approach can be an effective alternative in addressing these challenges. Ethnoscience is a learning approach that integrates local knowledge, cultural practices, and community wisdom into science learning. Through this approach, science concepts are not presented abstractly but are instead linked to phenomena students are familiar with in their everyday lives. This allows students to build deeper conceptual understanding while developing scientific literacy contextually (Husna & Munahefi, 2024).

Previous studies found that learning based ethnoscience are capable to improve understanding, and students' critical thinking skill. Furthermore, this approach contributes to fostering an appreciation for local culture and strengthening students' identity as members of a culturally rich society. Ethnoscience-based science

learning focuses not only on cognitive outcomes but also on developing students' attitudes and character, thus aligning with the educational goals of Islamic school (Supriyadi et al., 2022).

Kudus, as an area rich in local wisdom, has great potential to be used as a resource for science learning. One cultural icon rich in historical and scientific value is the Kudus Tower. The Kudus Tower is not only known as a historic building reflecting the acculturation of Islamic and Hindu cultures, but also holds various scientific concepts relevant to science learning. Aspects such as the technique of laying red bricks without modern adhesives, the sturdy traditional building structure, the concepts of force, balance, pressure, and material resistance to weather and time are concrete examples of science concepts that can be explored through the Kudus Tower.

The ethnoscience values embodied in the Kudus Tower can be utilized as a learning context to help students understand science concepts in a more concrete and applicable way. Through observation, discussion, and analysis of the Kudus Tower building, students can be encouraged to connect scientific concepts to real-world phenomena in their surroundings. This type of learning is expected to increase interest in learning, deepen conceptual understanding, and optimally foster students' scientific literacy (Puspita & Pradisa, 2017).

However, the utilization of the local wisdom of the Kudus Tower as a science learning resource in Islamic school remains relatively limited. Most teachers have not systematically integrated ethnoscience values into the planning and implementation of science lessons. Learning still tends to focus on delivering material based on textbooks, so the potential of local culture rich in scientific value has not been optimally utilized. This indicates a research gap that requires further study, particularly regarding how to integrate ethnoscience based on the local wisdom of the Kudus Tower into science learning in Islamic school (Fisika et al., 2025).

Based on the description, this study attempts to examine the application of ethnoscience integration based on the local wisdom of the Kudus Tower in science learning at Islamic school as an effort to improve students' scientific literacy. This study not only focuses on identifying the scientific values contained in the Kudus Tower, but

also on how these values can be implemented in science learning that is contextual, meaningful, and appropriate to the characteristics of Islamic school students. Thus, the results of this study are expected to provide theoretical contributions to the development of ethnoscience-based science learning studies, as well as practical contributions for teachers in designing and implementing innovative science learning that is oriented towards improving students' scientific literacy (The & Of, 2025).

METHOD

This study uses a descriptive qualitative approach because it aims to describe in depth the ethnoscience values contained in the local wisdom of the Kudus Tower and its relevance for integration into Natural Science (IPA) learning in Islamic school. A qualitative approach was chosen because it allows researchers to understand phenomena holistically, contextually, and meaningfully based on the reality that occurs in the field, not simply based on numbers or statistical data. With this approach, researchers can uncover facts, meanings, and cultural values that live in society naturally through direct interaction with data sources, without conducting treatments or experiments in the classroom learning process. The main focus of this study is not only on identifying physical elements of science, but also on the accompanying cultural meaning as part of the local wisdom heritage that is rich in educational value (Endah et al., 2025).

Data sources in this study included cultural informants, community leaders, managers of the Kudus Tower area, and others with a deep understanding of the history, philosophy, building structure, and socio-cultural functions of the Kudus Tower. Furthermore, data sources were obtained from various written documents, such as history books, scientific articles, archival records, and related reports discussing the Kudus Tower as a cultural and religious object. Informants were selected using purposive sampling, based on their ability and involvement in providing information relevant to the research objectives, ensuring that the data obtained were truly valid and met the research needs (Kota et al., 2021).

Data collection was conducted through three main techniques: observation, interviews, and documentation. Direct and

repeated observations were conducted in the Menara Kudus area to observe the physical condition of the building, its architectural structure, the types of materials used, construction techniques, and the cultural symbols contained within it. Through these observations, researchers identified various scientific elements such as the concepts of force, balance, building structure, material properties, energy changes, and weathering processes relevant to science learning materials in Islamic school. Observations were also directed at community activities around the Menara Kudus area to examine the relationship between cultural values, religion, and daily life practices that contain elements of science (Ornamen & Al, 2023).

In-depth interviews were conducted with cultural sources and competent parties to explore understanding, experiences, and information about the history, function, philosophical values, and scientific values contained in the Kudus Tower. The interviews were conducted semi-structured, thus researchers had guidelines for basic questions but still provided space for informants to convey information freely and broadly according to their experience and knowledge. Through these interviews, researchers sought to explore how the community interprets the Kudus Tower not only as a religious symbol, but also as a source of knowledge containing scientific elements that can be integrated into learning.

Documentation techniques were used to collect various supporting data, including building photographs, interview recordings, field notes, historical literature, cultural documents, and archives relevant to the research. This documentation serves to strengthen the results of observations and interviews and serves as authentic proof that the data obtained truly originates from the field. Documentation data is also used to deepen the analysis of the physical characteristics of the Kudus Tower and the ethno-scientific values it embodies.

The data obtained in this study were descriptive qualitative data in the form of words, statements, observations, and visual documentation. Data analysis was conducted using the Miles and Huberman interactive analysis model, which includes three main stages: data reduction, data presentation, and drawing conclusions or verification. In the data reduction stage, researchers sorted, selected,

focused, and simplified the raw data obtained from observations, interviews, and documentation to find data relevant to the research objectives. Data not directly related to the research focus was set aside to make the analysis more focused.

The data presentation stage involves organizing the reduced data into narrative descriptions, descriptive tables, and concept maps that illustrate the relationship between scientific elements and the cultural values embodied in the Kudus Tower. This data presentation aims to facilitate researchers in understanding the interrelationships between data and drawing meaning from the phenomena being studied. The final stage is drawing conclusions, which are carried out gradually and continuously throughout the research process. Conclusions are not drawn suddenly, but rather through a continuous verification process as data in the field increases.

To ensure data validity, this study employed triangulation techniques, both source and technical triangulation. Source triangulation was conducted by comparing data obtained from various informants, while technical triangulation was conducted by comparing the results of observations, interviews, and documentation. Thus, the resulting data has a high level of credibility and can be scientifically justified.

Through all these stages, the research is expected to be able to provide a comprehensive and in-depth illustration of the potential of the local wisdom of Menara Kudus as a relevant source of ethnoscience to be used as a basis for developing science learning in Islamic school, so that learning is not only theoretical, but also contextual, meaningful, and rooted in the local culture of students.

RESULTS AND DISCUSSION

The results of this study were obtained through direct observation of the Kudus Tower, interviews with cultural sources, and documentation in the form of photographs, historical records, and supporting literature. The data collection process was carried out in stages to ensure the accuracy and depth of the information obtained. Data from observations, interviews, and documentation were then analysed descriptively to identify the ethnoscience values

contained within the Kudus Tower and their relevance to science learning in Islamic school.

Based on field observations, the Kudus Tower exhibits the characteristics of a traditional building, demonstrating the empirical application of scientific principles. The building's structure, composed of red brick and still standing strong today, demonstrates that the construction techniques used took into account the strength and stability of the building. The primary material, traditionally fired red brick, demonstrates the physical and chemical changes occurring in the clay. Initially plastic, clay undergoes a change in properties after being fired at high temperatures, becoming hard, strong, and resistant to pressure. This process is relevant to science topics on changes in matter, the physical and chemical properties of materials, and the effects of temperature on matter.

Furthermore, observations indicate that the bricklaying technique used in the Kudus Tower was carried out without the use of modern cement. The bricks are arranged in tiers in a specific, interlocking pattern, ensuring they can support the building's weight evenly. This arrangement demonstrates the application of the principles of compressive force, balance, and load distribution. The symmetrical shape of the building also plays a role in maintaining structural stability. This finding is closely related to the science concepts of force, object balance, and building structure, which can serve as a concrete example in science learning in Islamic school.

Observations also show that the Kudus Tower design takes the surrounding environment into account. The wall thickness, building height, and the porous nature of the red brick allow for good air circulation. This contributes to temperature regulation inside the building and reduces the impact of heat from the outside environment. These aspects relate to the science concepts of heat transfer, conduction, and convection, as well as the building's adaptation to tropical climates. Thus, the Kudus Tower demonstrates not only the sophistication of traditional building techniques but also the utilization of local knowledge about the environment.

Interviews with cultural sources provided more in-depth information about the red brick-making process and the techniques

used to build the Kudus Tower. The sources explained that the brick-making process begins with selecting clay with a specific texture and moisture content. The clay is then molded, dried in the sun until its moisture content is reduced, and fired in a traditional kiln at high temperatures. This process demonstrates a traditional understanding of the properties of materials and the effect of heat on material transformation. This knowledge is acquired through experience and observation of nature, reflecting the application of traditional science process skills.

The informant also explained that the bricklaying techniques and material selection for the Kudus Tower were intended to create a structure that could withstand tropical weather conditions, such as rain and intense heat. Understanding the environmental durability of materials was fundamental to the construction process. These findings demonstrate that communities in the past possessed adaptive and functional local knowledge, aligning with the natural science concept of the interaction between materials and the environment.

In addition to ethno-scientific values related to physical and material aspects, historical documentation shows the socio-cultural ethno-scientific values inherent in the Kudus Tower. One of the most prominent values is the value of tolerance taught by Sunan Kudus. The prohibition on cow slaughter for the Kudus community during Sunan Kudus's reign was a form of respect for Hindus, reflecting mutual respect in community life. This value demonstrates that local knowledge encompasses not only technical and material aspects but also social values that govern human relationships with others.

The value of tolerance can be viewed as part of social ethnoscience, as it relates to how communities manage social life harmoniously based on cultural and environmental understanding. In the context of science learning, this value can be integrated to strengthen students' character, particularly when discussing the relationship between science, technology, the environment, and society. Thus, science learning focuses not only on cognitive aspects but also on the formation of social attitudes and values. In addition, incorporating these values into classroom activities can foster

empathy, respect for diversity, and collaborative learning among students.

Photographic documentation of the Kudus Tower building demonstrates traditional construction details, such as relatively uniform brick sizes, distinctive brickwork patterns, and architectural designs reflecting cultural acculturation. Historical archives and local literature also confirm that the Kudus Tower holds a significant place in the lives of the Kudus community, both as a cultural symbol and as a center for disseminating the teachings of Sunan Kudus. Furthermore, this documentation provides visual and contextual evidence that supports the interpretation of ethnoscientific aspects embedded in the structure. This documentation data reinforces the findings of observations and interviews, thus providing a comprehensive picture of the ethno-scientific values embodied in the Kudus Tower.

Overall, the research results show that the ethnoscience values of Menara Kudus can be classified into several aspects, namely the physics ethnoscience values (force, balance, and structural stability), the chemistry ethnoscience values (changes in material properties due to brick firing), the environmental ethnoscience values (building adaptation to climate and environmental conditions), and the socio-cultural ethnoscience values (tolerance and social harmony). The diversity of ethnoscience values shows that Menara Kudus has great potential as a holistic science learning resource. Furthermore, these findings highlight the importance of integrating local wisdom into educational practices, particularly in science learning, as it allows students to connect scientific concepts with their cultural surroundings.

The findings of this study confirm that the Kudus Tower is not only rich in historical and cultural values, but also contains scientific values relevant to science learning in Islamic school. The integration of scientific and cultural values in ethnoscience-based science learning has the potential to provide more contextual, meaningful, and relevant learning to students' lives. Moreover, this approach can encourage students to develop a deeper appreciation of their cultural heritage while enhancing their understanding of scientific concepts. These research findings provide an important

foundation for the development of local wisdom-based science learning that can improve scientific literacy while strengthening the character of Islamic school students.

Table 1. Summary of the Results of the Kudus Tower Ethnoscience Findings and Their Relation to the Concept of Science

Aspect Ethnoscience Tower Holy	Findings Field	Relevant Science Concepts	Room Scope Science material
Red brick building materials	Red bricks come from fired clay. with temperature high so it is hard and durable	Physical and chemical changes, properties of materials	Substances and their changes, physical and chemical properties of materials
Making process traditional bricks	Land selection stages, printing, drying and baking	The effect of temperature on matter, changes in form and properties of matter	Substances and their changes, energy and heat
Bricklaying technique without cement	Bricks are arranged in interlocking and tiered layers without modern adhesives.	Pressure, balance, load distribution	Style and movement, balance of objects
Tower building structure	The building has stood strong and stable for hundreds of years.	Structural stability, resultant force	Building structure and function
Symmetrical building shape	Symmetrical building design maintains balance and structural strength	Balance n static, symmetry	Style and balance
Wall thickness and brick pores	Porous brick and thick walls help	Heat transfer (conduction and convection)	Heat and its transfer a

Aspect Ethnoscience Tower Holy	Findings Field	Relevant Science Concepts	Room Scope Science material
	air circulation		
Adaptation to tropical climate	Heat and rain resistant buildings	Interaction of materials with the environment	Environment and adaptation
Local understanding of	Material selection is adjusted	Material properties and durability	Simple materials science
material	with environmental conditions		
Tolerance value Sunan Holy	The prohibition on slaughtering cows as a form of respect between religious communities	Connection science, technology, and public (STM)	Science and social life
Local wisdom in social life	Social harmony and respect for cultural differences	Social science literacy and ethics	Character and culture based science

The research results show that the Kudus Tower possesses strong ethnoscientific elements, encompassing its materials, building structure, construction techniques, and the socio-cultural values prevalent in the community. This finding aligns with the view that local wisdom not only reflects tradition but also encompasses scientific knowledge that can be linked to modern scientific concepts. In the context of science learning, these ethnoscientific elements can serve as relevant and contextual learning resources to enhance conceptual understanding and strengthen students' scientific literacy.

From a material and structural perspective, the use of traditionally fired red bricks in the Kudus Tower demonstrates the physical and chemical changes occurring in clay. These concepts can be linked to science topics such as changes in form, material

properties, and thermal properties. The high-temperature firing of bricks demonstrates how heat changes the shape, strength, and color of materials, providing a concrete example of the concept of physical and chemical changes. The interlocking bricklaying technique, without the use of modern cement, demonstrates the application of the principles of force, pressure, and balance, which are related to the concepts of force and motion. This demonstrates that local knowledge has long utilized scientific principles, even if not couched in modern scientific terms.

Research findings also indicate that the architectural aspects of the Kudus Tower reflect the concepts of symmetry, stability, and proportionality, which can be explained through physics and mathematics (Husna & Munahefi, 2024). The tower's multi-tiered design demonstrates proportional load distribution, while the wall thickness serves to maintain the building's stability and durability. Integrating these elements into science learning can help students understand the relationship between scientific concepts and real-world objects, thereby enhancing critical thinking and problem-solving skills.

In addition to its scientific value, this study also found that the Kudus Tower contains socio-cultural values, particularly Sunan Kudus' teachings of tolerance. The values of tolerance inherited from Sunan Kudus, such as the prohibition on slaughtering cows as a form of respect for the Hindu community, demonstrate the relationship between cultural traditions and the formation of community character (Puspita & Pradisa, 2017). In the context of ethnoscience, this value of tolerance reflects that science does not stand alone but develops in a social environment characterized by moral and ethical values (Ornamen & Al, 2023). Integrating cultural values such as tolerance into science learning can strengthen students' character education, increase understanding of the relationship between science and society, and foster mutual respect for diversity.
(Kharis, 2020).

Thus, ethnoscience-based science learning not only enriches cognitive aspects but also strengthens affective and social aspects. Incorporating the ethnoscience values of Menara Kudus into science learning can result in more holistic, meaningful, and relevant learning

for Islamic schoolh students. This aligns with the goal of scientific literacy, which is not only understanding concepts but also being able to apply scientific knowledge in cultural, environmental, and social contexts (Husna & Munahefi, 2024). These results reinforce the idea that local wisdom such as Menara Kudus can be a strategic learning resource for improving scientific literacy while strengthening students' character through cultural values such as tolerance (Kota et al., 2021).

CONCLUSION

Based on the research results and discussion, it can be concluded that the Kudus Tower has very strong ethnoscience potential and is relevant for integration into Natural Science (IPA) learning in Islamic schools. The Kudus Tower not only serves as a historical building and cultural symbol, but also embodies various scientific values related to science concepts. These values encompass aspects of physics, chemistry, the environment, and socio-culture, which can serve as contextual learning resources for students.

The physical and chemical aspects are reflected in the use of traditionally fired red bricks, which demonstrate the process of changing physical and chemical properties, as well as modern cement-free construction techniques that apply the principles of style, balance, and structural stability. The environmental aspects are evident in the building's adaptive design to tropical climate conditions, such as wall thickness and material properties that support air circulation and temperature control. Meanwhile, the socio-cultural aspects are reflected in the value of tolerance inherited from Sunan Kudus, which demonstrates the relationship between science, culture, and the social life of the community.

These findings indicate that the integration of ethnoscience based on the local wisdom of Menara Kudus into science learning at Islamic schools has the potential to produce more contextual, meaningful, and holistic learning. Science learning not only focuses on mastering scientific concepts but also fosters scientific literacy, scientific attitudes, and student character through strengthening local cultural values. Therefore, Menara Kudus can be utilized as a strategic ethnoscience-based science learning resource to support

improving the quality of science learning and science literacy among Islamic school students.

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