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Reconstructing Indigenous Science into Scientific Knowledge of Materials and Sounds of Traditional Musical Instruments in Indonesia through the Science–Technology–Engineering -Mathematics (STEM) Approach

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Abstract

This research aims to integrate the indigenous knowledge of the Amanatun community in Indonesia regarding the materials used in the construction and the sound properties of traditional drum instruments (gendang) into the domain of scientific knowledge through a STEM (Science, Technology, Engineering, and Mathematics) approach. The findings of this study serve as a STEM learning resource, enabling educators to design innovative and contextually relevant teaching methods. The research methodology employed a qualitative ethnoscience approach, utilizing data collection techniques such as observation, interviews, and documentation. The primary focus of the study was on the raw materials used in gendang production and the characteristics of the sound frequencies produced. The collected data were analyzed, verified, and synthesized within the context of scientific knowledge, and subsequently interpreted to derive meaningful insights. The reconstruction of scientific knowledge from this research encompasses concepts related to plant and animal taxonomy, the relationship between material density and sound frequency, and the correlation between frequency and the dimensions of the gendang. These findings have the potential to serve as a valuable teaching resource for understanding stationary waves within the STEM framework. This research represents a crucial step in preserving traditional knowledge and enriching scientific education within a local context.

Keywords: Indigenous science, Scientific knowledge, STEM, Standing wave

1. Introduction

In the current era of the 5.0 industrial revolution, information and communication technology has significantly impacted society's preparedness to face future challenges. Therefore, communities must develop 21st-century competencies such as critical, creative, collaborative, and communicative thinking, as well as problem-solving skills, all of which can be honed through the learning process (Larson & Miller, 2011; Wrahatnolo & Munoto, 2018).

Technological advancements have also led to a decline in the understanding of local wisdom in various regions (Komariah & Asyahidda, 2020). Consequently, the integration of local wisdom into school education has become imperative. This not only helps students compete globally but also preserves and nurtures local culture and potential (Nelisa et al., 2020). Nonetheless, there is a research gap in reconstructing traditional community knowledge into scientific knowledge that can be used as a learning resource in physics.

The development of contextual and interactive physics learning media can be achieved through the reconstruction of scientific knowledge from traditional community knowledge (Shofa et al., 2021). This effort aims to sustain the culture and traditions of communities while understanding their authentic knowledge (Ristiani, 2020). For example, the traditional drums (gendang) in the Timor tribe in Indonesia can be reconstructed to comprehend the materials and sound produced, which are integral aspects of local knowledge that can be integrated into modern science.

Innovation and contextualization of physics concepts with students' culture are crucial as they provide a deeper understanding of physics concepts. Previous research has shown that physics is often challenging to grasp because its its concepts lack direct analogies to everyday life (Fotou & Abrahams, 2020) (Ugur et al., 2012). Abstract physics concepts

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often involve paradoxes, antinomies, and complex mathematical equations (Borghi et al., 2017). Therefore, abstract physics learning requires visualization and analogies relevant to everyday life to facilitate comprehension (Didiş Körhasan & Hldlr, 2019). A relevant example is the consideration of sound waves, which are often seen as abstract physics concepts that are difficult for students due to complex mathematical equations and visualization challenges (Kanyesigye et al., 2022).

The development of contextual and interactive physics learning media can be realized through the reconstruction of scientific knowledge from traditional community knowledge. This effort aims to preserve the culture and traditions of the community while understanding their original knowledge. This approach can be implemented through STEM (Science, Technology, Engineering, Mathematics), which integrates original scientific knowledge into modern science with the goal of training 21st-century skills for students (Nugroho et al., 2019) (Sumarni et al., 2022). Thus, this approach remains relevant in the context of current science education.

This research aims to reconstruct community knowledge into scientific knowledge from the materials and sounds of traditional drum instruments (gendang), analyze the drum's sound frequencies, and map basic competencies in physics or science that can be integrated with local wisdom using the STEM approach.

2. Materials and Methods

This research was conducted in the village of Meusin, Boking sub-district, involving two traditional drum instrument makers. This particular hamlet was chosen due to its adherence to ancestral traditions and customs, including the preservation of the traditional drum instrument, gendang. The gendang is frequently used by the indigenous community as an accompanying musical instrument for the Amanatun likurai dance during traditional ceremonies and guest receptions.

The research methodology employed a qualitative ethnoscience approach, which involves the study of organized cultural systems within the knowledge of indigenous communities (Battiste, 2005)(Sumarni et al., 2016). The reconstruction of indigenous community knowledge focused on the primary materials used in gendang production, as well as the measurement and analysis of sound frequencies produced by the drum instrument. Data collection techniques included observation, documentation, discussions, interviews, and measurements of gendang dimensions and sound frequencies. Gendang sounds were recorded using a smartphone and subsequently analyzed using Audacity software installed on a laptop. In this study, the researcher served as the primary instrument, thus validating the data through participatory observation, data, and method triangulation, and a comprehensive literature review was essential.

3. Results and Discussion

Interviews with craftsmen were conducted to determine the types of materials used in the process of making the drum instrument. Two craftsmen were interviewed in the village of Meusin, Boking sub-district, East Nusa Tenggara, Indonesia. The craftsmanship of traditional gendang instruments has been passed down through generations from their ancestors. Figure 1 depicts the child of one of the craftsmen playing the gendang musical instrument.

Fig. 1 The craftsman's child is playing the traditional gendang musical instrument

Fig. 2 The type of seaweed stem used to make the drum

The results of the exploration of indigenous knowledge of the gendang-making process, which has been reconstructed into scientific knowledge, are presented in Table 1.

Table 1 Reconstructing original community knowledge into scientific knowledge

No.	Research Question Contains Scientific Concepts	Indigenous Science	Scientific Knowledge
1	What type of wood is used to make drums?	M1 and M2: The type of wood used is *ek fui* (local language), which in Indonesian is called pandan laut	The sea pandan is classified in the Pandanaceae family, as an angiosperm with the following taxonomy: **Kingdom** : Plantae **Order** : Pandanales **Family** : Pandanaceae **Genus** : Pandanus **Species** : *P. odorifer* **Scientific concept**: Characteristics and taxonomy of plants
2	Why choose this type of wood?	M1, M2: because this wooden stick is easy to shape.	Wood types that are easy to shape have a lower wood density. Wood types selected with lower wood density tend to be lighter. **Scientific concept**: density, the relationship between density and sound frequency
3	What type of animal skin is used to make drums (gendang)?	M1, M2: The type of animal skin used is goat skin.	Goats are a type of mammal with the classification of goats: **Kingdom**: Animalia **Phylum** : Chordata **Class** : Mammalia **Order** : Artiodactylia **Family** : Bovidae **Genus** : Capra **Species** : Capra aegagrus **Science Concept**: Characteristics and Taxonomy of Animals
4	Why use goat skin?	M1, M2: because goat skin is thinner, stiffer, and easier to install	The goat skin has good strength and durability against strikes and vibrations when the drum is played, the goat skin is elastic so it contracts well when the drum is struck, and the skin vibrates freely with a rich and diverse sound, resonating with specific frequencies. **Science concept**: stationary wave vibrations, elasticity frequency

Based on Table 1, the identified physics concepts from the drum musical instrument are the concepts of plant and animal characteristics and taxonomy, the concept of the relationship between frequency and the density of the material, and the concept of material elasticity, and vibration. The frequency analysis technique of the drum was conducted using a smartphone. The sound was recorded and then analyzed using Audacity software. Below are the results of the analysis of the drum sounds recorded from four different drums with varying lengths.

Fig. 3 Dimensions of the drum

Data pengukuran diameter dan suhu gendang dengan ukuran berbeda

No	Jenis gendang	L (cm)	dt (cm)	db (cm)	Temperature (℃)
1	1	47,8	19	8	22,4
2	2	38,3	12	5	25,3
3	3	58	19,5	8,1	24,5
4	4	42	14,2	7	24,4

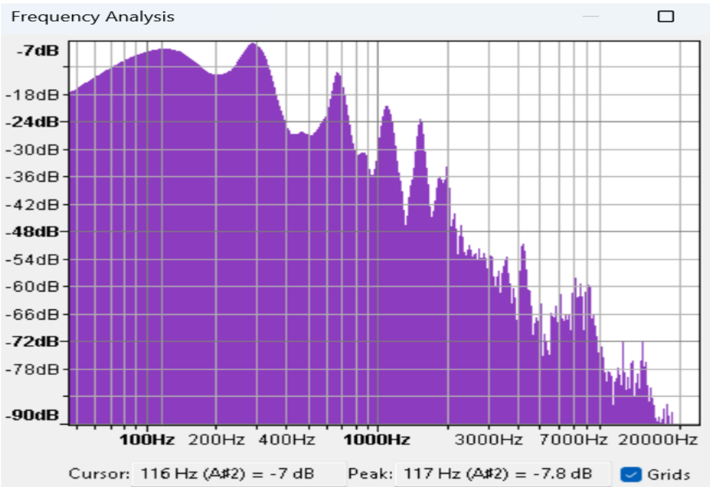


Fig. 4 Results of the sound spectrum analysis of drum 1 with L = 38.3 cm

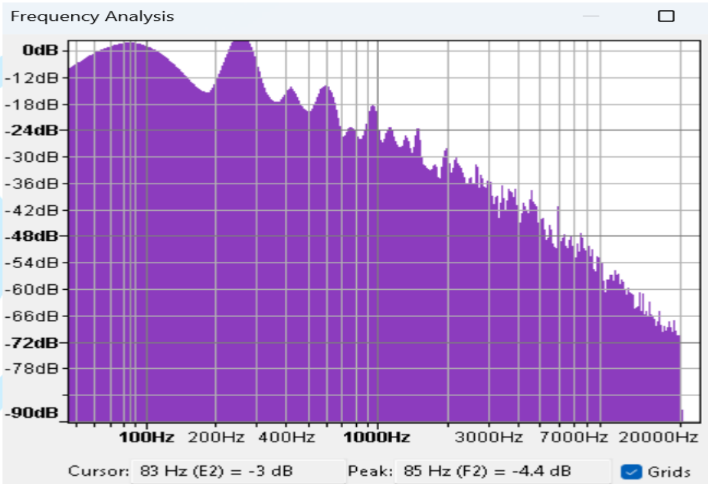


Fig. 5 Results of the sound spectrum analysis of drum 2 with L = 42 cm

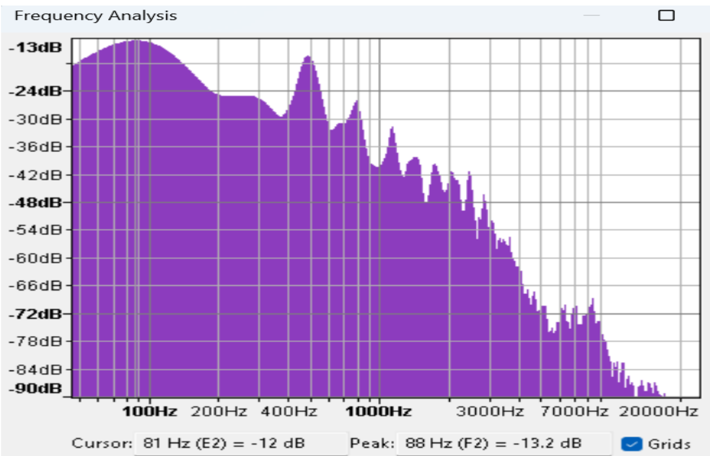


Fig. 6 The result of the sound spectrum analysis of drum 3 with L = 47.8 cm

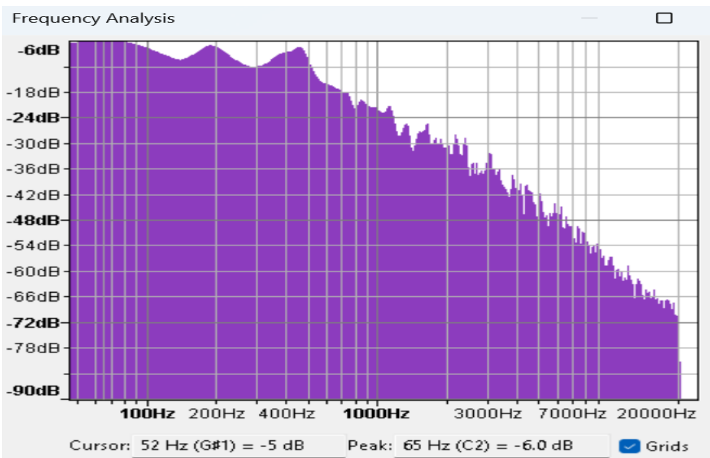


Fig. 7 The result of the sound spectrum analysis of drum 3 with L = 58 cm

Table 2 Measurements of drum length and drum frequency

Types of drums	L (cm)	f (Hz)	dt (cm)	db (cm)
1	38,3	116	12	5
2	42	83	14,2	7
3	47,8	81	19	8
4	58	52	19,5	8,1

Based on Table 2, it can be concluded that the frequency of drum sounds is inversely proportional to the length of the drum. The higher the drum's frequency, the shorter the drum's length, and the lower the frequency of the drum sound, the longer the drum's length. In other words, frequency is inversely related to the wavelength of sound.

Based on the analysis of the material and the frequency of drum sounds, several natural sciences concepts can be identified that can be constructed in scientific science. These concepts include the characteristics and taxonomy of animals and plants, the relationship between the density of drum material and the frequency of sound, the relationship between the elasticity of the material and the frequency of sound, and the relationship between wavelength and frequency of sound.

The integration of natural sciences into society can be achieved through the integration of these concepts into middle school science and high school physics education, as indicated in Table 3 and Table 4 for the respective competency standards.

Table 3 The relationship between sound frequency, drum material, and drum length with basic competence

No	Competency standards	The scientific concept of traditional musical instrument drums
1	To apply the concepts and principles of sound and light waves in technology	Relationship between frequency, wavelength, and material density, through measurements of drum length and frequency using Audacity.
2	Identifying the characteristics of living and non-living things among objects and living creatures in the surrounding environment	• The concept of high-level plant classification regarding seagrasses • The concept of animal classification

Table 4 Relationship between basic competencies and the scientific concept of drum musical instruments

No	Competency standards	The scientific concept of traditional musical instrument drums
1	To analyze the physical quantities of traveling waves and stationary waves in various real-life cases.	To determine the frequency of sound, the wavelength of the stationary wave on the drum's sound wave pattern
2	To conduct experiments on traveling waves and standing waves, along with presenting the experimental results and their physical significance.	Experiment on the relationship between sound frequency and wavelength in the traditional drum musical instrument.

Table 5 The form of STEM-integrated physics learning with traditional drum musical instruments

Competency standard

1. Analyzing the physical quantities of traveling waves and stationary waves in various real-life cases.
2. Analyzing the physical quantities of traveling waves and stationary waves in various real-life cases.

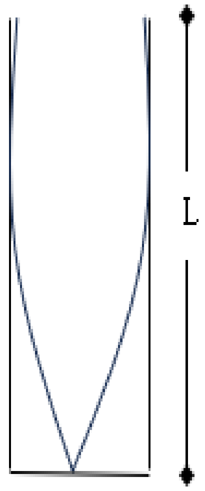
Framework for STEM learning approach

Science:

Factual: To investigate the relationship between sound frequency and the length of an open organ pipe in the pattern of stationary waves..

Conceptual

The relationship between the frequency and wavelength of open organ pipes.



Wave patterns in an organ pipe when resonance occurs at the fundamental frequency n = 1.

$$L = \frac{1}{4}\lambda$$

Velocity of wave sound in the air:

$$v = \lambda f = 4Lf$$

$$f = v\frac{1}{4L}$$

Where: f = frequency (Hz), L = length of the air column (m), v = speed of sound (m/s). Therefore, frequency is inversely proportional to the length of the organ pipe's air column. Assuming the drum acts as an open organ pipe, the hypothesis is: that the frequency of the drum sound is inversely proportional to the length of the drum.

Technology

- Investigating standing wave patterns through the virtual laboratory 'go labs,' which is accessible at the link: https://gateway.golabz.eu/os/pub/physics-bu/speed_of_sound/w_default.html
- Analyzing drum frequencies using Audacity software.

Engineering
To investigate the basic materials for making drums with sound frequency.
Mathematics
To calculate the wavelength, frequency, and speed of sound propagation using the pattern of standing waves in an organ pipe.

The analysis of the reconstruction of indigenous community knowledge regarding the selection of materials and drum frequency indicates that this knowledge remains intact. Therefore, this knowledge can serve as a source of scientific learning, especially in STEM approaches. Studies conducted by Sudarmin et al. (Sudarmin et al., 2020) demonstrate that the Ethno-STEM approach can enhance students' creativity, innovation, and entrepreneurial character.
The preservation of this indigenous knowledge continues because they acquire it through life experiences, using trial and error methods. Despite ongoing technological advancements, the community's way of thinking and beliefs will be passed down from generation to generation.

The integration of science or physics curriculum is crucial in adopting this Ethno-STEM approach. This not only provides meaningful learning for students (Aderonmu, Temitope S. B Adolphus, 2021)(Atmojo et al., 2019) but also enhances learning outcomes and scientific literacy (Suryanti et al., 2021)(Setiawan, 2023). Additionally, it helps students understand and appreciate culture, and promotes tolerance, and nationalism based on the spirit of "bhineka tunggal ika" (Dewy et al., 2022). This learning also contributes to the development of critical and creative thinking skills (Ariyatun, 2021), scientific process skills, and improves the quality of education, as well as encourages student self-learning (Iskandar et al., 2022).

In this context, the student learning environment and the culture of where they live are crucial. Therefore, teachers should connect the learning material with the students' environment and culture. Integrating cultural aspects into science or physics education facilitates the understanding of physics concepts that can be related to everyday life. Moreover, science education is not just about scientific knowledge but also involves the values of local wisdom in the community. Therefore, social and cultural environmental aspects should be seriously considered in science or physics education to ensure that students not only understand the physics aspects but also actively participate in preserving their culture (Aderonmu, Temitope S. B Adolphus, 2021).

7. Conclusions

The research results show that the indigenous knowledge of the Amanatun people regarding the materials and sounds of traditional musical instruments can be integrated into the context of scientific knowledge, which can be a valuable science (physics) learning resource for students. Therefore, teachers need to design and develop science (physics) material that is relevant to local culture in society, as well as connecting students' concepts, processes, and contexts. It is hoped that this will increase students' understanding of natural phenomena better, according to their context, and have meaning.

To optimize this approach, it is recommended to continue research in developing worksheets and natural science (physics) teaching material s that include the integration of the traditional Amanatun drum musical instrument. In this way, students can be more involved in learning that is relevant to their culture, which will have a positive impact on their understanding of science (physics).

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Declaration of Conflict

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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