SCIENCE : Jurnal Inovasi Pendidikan Matematika dan IPA
Vol. 4 No. 4 November-Desember 2024
E-ISSN : 2797-1031
P-ISSN : 2797-0744
Online Journal System : https://jurnalp4i.com/index.php/science

EXPLORING OF PHYSICS CONCEPTS OF "SOUND WAVES" IN THE MORONENE TRIBE'S TAMBURU MUSICAL INSTRUMENT AS A PHYSICS LEARNING MATERIAL

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ABSRACT
This research investigates the physics concepts embedded in the traditional musical instrument "Tamburu" of the Moronene tribe in Southeast Sulawesi, Indonesia. The Tamburu, a traditional plucked string instrument made from layers of bamboo bark, serves as a fascinating case study for exploring physics concepts. The research aims to uncover the connections between the physics concepts applied to this traditional cultural instrument. The methodology combines observational analysis, video recording, and theoretical physics calculations to provide a comprehensive understanding of the sound waves involved in the Tamburu. The results reveal intricate connections between interrelated physics principles, demonstrating how traditional local wisdom can provide explanations for complex scientific knowledge. The research found several connections between physics concepts in the Tamburu, including the concept of sound sources, types of sound waves, frequency, tone (timbre), resonance, and open organ pipes. This research not only highlights the significance of the local culture of the Tamburu but also emphasizes its potential in the field of education as a means of teaching and understanding physics in real-world contexts. This research seeks to integrate the heritage of local wisdom into the educational framework to enrich learning experiences and introduce a deeper appreciation for indigenous knowledge systems.
Keyword: Physics Consept, Tamburu, Sound Wave, Local Wisdom

INTRODUCTION
As the largest archipelago nation in the world with over 17,508 islands, Indonesia boasts an extraordinary cultural richness. The presence of 1,328 ethnic groups with diverse languages, arts, and traditions makes Indonesia one of the most culturally diverse countries in the world (Hakim & Darojat, 2023; Nofrizal et al., 2024). Each ethnic group in Indonesia possesses unique cultural identities and local wisdom, reflected in their languages, customs, and values (Husna et al., 2022; Febrianty et al., 2022). This cultural diversity and local wisdom are national treasures rarely found in other countries (Mayasari, 2017; Luthfia & Dewi 2021; Nurhidayah et al., 2022). The local wisdom inherent in each region mirrors the identity and character of its people (Naqiyah et al., 2019; Saminan et al., 2024). The cultural values embedded within have been passed down through generations and have become an integral part of people's lives (Rahmasari & Kuswanto, 2023; Damopolii et al., 2024). By studying local wisdom, students can develop a broader understanding of their regional cultural identity, including its potential and strengths (Elisa et al., 2022; Uyun et al., 2024). Although often marginalized by the passage of time, local wisdom has great potential to be used as a learning resource integrated into physics education (Naqiyah et al., 2019; Kang et al., 2022). Based on the aforementioned explanation, it can be concluded that Indonesia possesses a wealth of local wisdom as a form of national identity, which can be utilized and integrated into physics education.

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The integration of local wisdom is deemed suitable for application in physics education. Indonesia's diverse local wisdom can serve as a bridge for students to comprehend abstract physics concepts (Sriwahyui, 2024; Suprapto et al., 2021). By connecting physics theories with existing practices in society, physics learning can become more engaging and meaningful (Febrianty et al., 2023; Habibi et al., 2020). Physics learning not only requires students to possess observation, manipulation, and calculation skills but also compels them to develop critical thinking abilities when facing various problems (Astuti et al., 2022). Learning that connects subject matter to real-life contexts, as promoted in contextual learning approaches, can produce a deeper understanding in learners (Lestari et al., 2022). By integrating local culture into physics learning, students' perception of physics can shift from merely a collection of formulas and theories to a science that is relevant to everyday life (Sari et al., 2019). Based on the aforementioned explanation, it can be concluded that learning directly linked to concrete facts found in local wisdom can make the understanding of physics concepts more engaging and profound for learners.

One integration of local wisdom in physics learning is through traditional musical instruments related to sound. There are several traditional arts, such as bamboo or wooden musical instruments, in Bombana Regency, Southeast Sulawesi Province. One example of local wisdom that can be integrated with physics is the traditional "Tamburu" musical instrument of the Moronene tribe, a cultural heritage that has become an integral part of the Moronene tribal cultural identity. This musical instrument is a distinctive art of Bombana Regency and the Moronene tribe, but it is currently being forgotten by the community. Therefore, it is necessary to revisit the discussion of the Tamburu musical instrument. The Tamburu is a tubular instrument made from a section of bamboo played by plucking strings made from bamboo skin. The type of bamboo used is the thorny bamboo specific to Moronene, known as "tari". The preferred variant of thorny bamboo (tari) is the one that grows in the mountains and is exposed to a lot of wind. The Tamburu is usually played at traditional events or during leisure time, and it is more commonly played by women, usually alone without accompaniment. From a cultural perspective, the Tamburu is rich in historical and social values. The Tamburu involves a person plucking the strings, producing a variety of sounds that can help students understand physics concepts such as sound waves. Furthermore, the variation in hand movements, opening and closing the hole at the middle end of the bamboo, indicates the physics concept of a closed organ pipe. A comprehensive study of physics concepts in local wisdom, especially in traditional musical instruments, has not been widely conducted.

Integrating the concepts of physics with local wisdom and culture provides a new perspective that enriches students' understanding of the Tamburu musical instrument from Bombana, while demonstrating how scientific principles are embedded in the daily practices of traditional societies. Therefore, this study aims to investigate the physics concepts related to the local wisdom of the "Tamburu" musical instrument among the Moronene tribe and to evaluate the potential of using this musical instrument as a more diverse and relevant source of physics learning.

METHOD

This research employs a qualitative research method, with a focus on narrative data analysis. The objective is to investigate physics concepts related to the local wisdom of the "Tamburu" musical instrument among the Moronene tribe and to evaluate the potential of using this musical instrument as a more diverse and relevant source of physics learning. This research was conducted through observational analysis, video recordings, and in-depth interviews at the location of the "Tamburu" musical instrument in Bombana Regency. The collected data was then analyzed narratively to describe events and occurrences related to the tradition. By utilizing

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a qualitative research method, this research provides a deeper and more detailed understanding of the local wisdom of the "Tamburu" musical instrument and how related physics concepts can be used as a more diverse and relevant learning source.

RESULTS AND DISCUSSION

Bombana Regency boasts a variety of traditional musical instruments, one of which is the tamburu. The tamburu is a musical instrument made from a section of bamboo, with strings formed from the bamboo skin itself. Tari bamboo, a type of thorny bamboo native to the Moronene region, is the most commonly used raw material. Tari bamboo that grows in mountainous areas and is frequently exposed to wind is considered to have better flexibility. The tamburu is made while the bamboo is still fresh so that the skin can be more easily separated and formed into strings. This musical instrument typically has four strings, with two strings on each side connected by a wooden plate.

Both ends of the bamboo section are covered with rattan bindings or similar materials to secure the strings and prevent them from coming loose. Once dry, the taut strings are then adjusted in tension using small pieces of wood. In the middle of the tube, there is a square hole that acts as a sound resonator. Meanwhile, one end of the bamboo section is equipped with a round hole to produce variations in tone. The tamburu is often played as an accompaniment in various events or as personal entertainment, generally by women. This musical instrument is usually played solo without accompaniment from other instruments. The size of the tamburu can be adjusted to suit the player and the desired pitch. There is also a longer variation of the tamburu with one open end, played with a combination of plucking the strings and striking the bamboo cavity. For a clearer illustration, please refer to Figure 1.

Figure 1. Tamburu Musical Instrument
(Source: Rigal Picture)

The obtained research results are tabulated in Table 1 below:

Tabel 1. Identification of Physics Concepts in the Tamburu Musical Instrument

No	Overview of Tamburu	Physics Concepts	Description
1	Tamburu Strings	Sound Source	• The strings: When plucked, the strings of the tamburu undergo mechanical vibrations, which are then transmitted through the

			instrument's body, resulting in the production of audible sound waves. • Bamboo Cavity: The hollow bamboo cavity functions as a resonator, amplifying the vibrations produced by the strings and modifying the tonal quality of the sound. • Mechanical Waves: The vibrations produced by the strings create disturbances in the air particles within the bamboo cavity, resulting in the propagation of mechanical waves, or sound waves. • Longitudinal Waves: Sound waves are characterized by longitudinal vibrations, where the compressions and rarefactions of the medium (air) occur in the same direction as the wave's movement.
2	String Size, Tension, and Mass	Frequency and Pitch	• String Length: The length of a vibrating string determines the wavelength of the standing wave produced. Shorter strings produce shorter wavelengths, corresponding to higher frequencies and pitches. • String Tension: The tension applied to a string increases the restoring force acting on the vibrating segments, leading to higher frequencies of vibration. • Linear Density: The linear mass density of a string, which is the mass per unit length, influences the wave speed on the string. A higher linear density results in a lower wave speed, and consequently, a lower fundamental frequency.
3	Bamboo	Resonance	• The type of bamboo: used also influences the tone color, as the acoustic properties of each bamboo species vary. • Bamboo Cavity: The bamboo cavity acts as a resonator. When the vibration frequency of the string matches the natural frequency of the bamboo cavity, resonance occurs. This resonance amplifies the

			amplitude of the sound waves, resulting in a louder tamburu sound. • Holes in the Bamboo: The holes in the bamboo also influence the resonance and timbre of the produced sound.
4	Tamburu's voice	Sound Color (Timbre)	• Waveform: The sound color of the tamburu is influenced by the complex waveform, consisting of the fundamental frequency and its harmonics. Harmonics are integer multiples of the fundamental frequency. • Bamboo Cavity as a Pipe: The bamboo cavity of the tamburu can be considered as a pipe. When the string is plucked, its vibrations cause the column of air inside the bamboo cavity to vibrate as well.
5	The technique of opening and closing the tamburu's holes with the fingers	Open Organa Pipe	• Standing Waves: The vibrations in this air column will form standing waves. Standing waves occur when incident and reflected waves interfere, creating a wave pattern with constant amplitude at specific points. • Open Ends: Both ends of the bamboo cavity are typically open (not closed). This open-ended condition is characteristic of open organ pipes. In open organ pipes, a node of the wave is always formed in the middle of the pipe, while antinodes are always formed at both ends of the pipe.

When examining the tamburu while it is being played, many basic physics concepts can be identified. The most relevant topics are sound waves, particularly those related to strings and open-ended organ pipes.

A sound source is defined as anything that can produce vibrations that then propagate through a medium (in this case, air) and can be heard (Johansson & Wesberg, 2024). In the tamburu, the primary sound source is the string. The process of sound production in the tamburu involves: 1) Plucking: When the tamburu string is plucked, it vibrates. This vibration is mechanical energy that is then transferred to the surrounding medium, which is air (Batlolona & Jamaludin, 2024). 2) Sound Waves: The vibrating string creates pressure waves in the air. These pressure waves travel in all directions, including towards the listener's ear (Naqiyah et al., 2019). 3) Audible Sound: When the pressure waves reach our ears, the eardrum vibrates, and this vibration is transmitted to the auditory nerve, allowing us to perceive sound (Batlolona & Jamaludin, 2024). Therefore, it can be said that the string is one of the most ideal sound

sources. The reasons for the string being an ideal sound source are: 1) Elasticity: Strings are made of elastic materials, such as nylon or metal (Gulo & Panuluh, 2020). This elasticity allows the string to return to its original shape after being stretched or pressed, resulting in sustained vibrations (Sulaeman, 2018). 2) Tension: The tighter the string is pulled (the higher the tension), the higher the frequency of vibration produced, resulting in a higher pitch (Giancoli, 2001). 3) Length: The length of the string also affects the frequency of vibration. A shorter string produces a higher frequency (Crowell, 2006). A ccording to Halliday et al (2010), identified the following factors that affect the pitch of a string: 1) String length: Shorter strings produce higher pitches. 2) String tension: Higher tension produces higher pitches. 3) String thickness: Thicker strings produce lower pitches. 4) String material: The material of the string also affects the timbre (tone color) of the sound produced.

Sound waves in the tamburu are produced when the string is plucked, causing vibrations that propagate through the air as sound waves. These sound waves have specific characteristics that make them sound unique and distinctive. The characteristics of the resulting waves are: 1) Mechanical Waves: The sound waves produced by the vibrating string are classified as mechanical waves (Crowell, 2006). This means that these waves require a medium to propagate, in this case, air. If there were no air, the sound of the tamburu would not be heard. 2) Longitudinal Waves: Sound waves propagate longitudinally, meaning the direction of vibration of the medium's particles (air) is parallel to the direction of wave propagation (Giancoli, 2001). Imagine compressing a slinky (a spring toy); the spring will lengthen and shorten alternately in the same direction as the push. The same thing happens to air particles during sound waves.

Frequency and pitch are two closely related concepts in music, especially in instruments like the tamburu. Frequency determines the highness or lowness of a note, while pitch is the auditory sensation produced by a sound wave of a particular frequency (Young & Freedman, 2016). Frequency is the number of complete vibrations that occur in one second (Halliday et al., 2010). High frequency produces a high (sharp) pitch, while low frequency produces a low (flat) pitch. In the tamburu, frequency is determined by the length of the string, the tension of the string, and the linear density of the string. Besides frequency, another related concept is amplitude. Amplitude is the maximum displacement of a point from its equilibrium position (Halliday et al., 2010). Amplitude determines the loudness of a sound. The greater the amplitude, the louder the sound produced (Crowell, 2006). In the tamburu, amplitude is influenced by the force with which the string is plucked by the musician. Furthermore, there is the concept of wavelength, which is the distance between two points that are vibrating in phase. Wavelength is inversely proportional to frequency. The higher the frequency, the shorter the wavelength (Giancoli, 2001). Then there is the concept of the speed of sound, which is the distance traveled by a wave in one unit of time. The speed of sound is influenced by the properties of the medium through which it travels. In air, the speed of sound is affected by temperature and air pressure.

Resonance in the tamburu plays a crucial role in producing rich and characteristic sound. Resonance is defined as a phenomenon where an object begins to vibrate with a large amplitude when subjected to vibrations with a frequency equal to the natural frequency of that object (Hamdani, 2020). Resonance occurs in the tamburu due to several events, including: 1) String vibration: When the tamburu string is plucked, it vibrates at a specific frequency. 2) Energy transfer: This string vibration transfers energy to the surrounding air and to the body of the tamburu (especially the bamboo cavity). 3) Bamboo cavity resonance: When the frequency of the string vibration is equal to or close to the natural frequency of vibration of the air in the bamboo cavity, resonance occurs. The air inside the bamboo cavity will vibrate with a much larger amplitude. Then, 4) Sound amplification: This amplified air vibration produces a louder and clearer sound. The role of the bamboo cavity is as a resonator. The bamboo cavity will

select and amplify specific frequencies that correspond to its size and shape. These frequencies are called resonant frequencies (Crowell, 2006). Factors affecting resonance in the tamburu: 1) Size and shape of the bamboo cavity: This will determine the resonant frequency. Longer bamboo cavities generally produce lower resonant frequencies. 2) Number and size of holes: The holes in the bamboo can change the effective length of the air column in the bamboo cavity, thus affecting the resonant frequency. 3) Material of the tamburu: The material used to make the tamburu can also affect the quality of resonance.

Timbre, or tone color, is the unique quality of a sound that distinguishes it from other sounds, even if they have the same pitch and intensity. In the tamburu, timbre is determined by the combination of the fundamental frequency and its harmonics. Harmonics are integer multiples of the fundamental frequency (Young & Freedman, 2016). Harmonics contribute to the color or character of a sound. The more numerous and complex the harmonics, the richer and more unique the tone color (Giancoli, 2001). Factors affecting the timbre of the tamburu include: 1) Material of the tamburu. 2) Shape and size of the bamboo cavity. 3) Tension and type of string, and 4) Plucking technique. Therefore, it is essential to note that playing the tamburu should not be done carelessly. When observed comprehensively and in detail, the tamburu offers a significant connection to basic physics concepts. As such, it can serve as a new learning resource by utilizing local wisdom.

The concept of open organ pipes and the bamboo cavity in a tamburu can be considered as a complex open organ pipe, thus making the tamburu similar to an open organ pipe. An open organ pipe is a column of air that is open at both ends (Agustin et al., 2023; Fitriyani & Andryani 2023). When the air in this air column is vibrated, standing waves are formed (Crowell, 2006). These standing waves produce specific tones that depend on the length of the air column. The application of open organ pipes in the tamburu occurs when the tamburu string is plucked, and its vibrations propagate into the air inside the bamboo cavity. Then, the air vibrations inside the bamboo cavity form standing waves. The antinodes (points of maximum amplitude) are always at the ends of the bamboo cavity (because it is open), while the nodes (points of minimum amplitude) are in the middle of the bamboo cavity or between the holes in the bamboo (Young & Freedman, 2016). The holes in the bamboo tamburu play a very important role in producing a variety of tones. By closing or opening these holes, the effective length of the air column can be changed, thus changing the frequency of the produced tone (Giancoli, 2001). Closing a hole will shorten the effective air column, so the frequency of the produced tone will be higher. While opening a hole will lengthen the effective air column, so the frequency of the produced tone will be lower.

CONCLUSION

The utilization of the tamburu musical instrument as a learning medium goes beyond merely introducing physics concepts; it also provides a more meaningful learning experience. By involving students in the process of making or modifying musical instruments, critical thinking, creativity, and problem-solving skills can be honed. Additionally, culture-based learning like this can also enhance a sense of love for the nation's cultural heritage. This research reveals the enormous potential of the tamburu as a bridge between natural sciences, especially physics, and local cultural richness. An in-depth analysis of this musical instrument reveals various physics principles behind the beautiful sound it produces. The physics material found in the stages of playing this musical instrument is the material of sound waves, which consists of the concepts of sound sources, types of sound waves, frequency, tone (timbre), resonance, and open organ pipes. Thus, physics learning can be done in a more interactive and enjoyable way, where students not only passively receive information but are also actively involved in the process of investigation and exploration. The integration of science and culture not only

enriches students' understanding of physics concepts but also cultivates curiosity, creativity, and appreciation for cultural diversity. The tamburu musical instrument should be utilized as a learning resource or, in the future, can be developed into teaching materials based on local wisdom.

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