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# Ethnophysical Analysis of Sigale-Gale Statue Performance as Physics Learning Resources

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**Abstract**

Physics learning is often perceived as challenging by students due to the abundance of formulas and abstract theories, as well as the lack of contextual learning resources. One approach that can be implemented to enhance students' interest and understanding is integrating local wisdom into physics learning through ethnophysics. This study aims to identify physics concepts in the Sigale-Gale puppet performance in North Sumatra and to analyze how the ethnophysical approach can be utilized to create more contextual and meaningful learning experiences. This research serves as an initial study of North Sumatran cultural performances in the context of physics. The method used is qualitative, in the form of a literature review. The results indicate that the Sigale-Gale performance encompasses various physics concepts, such as sound waves produced by gondang musical instruments, and the principles of motion, levers, balance, and acceleration embedded in the puppet's mechanism. By applying the ethnophysical approach, students can gain a more tangible understanding of physics while also helping to preserve local culture. These findings can serve as a foundation for developing lesson plans (RPP) based on local culture, making physics learning more enjoyable, interactive, and meaningful.

**Keywords**: Ethnophysics; Local wisdom; Physics learning; Sigale-gale; Qualitative analysis.

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## INTRODUCTION

Physics is widely recognized as a complex and challenging subject for many students, largely due to its reliance on abstract theories and a multitude of formulas. Despite its significant role in technological advancement and its relevance to real-world applications, physics remains one of the least favored subjects among students. This lack of enthusiasm often results from difficulties in relating physics concepts to daily life and a scarcity of contextual learning resources (Sumarni et al., 2023). Consequently, student interest and academic achievement in physics across various educational levels tend to be low.

Several studies have confirmed that students frequently struggle to understand physics materials, which are commonly perceived as abstract and disconnected from their lived experiences. In addition to the inherent difficulty of the subject, a notable limitation is the lack of engaging and culturally relevant learning resources. This shortcoming contributes to students' anxiety and aversion toward physics, ultimately affecting their motivation and performance in the subject. To address this issue, innovative strategies are needed to renew the delivery of physics education. One such strategy is integrating local wisdom into the learning process through an approach known as ethnophysics (Sumarni et al., 2023).

Local wisdom, as an expression of cultural heritage, serves as a defining identity for a community or region. It refers to practices and beliefs that are collectively upheld by members of a society and typically passed down through generations. Nearly every region possesses unique cultural elements that can be harnessed to contextualize science education. Ethnophysics, in this context, offers a promising pedagogical approach by connecting physics concepts with traditional cultural practices. This method emphasizes the interaction between cultural knowledge and scientific principles, making learning more relatable and grounded in students' everyday experiences.

Ethnophysics-based learning transforms the traditional teacher-centered classroom into a student-centered learning environment. Such a shift empowers students to engage more actively in the learning process, allowing them to appreciate their own culture while also developing scientific understanding. By embedding physics in cultural narratives and practices, students experience a learning atmosphere that is contextual, meaningful, and enjoyable (Astuti & Bhakti, 2021).

Furthermore, culturally based instruction encourages students to explore and better understand their own cultural background. Cultural education, particularly when it includes traditional arts, rituals, and local knowledge systems, is not only an educational tool but also a form of identity preservation. Recognizing culture as an essential part of educational expression and communication fosters a holistic learning process that integrates knowledge development with cultural appreciation (Astuti & Bhakti, 2021).

Indonesia, with its diverse and rich cultural heritage, provides ample opportunities for implementing ethnophysics in education. As a Southeast Asian country with a wealth of traditional customs, languages, ethnic groups, and dances, Indonesia's cultural assets can serve as powerful educational resources. Among these is the Sigale-Gale puppet dance, a traditional performance from the Batak Toba ethnic group in Ambarita Village, Samosir Regency, North Sumatra. This ritual dance depicts the sorrow of a king mourning the loss of his only son to a mysterious illness (Simanihuruk, 2024). Over time, the dance has evolved in parallel with the community's religious and social developments (Sihombing, Kasmahidayat, & Sunaryo, 2022).

Integrating local cultural expressions such as the Sigale-Gale performance into physics learning allows students to engage with scientific content in a way that is both intellectually and culturally enriching. This educational approach not only enhances students' understanding of scientific concepts but also fosters cultural awareness and pride. By learning physics through the lens of their own heritage, students are more likely to find the subject approachable and engaging.

This study aims to make a significant contribution to both theoretical and practical aspects of physics education. Theoretically, it introduces the "Cultural-Based Physics Integration Framework," a model designed to connect physics concepts with local cultural practices. This framework provides a deeper understanding of how scientific ideas can be interpreted and taught within specific cultural contexts. Although the present study focuses on the Sigale-Gale performance, the framework has the potential to be adapted to other cultural traditions, thereby enriching science education across different regions.

Practically, this research offers implementable strategies for classroom instruction by developing teaching tools rooted in local culture, including lesson plans (RPP) tailored to specific cultural settings. Such strategies enable educators to deliver physics content in ways that are relevant and accessible to students. In doing so, they help transform physics education from a traditionally rigid and abstract subject into one that is dynamic, interactive, and contextually meaningful. The findings of this study thus contribute not only to the academic discourse on ethnophysics but also provide practical insights for improving the teaching and learning of physics through culturally responsive education.

## METHODS

This research adopts a qualitative method with a focus on literature review to explore and analyze the integration of local culture into physics education through the ethnophysical study of the Sigale-Gale performance. A qualitative literature review allows the researcher to systematically examine previous studies, theories, and documented cultural practices to gain a comprehensive understanding of how traditional performances can be interpreted through the lens of physics. According to Magdalena et al. (2021), literature review involves studying books, scholarly references, and previous research to establish a theoretical foundation for the research problem.

The data sources utilized in this study comprise a range of secondary materials, including peer-reviewed journals, academic books, conference proceedings, and articles discussing physics concepts, ethnoscience, and traditional cultural practices. The selection of these sources was guided by their relevance to the topic and their contribution to the field of ethnophysics. The review primarily focused on literature published within the last ten years to ensure the use of up-to-date scientific perspectives and educational frameworks. This timeframe also aligns with recent developments in contextual science education and cultural integration strategies in learning.

The analysis was conducted using content analysis techniques. This involved identifying recurring themes, physics concepts, and cultural elements embedded in the Sigale-Gale performance. The performance stages—opening, main dance sequence, and closing ritual—were used as analytical categories to map corresponding physics principles such as rotational motion, torque, sound waves, momentum, and equilibrium. By categorizing these elements, the researcher was able to create an analytical framework that aligns traditional cultural narratives with scientific phenomena.

Furthermore, the research considered how the identified physics concepts could be translated into teaching materials for secondary school physics education. Practical suggestions such as classroom experiments, video-based analysis, and cultural demonstrations were derived from the literature findings. These applications highlight the pedagogical potential of integrating ethnophysics into lesson planning, emphasizing the relevance of physics to students' cultural environments. This process ensures that the study's findings are not only theoretically grounded but also pedagogically applicable.

Overall, the qualitative literature review method is deemed appropriate for this study, as it allows for an in-depth exploration of the cultural and scientific dimensions of the Sigale-Gale performance without the need for field-based data collection. This foundational research serves as a conceptual platform for future empirical studies, including classroom implementation and ethnographic investigation of traditional performances in physics education contexts. The methodological approach thus ensures academic rigor while embracing cultural richness and contextual relevance.

## RESULTS AND DISCUSSION

Previous studies have extensively explored the integration of local culture into physics education through the ethnophysical approach in various traditional dances, such as the Soya-soya Dance (Astuti et al., 2022), the Tortor Dance (Nasution et al., 2024), and the Plate Dance (Astuti & Bhakti, 2021), all of which have examined physics concepts such as motion, rotation, force, and balance within cultural contexts. However, to date, there has been no in-depth physics study on the Sigale-Gale puppet performance as a learning resource for physics. Unlike the aforementioned dances, which primarily feature human motion, the Sigale-Gale performance involves a wooden puppet controlled from behind, making it a unique subject for physical analysis. This study aims to examine physics concepts such as angular momentum and rotational equilibrium in the Sigale-Gale performance as a culturally-based source of physics learning.

Research by Hidaayatullaah et al. (2021) demonstrates that ethnoscience-based learning contributes significantly to physics education from secondary schools to universities. Ethnoscience can be integrated through innovative teaching approaches in schools and has been shown to enhance critical thinking skills. Nurcahyani et al. (2020) further emphasize that ethnoscience learning significantly improves students’ scientific literacy, which is essential for developing 21st-century science education. Similarly, Wilyanti et al. (2023) show that local wisdom-based learning using traditional Lampung games enhances science skills, particularly in topics such as momentum and impulse. These findings reinforce the potential of culturally-based approaches to improve students’ contextual understanding of physics concepts in a meaningful way.

Performing arts refer to a branch of art characterized by live performance (Susi, 2023). The Sigale-Gale performance is one of the unique traditions of the Batak people in North Sumatra, where a wooden puppet resembling a human dances in sync with the rhythm of gondang sabangunan music. In the Sigale-Gale performance, the dominant physical elements are rotational motion and balance, which set it apart from other traditional performances like the Plate Dance. As described by Astuti and Bhakti (2021), the Plate Dance emphasizes translational motion, whether through the dancers' movements or the shifting of plates in their hands. In contrast, Sigale-Gale's movement is generated through a lever and rope system connected to various joints of the puppet. This system allows parts of the puppet's body, such as the arms, head, and torso, to rotate around different axes, mimicking human dance movements.

In addition to rotational motion, balance is a critical component for maintaining the puppet’s stability, especially when operated remotely by the puppeteer. Physical principles such as torque, moment of inertia, and center of mass can be directly observed in how the puppet adjusts to the applied forces. These aspects underscore the significant potential of the Sigale-Gale performance to serve as an educational medium for physics learning grounded in local culture (ethnophysics). The puppet is animated through a manually controlled system of levers and ropes operated by a puppeteer.


**Figure 1.** Sigale-Gale statue performance

From a physics perspective, the Sigale-Gale performance encompasses various scientific concepts, including sound waves, lever mechanics, balance, acceleration, and deceleration. Table 1 presents an in-depth analysis of each of these physical aspects as observed in the Sigale-Gale puppet performance.

**Table 1.** Analysis and review of physical aspects in the Sigale-Gale puppet performance

| Phase of Performance | Movements and Music in the Sigale-Gale Performance | Physics Concepts Identified |
|---|---|---|
| Opening Phase | 1. The performance begins with gondang sabangunan music, featuring traditional Batak instruments such as taganing (drum), serunai (wind instrument), and hasapi (lute).<br>2. The music creates a sacred and mystical atmosphere. The Sigale-Gale puppet begins to move slowly to the rhythm, activated by a puppeteer who controls levers and ropes from behind the puppet. | Based on our analysis, the relevant physics concepts include:<br>1. Sound waves produced by the instruments are mechanical longitudinal waves propagating through the air, with particle vibration direction parallel to the wave direction (Yuberti, 2014).<br>2. Resonance principles are observed in the serunai and taganing to produce characteristic sounds. Serunai and hasapi utilize resonance, where the natural frequency of an object is amplified by external waves, resulting in louder and clearer sound (Elisa et al., 2023).<br>3. Levers are a simple machine consisting of a rigid bar rotating around a fixed point called a fulcrum (Meidayanti et al., 2023). The puppet's movement utilizes this simple mechanical principle through lever and pull force systems. |

| Phase of Performance | Movements and Music in the Sigale-Gale Performance | Physics Concepts Identified |
|---|---|---|
| Main Phase | 1. The puppet starts dancing in rhythm with the gondang music.<br>2. The puppeteer controls the movement of the puppet's arms, head, and body using a rope-and-lever mechanism.<br>3. The tor-tor dance includes swinging arm motions and slight movements of the head and body.<br>4. Ritual participants or family members may join the dance around the puppet as a form of ancestral reverence. | The physics concepts observed include:<br>1. The swinging motion of the puppet's arms and head demonstrates principles of balance and angular momentum.<br>2. The lever system used in the puppet's mechanics illustrates the concept of torque, where the fulcrum enables the motion of the puppet's limbs (Fadli et al., 2022).<br>3. As the music tempo increases, changes in sound wave frequency and amplitude are observed, affecting the vibration intensity of instruments and emotional response of the audience. |
| Main Phase (continued) | 1. The gondang music intensifies, making the puppet's movements more dynamic.<br>2. Several participants enter the performance area to dance with the puppet.<br>3. There is a belief that if the Sigale-Gale puppet dances on its own, it signifies the presence of ancestral spirits. | Identified physics concepts include:<br>1. The concept of acceleration is reflected in the increasing speed of the puppet's arm and head movements. As the music reaches its peak, angular momentum increases. If movements become too rapid, the puppet may lose balance, requiring the puppeteer to carefully regulate the pulling rhythm.<br>2. Friction between the rope and the mechanical system affects the smoothness of the puppet's movements. This friction always acts parallel to the surface and opposes the direction of motion (Nopriantoko, 2022).<br>3. Angular momentum in the puppet's limbs demonstrates how mass and angular velocity influence movement. |
| Closing Phase | 1. Gondang music gradually slows down.<br>2. The Sigale-Gale puppet reduces its movements until coming to a full stop.<br>3. A final ritual is conducted by family members or spectators, often involving offerings or prayers to the ancestors. | The physics concepts observed include:<br>1. Deceleration, or reduction in speed.<br>2. The decreasing sound volume reflects a drop in amplitude and frequency of sound waves (Wijaya, 2022).<br>3. Force equilibrium is required to keep the puppet stable and upright while stopping. |

### Sound Waves and Resonance in Gondang Music

The Sigale-Gale performance begins with the rhythm of *gondang sabangunan*, a traditional Batak musical ensemble consisting of various instruments, including:

1. Taganing (Batak drum) → Produces sound through membrane vibrations.
2. Serunai (wind instrument) → Operates based on the principle of air resonance within its tube.
3. Hasapi (Batak lute) → Generates sound through string vibrations amplified by the resonance of its soundbox.

In physics, the sound produced by these instruments is a mechanical longitudinal wave, meaning the wave travels in the same direction as the vibration of its source. Moreover, instruments like the serunai and hasapi utilize resonance, a phenomenon in which an object's natural frequency is amplified by external waves, resulting in louder and clearer sound.

As the tempo of the music increases, both the frequency and amplitude of the sound waves rise, intensifying the atmosphere and enhancing the dynamism of the Sigale-Gale dance (Rustianto, 2021). Table 2 presents how these concepts can be directly integrated into physics learning.

**Table 2.** Concept integration in direct physics learning

| **Integration Method** | **Description** |
|---|---|
| Simple Resonance Experiment Using Basic Materials | This experiment can be conducted using the following method:<br>String Resonance (Hasapi Simulation):<br>a. Stretch rubber bands across an empty tissue box to simulate the strings of a *hasapi*.<br>b. Students pluck the rubber bands at varying tensions and observe the changes in the pitch of the sounds produced.<br>c. This experiment demonstrates how string tension affects sound frequency, as in the case of the *hasapi*.<br>Through this activity, students can understand the importance of resonance in traditional musical instruments and how this concept is explained in physics using sound wave principles. |
| Performance Video Analysis | Physics learning can also be conducted through video analysis of the Sigale-Gale performance. The learning stages include:<br>1. Video Observation<br>Students watch the Sigale-Gale performance video and are instructed to observe two main aspects: the puppet's movements and its mechanical operation, as well as the musical instruments played and tempo changes during the performance.<br>2. Discussion and Analysis<br>Students discuss physics concepts related to the performance, such as lever mechanics in puppet motion, the relationship between musical tempo changes and puppet acceleration, and the application of resonance in the instruments used during the performance. |

## Frictional Force

### *Friction in the Rope and Lever System*

The Sigale-Gale puppet is operated using ropes controlled by a puppeteer. When the rope is pulled, friction occurs between the rope and the wooden components or lever system that connect it to the puppet's arms, head, and body.

- Static friction occurs when the rope is not yet moving but has already received a pulling force from the puppeteer. If the pulling force exceeds the static friction, the rope begins to move, and so does the puppet.
- Kinetic friction occurs once the rope is in motion through the lever system. This friction can either hinder or smoothen the puppet's movements depending on the rope's surface and the wooden material used.

If the friction is too high (e.g., due to rough ropes or poorly maintained grooves), the puppet's motion may become jerky or unresponsive. Conversely, if the friction is too low, the puppet may become unstable or difficult to control. Therefore, selecting appropriate rope material and maintaining the lever system are crucial for ensuring smooth movements of the Sigale-Gale puppet.

### *Friction Between the Puppet and the Floor*

The Sigale-Gale puppet typically stands on a wooden stage or platform. To maintain balance, the friction between the puppet's base and the floor must be sufficient to prevent slipping during movement.

- If friction is too low → The puppet may slide or fall when the rope is pulled forcefully.
- If friction is too high → The puppet may struggle to perform smooth or slight rotational movements, as the base adheres too strongly to the floor.

This friction becomes even more essential as the puppet decelerates and comes to a stop at the end of the performance. Just like friction slows down a car when braking, it helps to naturally stop the puppet's motion.

## Lever System and Pulling Force in Puppet Movement

The Sigale-Gale puppet cannot move autonomously; it is controlled by a puppeteer using a system of levers and ropes to manipulate its arms, head, and body. In physics, this motion utilizes the lever mechanism composed of three main elements:

1. Fulcrum (pivot) → The puppet's shoulder and neck joints.
2. Effort force → The pulling force applied by the puppeteer via the rope.
3. Load force → The weight of the puppet's limbs or head that needs to be lifted or moved.

When the puppeteer pulls the rope, the puppet reacts by rotating at specific joints. This movement involves torque, which is the rotational effect of a force applied to an object. Additionally, the rope used experiences friction. Excessive friction can make the puppet's movement stiff or jerky. Therefore, material selection and pulling technique must be considered to ensure the Sigale-Gale's motion remains smooth and natural.

## Balance and Angular Momentum in the Sigale-Gale Dance

As the puppet dances, it must maintain balance to avoid falling. In physics, balance is achieved when the net force acting on the puppet is zero. This requires precise coordination of the puppet's mass distribution, pivot points, and the direction and magnitude of pulling forces.

Moreover, the puppet's arm and head movements involve angular momentum, which describes an object's tendency to continue rotating. Angular momentum is influenced by:

1. The mass of the moving body parts → such as the arms and head.
2. The distance from the pivot point → longer arms require greater torque to move.
3. The rotational speed → as the music tempo increases, the angular speed of movements increases, thereby raising angular momentum.

When human dancers join the puppet, they also need to maintain balance, especially when performing swinging or spinning motions in sync with the music.

### Acceleration with Increasing Music Tempo

Newton's Second Law states that an object's acceleration is directly proportional to the force applied and inversely proportional to its mass ($F = ma$). In the context of Sigale-Gale:

1. A stronger pull from the puppeteer results in faster puppet movement.
2. A heavier puppet requires greater force to achieve the same acceleration.

As the music tempo reaches its peak, the puppet's movements become increasingly dynamic, and its angular momentum grows. Excessive speed may compromise stability, requiring the puppeteer to regulate the pulling rhythm carefully.

### Deceleration and Stability

Acceleration occurs when the speed of an object changes over time (Riana & Sembiring, 2022). After the climax of the performance, the gondang music gradually slows down. This leads to a reduction in the puppet's movements until it eventually stops. In physics, this reduction is known as deceleration, which happens when the force acting on an object decreases.

In the Sigale-Gale performance, deceleration is observed through:

1. The puppeteer gradually reducing the pulling force on the ropes.
2. A decrease in the amplitude and frequency of the gondang sound waves, which lowers the kinetic energy transferred to the puppet.
3. The puppet reaching a state of force equilibrium, where no net force induces further movement.

Stability is crucial during this final phase. If the rope is suddenly released, the puppet may lose balance and fall. Thus, deceleration must be executed smoothly to keep the puppet upright at the end of the performance.

## CONCLUSION

Ethnophysics is an approach that links physics concepts with local culture, enabling students to understand physics in a more tangible and life-relevant manner. This study examined the Sigale-Gale puppet performance in North Sumatra to identify physics concepts such as sound waves, motion, levers, balance, and acceleration. This approach not only enhances students' comprehension of physics but also contributes to the preservation of local culture. By integrating local wisdom, physics learning becomes more enjoyable, interactive, and student-centered. The study contributes to the development of culturally based physics education, supporting contextual approaches aligned with the Merdeka

Curriculum. Therefore, further research is encouraged to implement this approach in various regions, making physics learning more contextualized and relevant.

## RECOMMENDATION

Ethnophysical research should ideally be conducted directly within the cultural context being studied to obtain a deeper and more comprehensive understanding. It is also recommended to develop models or frameworks for integrating physics concepts with local culture that can be adapted to other cultural settings. This would enrich physics education by providing more diverse and contextually grounded learning experiences..

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