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Integrating Technology and Ethnophysics to Support Sustainable Education and Cultural Preservation through Traditional Games of Gasing and Hula Hoop in Rotational Physics Learning

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ABSTRACT

Objective: *This study explores the rotational physics concepts embedded in traditional children's games, specifically gasing (pulling tops) and hula hoops, to support sustainable education and cultural preservation. The research integrates ethnophysics and technological analysis to examine how these games can be utilized in contextual and meaningful physics learning.* ***Method:*** *This research used a qualitative exploratory approach to map physical phenomena in traditional games. Data were collected through purposive sampling involving two participants with expertise in playing gasing and hula hoop. Data collection methods included observation, interviews, and literature review. To support deeper analysis, digital technology such as slow-motion video recording, motion-tracking applications (e.g., Phyphox), and angular velocity sensors were used to visualize and quantify rotational motion.* ***Results:*** *The findings indicate a strong correlation between the mechanics of traditional games and the principles of rotational motion, such as torque, angular velocity, moment of inertia, and conservation of angular momentum. Both gasing and hula hoop exhibit consistent patterns of rotation around a fixed axis, which are fundamental concepts in rotational dynamics. Technology integration allowed for enhanced visualization and interpretation of motion parameters, enriching the learning process.* ***Novelty:*** *The study offers a novel interdisciplinary approach by combining local cultural practices with digital technology to facilitate physics learning. It bridges traditional knowledge with modern scientific tools, supporting SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities). This ethnophysics-based framework contributes to culturally responsive pedagogy and digitalized STEM education.*

INTRODUCTION

Physics has significantly contributed to development and technology, making it an essential subject in education (Novita Sari, 2017). Despite its importance, physics is often perceived as difficult due to its abstract nature and the lack of engaging and contextualized learning media. A Yunika (2018) study found that 56.45% of students identified rotational dynamics as one of the most challenging topics. Contributing factors include the dominance of textbook-based instruction and the limited use of interactive and meaningful media in the classroom, resulting in monotonous learning and low student motivation.

In contrast, traditional children's games offer a rich source of contextual phenomena that can be linked to physics concepts. The gasing (spinning top) and hula hoop games are examples of play that naturally integrate rotational motion. These traditional games reflect cultural wisdom and physical principles such as torque, angular momentum, and centripetal force (Wibowo & Rahmawati, 2020). Playing gasing involves pulling a string to induce spinning around a fixed axis, while hula hooping requires maintaining balance and rhythmic motion to keep the hoop rotating around the waist. Both illustrate the real-life application of rotational physics, making them excellent pedagogical tools.

From an ethnophysics perspective, these games embody the integration of indigenous knowledge and scientific understanding. Ethnophysics, as defined by Harrison (2011), examines how people from diverse cultures conceptualize, utilize, and develop physics-related knowledge. By incorporating cultural artifacts such as traditional games into science education, students can better connect with the material while developing a sense of identity and belonging (UNESCO, 2021).

Technological tools can be incorporated into ethnophysics-based physics learning to deepen the scientific inquiry into such games. Advances in sensor-based technology and mobile applications now allow students and educators to measure and analyze physical quantities involved in rotational motion. For instance, using motion-tracking apps such as Phyphox or Vernier Video Analysis, students can record angular velocity, acceleration, and torque in real-time as the spinning top or hula hoop is in motion (Goh et al., 2018). Similarly, smartphones equipped with gyroscopes and accelerometers can be used to visualize motion dynamics, providing concrete feedback that enhances conceptual understanding.

These technologies do not aim to replace traditional play but rather to augment the learning experience by transforming local cultural practices into scientifically rich, measurable phenomena. Through this approach, students engage in digital ethnophysics, combining local wisdom with global tools. Thus, by promoting contextual learning and cultural preservation, they support SDG 4 (Quality Education) and SDG 11 (Sustainable Cities and Communities).

Furthermore, technology-enhanced ethnophysics learning helps bridge the gap between traditional knowledge and modern science education. While current technology is often blamed for reducing face-to-face interaction and promoting passive screen time, integrating it meaningfully into educational contexts can cultivate analytical thinking, collaboration, and respect for cultural heritage instead. Such integration also supports character development and strengthens the relationship between learners and their sociocultural environment (Nugroho & Prabowo, 2022).

Based on the description above, the traditional games of gazing and hula hoop are closely linked to the concepts of rotational physics. This study limits its scope by specifying that the gasing used is made of plastic and the hula hoop is made of wood with a diameter of 70 cm. Integrating ethnoscience and modern technology in these traditional games provides a unique opportunity to create contextualized and engaging learning experiences in physics education.

RESEARCH METHOD

This study employs a qualitative research method with an exploratory design to map a relative object (Sugiyono, 2020). The research uses qualitative research methods to explore the physics concepts within the traditional Indonesian games of the Spinning Top and the Hula Hoop. The data collection technique used in this study is purposive sampling. The data was triangulated and analyzed descriptively and qualitatively to identify the physics concepts in the game and their relevance to physics material in everyday life. Two individuals who clearly understand how to play Spinning Top and Hula Hoop were selected as the sample, and data were collected through interviews, observations, and literature review as in Figure 1.

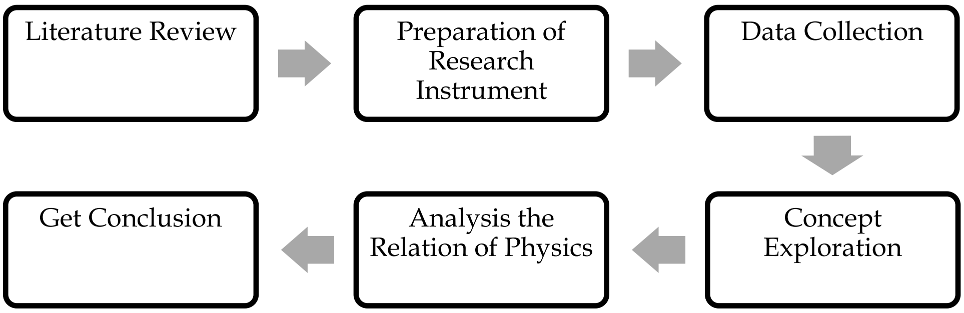

Figure 1. Research design

RESULTS AND DISCUSSION
Results
Flying Wheel Toy/Pull Top

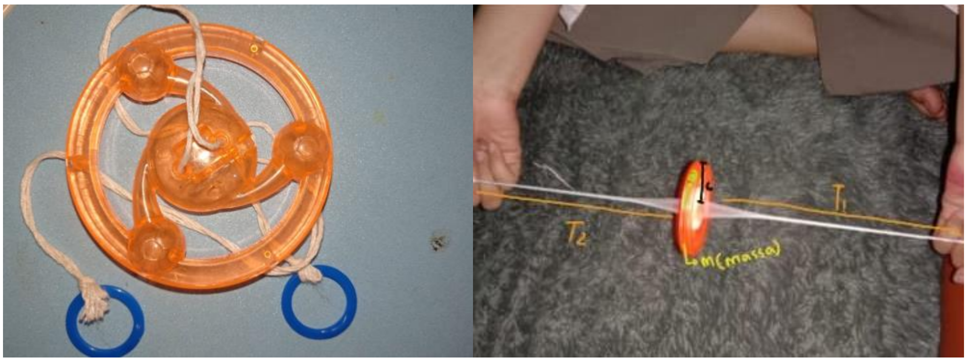

Figure 2. Flying wheel toy/pull top play on your left, and the flying wheel toy/pull top on your right

The traditional game of Spinning Top, also known as "Gasing Tarik," was highly popular and has undergone modifications over the years, resulting in more attractive and diverse designs. As a traditional children's toy, the gameplay is relatively simple. It involves pulling a string attached to the center or pivot point of the spinning top. When the string is pulled, the top starts to rotate.

The game of Spinning Top involves several important physics concepts. First, there is rotational motion as the spinning top rotates around its axis of rotation. Second, torque is applied when pulling the string, which causes the top to rotate. Pulling the string imparts angular momentum to the top, affecting its rotational speed. Lastly, rotational stability is influenced by the shape and mass distribution of the spinning top, which affects its stability while spinning.

These physics concepts are integral to understanding the mechanics of the Spinning Top game. By exploring and studying these concepts, we can better understand the physical principles at play.

Hulahoop
The hula hoop is a traditional game commonly encountered. It is created from a circular-shaped rattan hoop with a diameter ranging from 50 to 100 cm. The game is

played by spinning it around the player's waist without letting it fall. The hula hoop requires the player to maintain body balance to keep it spinning around the waist.

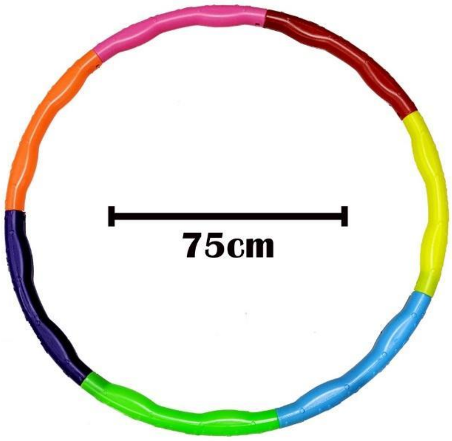

Figure 3. Hula hoop with a 75 cm diameter

In its usage, the hula hoop is related to several physics concepts. The physics concepts related to the hula hoop include rotational motion, angular velocity, angular acceleration, and moment of inertia. The game of Gasing Tarik and the hula hoop share similar physics concepts. Here are some formulas commonly used to describe these concepts in the game:

a) Rotation

The rotational motion refers to an object rotating around a fixed axis. In the case of the hula hoop, the hoop rotates around the person's body axis. The formula for rotational motion is:

$$\omega = \frac{\Delta\theta}{\Delta t} \quad (1)$$

b) Angular Velocity

In the case of a hula hoop, angular velocity describes how fast the circle rotates around the axis of one's body. Angular speed formula:

$$\omega = \frac{V}{r} \quad (2)$$

c) Angular Acceleration

Angular acceleration describes how fast the circle's angular velocity changes on a hula hoop. For example, in the following hula hoop image, which applies the angular acceleration formula:

$$\alpha = \frac{\Delta\omega}{\Delta t} \quad (3)$$

Figure 4. Hula hoop with the physics concept of angular acceleration

Rotating the hula hoop around the waist creates a centripetal force. This force is directed towards the circle's center and keeps it moving in a circular path. The faster the hula hoop rotates, the greater the centripetal force needed to keep it moving in a circle. When the hula hoop rotates around the hips, which shows a regular pattern, or when a top pull is rotated with a constant pull, it will produce a regular graphic pattern as shown in Figure 5 below.

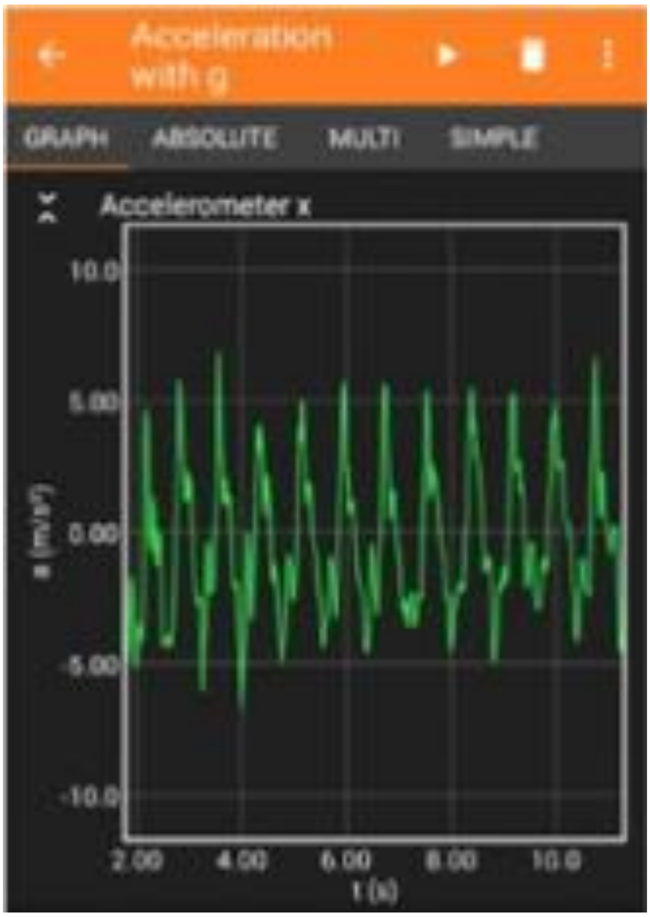

Figure 5. An example graph showing data recorded with the Phyphox app while playing a hula hoop.

The x-axis shows the time in seconds of the hula hoop performance, and the y-axis shows acceleration in meters per second squared.

Figure 6. Playing a hula hoop

One of the main principles of physics that works when playing with the hula hoop is the moment of inertia. The moment of inertia is the tendency of an object to continue rotating around a center point. When you start rotating the hula hoop around your waist, it will impart a moment of inertia to the hula hoop. If we maintain the same rotation rate, the moment of inertia will be maintained, and the hula hoop will continue to rotate.

d) The Moment of Inertia

The moment of inertia is the tendency of an object to maintain its state of rotational motion. In a hula hoop game, the center of rotation is the person playing it (picture 4). When a person tries to maintain a hula hoop position so that it continues to rotate at his waist, that is called the moment of inertia. In the case of the hula hoop, the moment of inertia describes how difficult it is to rotate a circle around the axis of the person's body.

$$I = mr^2 \quad (4)$$

Another important factor in the hula hoop is its mass distribution. A heavier hula hoop will require more force to keep it spinning than a lighter hula hoop. Size and shape also play a role in the balance of the hula hoop's rotation at the waist. Overall, the hula hoop involves concepts related to rotational motion, angular velocity, angular acceleration, and moment of inertia.

Discussion

Traditional games like Gasing Tarik (pull top) and hula hoop are part of a rich cultural heritage and valuable tools for teaching fundamental physics concepts. These games naturally exhibit physical phenomena such as rotational motion, angular momentum, torque, and moment of inertia—key elements in classical mechanics. Integrating technology into these traditional games' learning process offers a unique opportunity to blend ethnophysics with modern pedagogical approaches, thereby supporting sustainable education and preserving cultural identity.

Ethnophysics in Traditional Games

Ethnophysics is an interdisciplinary approach that connects indigenous knowledge systems with physical science concepts. In Gasing Tarik's case, pulling the string applies a torque that causes the top to spin. The rotational stability and duration of the spin depend on the top's mass distribution and angular momentum. Similarly, in hula hooping, rotational motion around the body axis, centripetal force, and angular acceleration are inherently involved in maintaining the hoop's motion. While played for recreation, these games are deeply embedded with scientific principles understood and applied implicitly through generations (Zhai et al., 2021).

Technological Integration: A Path Toward Contextualized Learning

Integrating mobile applications like Phyphox (Physical Phone Experiments) enables students to collect real-time data on acceleration, angular velocity, and torque while engaging with these traditional games. For example, as illustrated in Figure 5, a smartphone placed on the body while hula hooping can record acceleration data over time. This data can then be visualized, analyzed, and interpreted, bridging the gap between physical experience and abstract theory. The technology transforms a traditional game into a live physics experiment, enhancing conceptual understanding through experiential learning (Kuhn & Vogt, 2020).

Furthermore, augmented reality (AR) and motion tracking software can be incorporated to visualize vectors of force, angular displacement, and trajectories during gameplay. These tools help students grasp complex concepts more intuitively and offer opportunities for gamification and increased engagement in learning environments (Lin et al., 2022).

Preserving Culture through STEM

Combining traditional games with physics education and modern technology does more than teach science; it helps cultural preservation. Many traditional games are fading due to modernization and a lack of exposure among younger generations. By including these games in science curricula, they regain relevance in youth and educators' eyes, enriched with data collection, digital visualization, and interactive simulations.

As defined by UNESCO, sustainable education emphasizes relevance, continuity, and context. Traditional games such as Gasing Tarik and hula hoop fulfill these aspects by offering culturally relevant content, physical engagement, and a platform for interdisciplinary learning. When digital tools are added to the mix, the result is a powerful synergy that supports physics learning and strengthens local identity and heritage appreciation (UNESCO, 2017).

Integrating technology into studying traditional games like Gasing Tarik and hula hoop exemplifies how ethnophysics can serve educational and cultural goals. This approach allows learners to experience and analyze core physics principles in a tangible, culturally rooted context. Technological tools such as mobile sensors, augmented reality, and simulation software not only make abstract concepts more accessible but also help document and revive traditional practices. As a model of sustainable education, this integration nurtures scientific literacy, promotes heritage preservation, and inspires innovative pedagogical methods grounded in local wisdom.

CONCLUSION

Fundamental Finding: This study concludes that traditional games such as the Flying Wheel/Pull Top and Hula Hoop are effective, culturally grounded tools for exploring the physics concept of rotational motion. Both games demonstrate a common underlying principle: objects rotating around a fixed axis, which directly connects to core physics topics like angular velocity, torque, angular acceleration, moment of inertia, and centripetal force. By analyzing these games through the lens of physics, learners can concretely grasp abstract concepts in a relatable and engaging way, reinforcing the idea that indigenous knowledge systems can enrich modern science education. **Implication:** Integrating ethnophysics with modern educational technologies fosters a holistic and sustainable learning approach. Students who use digital tools like the Phyphox app to analyze traditional gameplay bridge cultural heritage with scientific reasoning. This not only enhances cognitive understanding but also nurtures cultural appreciation and identity. It highlights the potential of contextualized STEM education to make learning more relevant, inclusive, and inspiring for diverse learner populations. **Limitation:** This study focuses primarily on qualitative observations and basic sensor data interpretation through accessible technologies. It does not delve deeply into quantitative modeling or the effects of long-term exposure to this learning model on conceptual mastery. Additionally, the study is limited to the cultural context of the selected traditional games, which may affect generalizability to different regions or cultures. **Future Research:** Future investigations should explore the impact of integrating ethnophysics-based learning with advanced technologies such as augmented reality (AR), motion capture systems, or AI-based analysis tools to provide more precise, immersive experiences. Research could also examine the longitudinal effects of this approach on students' physics performance, cultural identity development, and interest in STEM fields. Comparative studies across different traditional games and cultures would further enrich the understanding of how indigenous play can contribute to global science education and cultural sustainability.

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