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Dynamics of Motion and Force in Bantengan Art: A Kinematic Analysis Based on Newton's Laws from An Ethnoscience Perspective

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Abstract

This study aims to analyze the dynamics of movement and force in Bantengan art through an ethnoscience perspective and to examine its potential as a context for learning Natural Sciences (IPA). Using a qualitative method with an ethnographic design, data were collected through participant observation, in-depth interviews with six informants (two main players, three musicians, and one instructor), and qualitative video analysis of Bantengan performances. The analysis reveals that specific Bantengan movements map onto distinct physics concepts: foot-stomping demonstrates Newton's Third Law and the impulse–momentum theorem, running and headbutting illustrate the change of momentum during collision, body rotation exhibits the conservation of angular momentum, static jumps show the conversion of potential energy into kinetic energy, and extreme flexion movements reveal torque and biomechanical force balance. Beyond mechanics, Bantengan integrates cultural and spiritual values that offer an ethnoscience approach deepening students' grasp of scientific concepts. These findings position Bantengan as a promising context for contextual science learning that bridges scientific theory and cultural practice while preserving local heritage.

Keywords: Bantengan Arts; Ethnoscience; Motion and Force; Newton's Laws; Science Learning

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INTRODUCTION | مقدمة

Science instruction is a pivotal role of student's educational path. Beyond simply teaching fundamental concepts like motion and force, it actively sharpens cognitive abilities and shapes learning behaviors (Alberts, 2022; Harper, 2018). Despite these benefits, school instruction often struggles to bridge the gap between theoretical concepts and real-world application (Wandi et al., 2023; N. H. Zakaria et al., 2019). As a result, it is leads students to perceive topics such as force, motion and equilibrium as abstract and difficult to grasp (Barsoum et al., 2022; Bogdanovic et al., 2015; Erinosho, 2013). A major challenge in science education is students frequently enter science instruction with pre-existing misconceptions about core concepts, such as force and motion (Kamilah et al., 2025; Pablico, 2010; Piyatissa & Waduge, 2023). This challenge is worsened by the current lack of effective teaching strategies specifically designed to tackle conceptual difficulties in mechanics (Kamilah et al., 2025; Potvin et al., 2023; Self et al., 2020). While science educators report strong self-perceptions of their knowledge, research shows a functional disconnect between its components (Jita & Tsakeni, 2022), which translates into a poor application of knowledge in teaching (Yunus, 2001).The result is instruction that focuses on rote memorization of formulas instead of genuine conceptual insight (Wieman & Perkins, 2005).

As a solution, cultural phenomena, such as Bantengan art, can serve as an excellent alternative, linking physics theory directly to students' own cultural experiences to bridge the theory-practice gap (Fasasi, 2017; Kasi et al., 2022; Wandi et al., 2023).

This ethnoscience approach provides a culturally relevant framework for exploring physics, enabling students to connect abstract scientific ideas with tangible, real-world events (Agustina & Desstya, 2022). Specifically, traditional Indonesian performing arts that incorporate martial arts movement, found in pencak silat, offer clear demonstrations of core physics concepts. Force, motion, balance, and application of Newton's Laws are realized through the controlled dynamics and performers' skill in maintaning equilibrium (Wulansari & Admoko, 2021; A. Zakaria et al., 2025). Horse stances and trance induced actions are practical demonstrations of kinematics, both require excellent control of gravitational forces and maintaining inertial stability (Agustina & Desstya, 2022; Elvianasti et al., 2023). The ethnoscience lens is powerful because it dispels persistent student misconceptions about mechanics by rooting abstract scientific ideas within familiar cultural rituals context (Kamilah et al., 2025). Furthermore, the cultural integration promotes more than just learning, thereby fostering active engagement, scientific literacy, and creative thinking (Wandi et al., 2023; Wulansari & Admoko, 2021). Ultimately, this approach cultivates a holistic grasp of movement and force aligns education with the students' cultural background.

The Bantengan Art, a traditional performance rooted in Malang Regency, specifically Pakis Regency, holds significant potential as both cultural staple and an educational resource, rich in scientific values. As an integral part of local traditional and cultural events (Nashichuddin & Rifki, 2018), Bantengan is characterized by the combination of dance, music, and martial arts elements (Farhan et al., 2025; Faris et al., 2017). The experience is often intensified by mystical elements, most notably trance, which practitioners regard as a communication channel with ancestral spirits (Farhan et al., 2025; Faris et al., 2017; Nashichuddin & Rifki, 2018). Therefore, Bantengan arts serves as rich source of inspiration to link physics concepts, such as force, motion and balance, with genuine cultural practices familiar to students. Bantengan is thought to have existed since the Singhasari Kingdom in the 13th century AD (Nashichuddin & Rifki, 2018). At that time, the dance was simpler and closely related to the Kembangan movement, a technique in pencak silat that functions as a warm-up dance before fighting (Farhan et al., 2025). Bantengan not only serves as entertainment, but also as a medium to instill the values of courage, unity, and respect for nature and ancestors (Nashichuddin & Rifki, 2018), which are highly relevant to the educational context in schools.

Compared to other Indonesian performing arts previously examined for their physics content, such as Dhadak Merak of Reog Ponorogo and the Soya-Soya dance (Wulansari & Admoko, 2021), Bantengan offers a distinctive and previously unexplored analytical opportunity. Its choreography centers on trance possession, headbutting collisions, and extreme flexion postures, movements that involve considerably greater force magnitudes, non-elastic impacts, and more complex multi-joint dynamics than the largely graceful and symmetrical movements documented in prior ethnophysics studies. This intensified physical dynamism makes Bantengan a particularly rich case for kinematic and dynamic analysis within an ethnoscience framework, justifying its selection as the focus of the present study. Thus, Bantengan can be a source of inspiration to connect physics concepts, such as force, motion, and balance, with cultural practices that are real and close to students' lives. By exploring the kinematic principles embedded in the Bantengan art form, such as the forces exerted by the performers and the resulting movements, students can develop a deeper conceptual understanding of Newton's laws through a culturally relevant and engaging medium (Chen, 2023). This integration of ethnoscience with physics education, particularly through a problem-based learning model, has proven effective.

METHOD | منهج

This research method uses a qualitative approach with an ethnographic design, which aims to dig deep understanding of the dynamics of movement and style in Bantengan art. The ethnographic approach was chosen because it allows researchers to understand the phenomena that occur in the social and cultural context of the community, especially those related to traditional performing arts practices. In this study, the sampling technique used was purposive sampling, where the research sample was deliberately selected based on their role and involvement in Bantengan art in Malang Regency. The research sample consisted of six informants: two main players, three musicians, and one instructor from a Bantengan studio, all of whom have direct knowledge and experience in this performance.

The data collection techniques used included participant observation, in-depth interviews, and video analysis. Participant observation was conducted by directly observing the Bantengan performance, recording the movements of the performers, interactions between the performers and the audience, and the audience's response to the music and movements. In-depth interviews were conducted with the performers and musicians to understand the practices they employ during the performance, including their understanding of the forces, motion, and balance involved. Furthermore, video analysis was used to examine the Bantengan performance footage in greater detail, specifically to analyze the acrobatic movements and their relationship to physics concepts, such as force and balance. This video analysis was conducted qualitatively as a conceptual mapping exercise, identifying and interpreting the physics principles embedded in observable movement patterns, rather than as an empirical kinematic measurement using motion-tracking software (e.g., Tracker); this qualitative-conceptual scope is acknowledged as a methodological boundary of the present study. The videos analyzed were YouTube videos on the channel: https://www.youtube.com/watch?v=QFZQKODenf8 and Tiktok account: https://www.tiktok.com/@newronggojoyoo.

This research data analysis used thematic analysis to identify themes emerging from interviews and observations. These themes will then be connected to relevant physics concepts, particularly motion, force, and equilibrium. To ensure the scientific validity of the resulting physics-movement mapping, the identified concepts were reviewed through expert judgment involving physics education lecturers, who evaluated the accuracy and appropriateness of aligning each observed movement with its corresponding physical principle. The results of this thematic analysis explore the physics concepts contained in the art of Bantengan, with the aim of understanding the relationship between movement, force, and balance in the performance, so that it can bridge the gap between theory and practice in science learning.

RESULT | نتائج

This research identifies several physics concepts contained in the Bantengan art form, particularly those related to the performers' movements and physical interactions during the performance. Some of the key concepts identified include force, motion, balance, and Newton's laws.. In addition, this study also analyzes the implications of bantengan art as a problem context in science learning.

Identification of Physics Concepts in Bantengan Art

The Bantengan performance art, performed in a trance state, is rich in cultural and spiritual values (ethnoscience) that can be used in the context of learning problems. The Bantengan performance art, with its foot-stomping, running and headbutting movements, body rotations, jumps, and extreme flexion movements, presents unique scientific challenges. The Bantengan performance art is closely related to the principles of physics. These movements can be linked to Newton's Laws of Motion, Impulse, Momentum, and Rotational Dynamics. The following presents the identification and analysis of concepts such as Impulse, Momentum, Rotational Dynamics, and Newton's Laws in various Bantengan art movements.

Stomping (Trampling)

Dancer The Bantengan art form involves stomping (trampling) by lifting one or both legs until the knees are in a position high enough to be level with the hips. This movement is performed quickly and is driven by a powerful energy push. Next, the legs are dropped back to the ground with very high speed and acceleration. This stomping produces a rhythmic thumping sound. This stomping movement is usually done repeatedly, either alternately or simultaneously with both legs in a short and rapid time. The intensity and frequency of this stomping indicate the power of the manifesting Banteng spirit. The physical aspects contained in the stomping movements of the Bantengan art form are presented in Table 1.

Figure 1. Bullfighting Foot Stamp (generated by AI)

Table 1. The Concept of Physics in the Foot-Stomping Movement of the Bantengan Art

Physics Concept	Bantengan Movement	Ethnoscience Perspective
Newton's Third Law	The dancer's feet exert a large Action Force on the ground. In response, the ground exerts an equal and opposite Normal Force (N) on the dancer's feet.	Culturally, the community interprets the intensity of this force as reflecting the power of the possessing spirit, believed to exceed the physical limits of ordinary human consciousness.
Impulse - Momentum Theorem	The time the foot contacts the ground is very brief, but the change in momentum is enormous due to the extremely high speed of the kick.	Loud, short beats are considered a way to break or expel negative energy at the performance venue.
Gravitational Force	In a state of rest, the Normal Force is only proportional to the weight. In a jolt, the Normal Force is much greater because of the presence ofnegative acceleration (deceleration)which suddenly occurs when the feet touch the ground.	Culturally, the community perceives that the performer's spirit 'ignores' the Law of Gravity while in trance, interpreting the apparent lightness of movement as a manifestation of supernatural power.

As an illustrative estimation to substantiate the kinematic-analysis claim, the impulsive *force generated during a single foot-stomp can be approximated using the impulse–momentum theorem, $F\Delta t = m\Delta v$. Assuming an average adult performer mass of 60 kg, a foot velocity of approximately 2 m/s at ground contact (a conservative estimate derived from qualitative frame-by-frame observation of the analyzed videos, not from motion-tracking measurement), and a contact duration of approximately 0.1 s, the estimated impulsive force is on the order of 1,200 N, roughly twice the performer's body weight. This calculation is offered strictly as an illustrative, assumption-based approximation to demonstrate the plausibility of the physics concepts identified, rather than as a validated empirical measurement, given the qualitative-conceptual scope of the video analysis described in the Methods section.*

Running and Heading

Movement Running and headbutting aims to imitate the aggressive and uncontrolled behavior of a raging bull, which ethnocentrically indicates the peak of the Bull spirit. In the acceleration stage, the bull dancer begins this movement with a rapid transition from a static state to a high running speed. The dancer runs forward with strong, irregular steps. The direction of the run is often straight towards the target object, sometimes also directed towards fellow dancers / bull handlers. In the headbutting movement, the dancer stops his movement suddenly by hitting the target object with the mask (bull's head) or his body. The dancer dives down or forward using the bull's head mask as the main point of contact for the headbutting. The collision is non-elastic, so the energy is absorbed by the bull and the object being hit. The physical aspects contained in the running and headbutting movements of the Bantengan art are presented in Table 2.

Table 2. The Concept of Physics in the Running and Heading Movements of the Bantengan Art

Physics Concept	Bantengan Movement	Ethnoscience Perspective
Newton's First Law	The Bantengan dancer is in uniform linear motion (or acceleration). The body (mass) tends to maintain its motion until an external force act on it (e.g., a collision, the touch of a handler, or fatigue).	Culturally, dancers are believed to be 'spiritually' prepared to handle inertia and sudden acceleration without injury, attributed to the presence of an invisible 'protector'.
Newton's Second Law	While running, the dancer produces positive acceleration driven by muscle forces that are amplified by the trance state.	The quality of the Force (F) produced can be measured from the magnitude of the Acceleration (a) when charging, which correlates with the "rage" of the Bull spirit.
Kinetic Energy	The large kinetic energy from running will be transferred or dissipated when heading.	This is locally interpreted as evidence that the performer's body is "soft" to damage but "hard" in force, allowing collisions with objects without serious injury.

Body Turns

Movement Body rotation in Bantengan art is a form of kinetic expression that depicts the dynamics of the bull in a symbolic and aesthetic context. Kinematically, this movement is included in the rotational motion, where the dancer's body as a system of objects rotates about an imaginary axis that generally passes through the center of mass of the body. In practice, the rotation is performed quickly with support on one leg, while the other leg maintains balance and momentum. This rotational movement produces angular momentum that is maintained as long as the torque acting on the dancer's body is relatively small. Based on the law of conservation of angular momentum, the smaller the body's moment of inertia, for example when bending the body, the greater the angular velocity. This phenomenon is seen when the dancer performs a rapid rotation as part of the movement transition to an attack or evasion position.

Ethnocentrically, the body rotation movement in Bantengan represents the rotation of spiritual energy and the balance between human power and the animal spirit represented in the dance. In local tradition, this rotation movement is seen as a transition between the dimensions of human consciousness and the metaphysical power of the bull, which in practice is presented through harmonious coordination between the body, the rhythm of the music, and the collective movements of the group of performers. Thus, the body rotation movement in Bantengan art reflects the integration between the concept of physical rotation with the cultural and symbolic values of the supporting community. The physical aspects contained in the body rotation movement of Bantengan art are presented in Table 3.

Figure 2. Body Turns Movement (generate by AI)

Table 3. The Concept of Physics in the Rotating Body Movement of the Bantengan Art

Physics Concept	Bantengan Movement	Ethnoscience Perspective
Centripetal Force	A force must act toward the center to maintain circular motion. This force is generated by the dancer's muscular tension and internal balance.	Perfect balance while spinning rapidly is seen as a result of cosmic/spiritual balance, where the spirit helps maintain a stable center of gravity.
Law of Conservation of Momentum	Dancers can change the angular velocity of their rotation by changing their Moment of Inertia, that is, by pulling their arms or legs close to their body (reducing Inertia or, increasing angular velocity).	A sudden increase in rotational speed is considered evidence of energy absorption from the environment or from an incoming spirit.
Centrifugal force	Dancers can counteract the effects of Centrifugal Force which tends to throw the body out of the center of rotation without losing consciousness or becoming dizzy.	This is evidence that the vestibular balance system (in the inner ear) has been 'overridden' or replaced by trance control, according to local belief.

Static Jump

The static jumping movement in the Bantengan art form is a form of physical expression imbued with symbolic meaning and strongly linked to the principles of kinematics and dynamics in physics. This movement typically occurs at the climax of the performance, when the dancer portraying the bull expresses an explosion of energy, strength, and dominance through a vertical leap without a prelude.

Kinematically, a static jump can be categorized as an upward vertical motion. In a static jump, the dancer bends the knees and lowers their center of mass, thereby storing potential energy in the muscles and tendons. The dancer rapidly extends the knee and ankle joints, transferring chemical energy from muscle metabolism into vertical kinetic energy. The dancer's body lifts off the floor and moves vertically. This movement is influenced by gravitational acceleration, which slows the speed until reaching a peak, before the dancer descends again.

From an ethnoscientific perspective, this static jumping movement reflects a symbolic representation of the bull's spiritual strength and magical readiness to face an opponent or mystical situation. The dancers do not simply perform physical activity but also visualize the inner energy that connects the human body with supernatural powers. In a scientific context, this energy can be analogized to the potential mechanical energy stored in the muscular system before being released as kinetic energy. Therefore, the static jumping movement in the Bantengan art form illustrates the synergy between the concepts of force and energy in Newton's Laws and the symbolic and spiritual values of the people of Malang Regency. The physical aspects contained in the static jumping movement of the Bantengan art form are presented in Table 4.

Figure 3. Static Jump (Generate by AI)

Table 4. Physics Concepts in Static Jumping in the Art of Bullfighting

Physics Concept	Bantengan Movement	Ethnoscience Perspective
Potential Energy	The dancer exerts a great deal of effort on the ground (pushing force) to generate enough initial kinetic energy to achieve maximum jump height.	The high jump is often interpreted as a momentary withdrawal from the physical world or as a symbol of the desire to fly (lightness).
Kinetic Energy and Gravity	At the highest point of the jump, all Kinetic Energy is converted into Gravitational Potential Energy.	Culturally, the ability to jump high and land without injury is considered by the community as evidence of anti-gravity powers or spirit protection, rather than as a literal suspension of gravity.
Thrust Force	Analyze the total thrust generated by the dancer's muscles on the ground during the take-off phase to determine the initial vertical acceleration.	This movement is locally believed to visualize a power of the push from within (spirit) that goes beyond the limits of human muscles.

Extreme Flexion Movement

The extreme flexion movements in the Bantengan art form are a form of body dynamics that demonstrate the flexibility, muscle strength, and balance control of the Bantengan performer. This movement is seen when the Bantengan dancer (carrier of the mask and bull frame) flexes his body to the maximum, including his knees, hips, and spine, to create a visual effect that resembles the behavior of a bull preparing to attack.

Kinematically, this extreme flexion movement occurs through a decrease in the angle between body segments, particularly at the knee and hip joints. This process results in the center of mass dropping significantly closer to the ground, thereby increasing the dancer's dynamic stability. This is important because in the following moments, explosive movement transitions often occur, such as jumps or head jerks that require strong initial balance. Based on Newton's Second Law, extreme flexion involves large muscle forces acting against the force of gravity. A normal force from the ground reacts upward, thus maintaining the vertical stability of the body system. When the dancer shifts from flexion to extension (the movement to rise again), positive acceleration occurs, indicating a change in body momentum, due to the sudden increase in muscle force.

In the context of ethnoscience, this extreme flexion movement holds not only physical value but also symbolic and cultural significance. Bending the body to a low position symbolizes the banteng's respect, humility, and readiness to face threats. This movement knowledge is passed down through the collective body practices of bantengan practitioners, but also embodies complex biomechanical principles and Newton's laws of motion. The physical aspects of the extreme flexion movements of Bantengan art are presented in Table 5.

Figure 4. Flexion Extreme Movement

Table 5. The Concept of Physics in the Extreme Flexion Movement of Bantengan Art

Physics Concept	Bantengan Movement	Ethnoscience Perspective
Moment of Style	The body is bent or twisted at the joints to extreme limits, producing enormous Moments of Force on the joints and ligaments.	The body's ability to withstand extreme torque without tearing ligaments is considered inner strength or a spiritually 'tendered' body.
Vibration and Frequency	The body experiences rapid and repeated vibrations (tremors), the frequency of which can be measured.	This vibration is culturally believed to symbolize the internal struggle between the spirit and the body, or interpreted as a form of rapid release of energy.
Body Pressure and Balance	The body position is unstable (e.g., bending very low or kneeling with an arched back), but they maintain balance without falling.	Balance maintained in this biomechanically unstable position is locally believed to indicate the center of gravity being 'reset' by non-physical conditions.

Implications Bantengan Art in Science Learning

Learning Natural Sciences in elementary schools requires the integration of scientific knowledge, socio-cultural contexts, and local wisdom values to not only transfer abstract concepts but also foster meaning in students' lives (Ee et al., n.d.; Wandi et al., 2023). Within the ethnopedagogical paradigm, local culture, such as bantengan art, serves as a pedagogical tool that represents scientific knowledge in the form of cultural practices (Damayanti & Kuswanto, 2021; Elvianasti et al., 2023). Through this integration, science is not simply taught as a collection of facts and laws, but as a social construct that grows from human interactions with their environment (Rahmasari & Kuswanto, 2023).

The movements in bantengan art incorporate various aspects of physics relevant to the topics of kinematics and dynamics in the science curriculum (Astuti et al., 2022; Wulansari & Admoko, 2021). For example, the stomping motion illustrates the application of force to the ground, which produces a reaction according to Newton's third law (Sholahuddin & Admoko, 2021; Susanto et al., 2021). Teachers can encourage students to analyze the magnitude of the force generated based on the mass of the performer and the acceleration of their body movements, so that the concept of force is understood not only symbolically but also through real-life experiences (Sari et al., 2025).

The running and heading movements represent the principles of momentum and impulse(Astuti et al., 2022; Damayanti & Kuswanto, 2021). When the bull's head dives, a rapid change in momentum occurs due to the force of contact with another object (Wulansari & Admoko, 2021). This activity can be used as a learning context for simple experiments on the law of conservation of momentum using miniature models or digital simulations (Sholahuddin & Admoko, 2021). Meanwhile, the spinning and jumping movements illustrate the combination of centripetal force and potential-kinetic energy (Rumiati et al., 2021; Sholahuddin & Admoko, 2021). When a matador spins, a force is applied toward the center of the circle, so that his body's circular trajectory is maintained (Handayani et al., 2016). Students can be encouraged to examine the relationship between angular velocity and centripetal force in the context of local culture, not only through mathematical formulas (Wulansari & Admoko, 2021). This approach is in line with the principles of contextual learning, which emphasizes the application of concepts through real-life contexts (Wandi et al., 2023).

Furthermore, the players' extreme flexion movements demonstrate the biomechanical adaptation of the human body to acceleration and gravitational forces (Elvianasti et al., 2023). Teachers can encourage students to measure knee angles and foot contact times to understand normal forces and muscle torques (Elvianasti et al., 2023). Thus, bantengan can be used as an ethnoscience laboratory that integrates empirical observation and scientific analysis (Astuti et al., 2022).

Ethnoscience in science learning plays a crucial role in developing scientific literacy rooted in local culture (Zulirfan et al., 2023). Through bantengan activities, students not only learn Newton's laws but also develop the ability to reason, predict, and evaluate natural phenomena based on contextual experiences (Sholahuddin & Admoko, 2021; Susanto et al., 2021). According to Bybee, scientific literacy encompasses not only conceptual mastery but also an awareness of the relevance of science in social and cultural life. This perspective highlights how ethnoscience can bridge the gap between abstract scientific principles and concrete cultural experiences, thereby fostering a deeper and more relevant understanding of scientific concepts (Zulirfan et al., 2023). Such an approach encourages students to analyze how traditional practices, such as those found in Bantengan, implicitly apply scientific principles, thereby fostering a more holistic appreciation of cultural heritage and scientific inquiry.

By analyzing bantengan movements, students internalize the interconnectedness of the body, the environment, and the physical laws that govern both (Elvianasti et al., 2023; Kasi et al., 2022). This approach strengthens students' metacognitive abilities in connecting empirical experiences with theoretical representations (Mudau & Tawanda, 2022). In the long term, this model supports the development of a local identity-based curriculum, where science is not viewed as Western knowledge separate from students' cultures, but rather as part of local knowledge systems (Boakye-Yiadom et al., 2025; Zulirfan et al., 2023). This integration enables students to critically engage with indigenous knowledge systems and apply scientific principles to real-world cultural challenges, ultimately fostering a deeper understanding of both (Idul & Fajardo, 2023; Mudzamiri, 2019). This pedagogical strategy, by leveraging cultural context, enables learners to bridge the gap between abstract scientific theories and practical applications within their own heritage, thus making science more meaningful and accessible.

The practical implication of these findings is the opportunity to develop project-based or inquiry-based learning models based on ethnoscience (Boakye-Yiadom et al., 2025; Ee et al., n.d.; Rosmiati et al., 2025). For example, elementary-school students can analyze Bantengan movements through recorded video or photographic sequences, design simplified miniature models or digital simulations of the observed forces, and write the results in a scientific report, without physically imitating the high-risk elements of the performance such as headbutting or extreme flexion. For secondary-school or university students, a supervised mini-Bantengan performance analyzing the forces acting at each stage of movement may be undertaken. This activity not only hones understanding of physics concepts but also fosters critical thinking, data literacy, and scientific communication skills (Syaifuddin et al., 2025). This interdisciplinary approach, grounded in local cultural practices, can significantly increase student engagement and motivation in STEM fields, in line with recent research on the benefits of culturally responsive pedagogy and project-based learning (Krupa et al., 2025; Rillero et al., 2025; TSUTSUMI, 2025). These models foster deeper conceptual understanding by allowing students to apply theoretical knowledge to culturally relevant practical contexts, thereby fostering scientific thinking and problem-solving skills (Chen, 2023). Integrating cultural contexts, such as bantengan, into problem-based or project-based learning models has been shown to deepen scientific understanding and revise conceptual frameworks by providing contextual stimuli from everyday life (Rahmasari & Kuswanto, 2023).

Furthermore, teachers can develop local wisdom-based teaching modules that integrate bantengan into the "Force and Motion" theme in the Independent Curriculum (Hartini et al., 2018; Rosmiati et al., 2025). These modules can include field observations, motion simulations, simple experiments, and reflections on the cultural values embodied in bantengan practices (Ee et al., n.d.). Through culturally rooted learning, science becomes not only an academic discipline but also a means to preserve and actualize the nation's cultural identity (Kasi et al., 2022). This integration not only increases student engagement by making science relevant to their lived experiences but also fosters a deeper appreciation of local knowledge systems (Boakye-Yiadom et al., 2025; Zulirfan et al., 2023). This approach can also foster an understanding of environmental issues and sustainable practices embedded in local wisdom, aligning scientific principles with community-based ecological knowledge (Lestari & Suyanto, 2024).

DISCUSSION | مناقشة

Research shows that Bantengan art has great potential as an ethnoscience context capable of contextualizing physics concepts such as force, motion, momentum, and balance into science learning (Astuti et al., 2022; Sholahuddin & Admoko, 2021; Wulansari & Admoko, 2021). The integration of local knowledge and science not only broadens the scope of application of physics theory but also reconstructs the relationship between science and culture in educational contexts

(Kasi et al., 2022). Through an ethnopedagogical approach, Bantengan functions not only as an illustrative medium but also as a local knowledge system that represents scientific phenomena through symbols, values, and social practices (Elvianasti et al., 2023). This method aligns students' everyday cultural experiences with formal physics concepts to foster deeper understanding (Kamilah et al., 2025). Furthermore, it strengthens the bridge between abstract theory and concrete cultural scenarios through its application in the real world (Wandi et al., 2023).

Kinematic analysis of the Bantengan movement shows that the entire body dynamics of the dancers represent Newton's laws (Astuti et al., 2022; Sholahuddin & Admoko, 2021). The foot-stomping movement demonstrates the application of Newton's Third Law, while the running and heading movements illustrate the principles of impulse and momentum in collisions. The body's rotational movement reflects the law of conservation of angular momentum, and the static jump illustrates the conversion of potential energy into kinetic energy (Handayani et al., 2016; Rumiati et al., 2021). These findings align with international research confirming that movement-based learning can significantly strengthen conceptual understanding of physics(Skulmowski & Rey, 2018; Wandi et al., 2023). Ethnophysics analyses of other traditional Indonesian dances, such as Soya-Soya and Dhadak Merak (Reog Ponorogo dance), have also revealed physics concepts such as equilibrium forces, moments, and various principles of motion that can be applied in science education (Wulansari & Admoko, 2021). Biomechanical models of martial arts movements that incorporate rotation, angular momentum, and striking further validate these dynamics in cultural performances (Merk & Resnick, 2021). Thus, Bantengan can be viewed as a living laboratory that allows students to interpret scientific concepts through empirical and cultural experiences. From a pedagogical perspective, Bantengan-based learning supports an embodied learning paradigm, where scientific knowledge is constructed through bodily activity, movement, and sensorimotor interactions (Castro-Alonso et al., 2024; Macrine & Fugate, 2021). This approach has been shown to enhance students' conceptual understanding and learning engagement in science (Lyu & Deng, 2024; Mavilidi et al., 2022). In the context of physics, the bodily experience of a jolt, a spin, or a jump allows students to directly connect the sensation of force and acceleration with Newton's laws. This strengthens the link between physical experience and abstract understanding, as demonstrated in a meta-analysis that embodied learning has a positive effect on science achievement (Lyu & Deng, 2024). This active engagement facilitates a more intuitive understanding of complex physical phenomena, moving beyond rote learning to a deeper, experiential understanding of scientific principles (Kersting et al., 2024; Zheltukhina et al., 2023). It is important to note that this embodied dimension must be applied with developmental caution. Because Bantengan choreography involves trance-related actions, headbutting, and extreme flexion that carry a genuine risk of injury if physically imitated, direct sensorimotor replication of these movements is appropriate only for secondary-school (SMP/SMA) or university students under proper supervision, and is not recommended for elementary-school (SD) learners. Specifically, replicating the safer elements of Bantengan, such as controlled foot-stomping and simple rotational movements, allows older students to sensorimotorically experience Newton's third law, the impulse-momentum principle, and the conservation of angular momentum (Merk & Resnick, 2021; Wulansari & Admoko, 2021). For secondary and higher-education learners, this kinesthetic immersion in cultural dance not only reinforces physics concepts through physical demonstrations, but also encourages culturally responsive science education and preserves local wisdom (Kontra et al., 2015).

The integration of scientific and spiritual dimensions in Bantengan also represents an epistemological dialogue between modern and local knowledge (Kasi et al., 2022; Snively &

Corsiglia, 2000). Concepts such as "bull spirit" or "inner energy" are not simply forms of traditional beliefs, but rather expressions of the community's symbolic knowledge of energy, balance, and the power of nature. In the context of science learning, this interpretation can be directed toward developing epistemological awareness, the realization that science is not separate from culture but rather rooted in human experience(Meyer & Crawford, 2011; Zulirfan et al., 2023). This reflective approach helps students understand that scientific and cultural knowledge complement, rather than exclude, each other (Boakye-Yiadom et al., 2025). By recognizing spiritual elements as epistemic resources, educators enable students to cross cultural boundaries between Indigenous ways of knowing and Western science, fostering epistemic insight and respect for diverse knowledge systems (Snively & Corsiglia, 2000; Zidny et al., 2020). Such dialogues transform science education into a holistic process, where learners integrate cultural narratives with empirical inquiry to address real-world phenomena such as energy dynamics in cultural performances (Michie et al., 2023; Robles-Piñeros et al., 2020). Ultimately, this fosters transformative learning experiences that value Indigenous knowledge alongside scientific principles, enhancing motivation and conceptual depth in physics (Boakye-Yiadom et al., 2025; Zidny et al., 2020).

However, the integration of ethnoscience into science learning requires methodological caution. Cultural reductionism poses a significant challenge, especially when cultural elements are used merely as learning ornaments without strong conceptual elaboration (Zinyeka et al., 2016). Such superficial application fails to address the nuanced cultural and contextual dimensions, which are essential for deep conceptual understanding in physics education (Wandi et al., 2023). Therefore, teachers need transformative pedagogical competence, namely the ability to interpret cultural meanings within a scientific framework without losing their symbolic value (Richelle et al., 2017). This requires providing educators with specific pedagogical content knowledge through targeted professional development, including hands-on training and regular needs assessments to bridge the epistemological gap between local wisdom and formal science (Mahmud et al., 2018; Petersen, 2020). This approach is in line with recent research recommendations that emphasize the need for the development of ethnopedagogy-based teaching modules and teacher training to ensure authentic and sustainable culture-science integration (Zaki et al., 2024).

From an instructional design perspective, the results of this study reinforce the relevance of project-based learning and ethnoscience-based contextual teaching (Boakye-Yiadom et al., 2025; Rillero et al., 2025). Through activities such as observing the Bantengan movement, force and momentum experiments, and performative video documentation, students can apply physics principles in real-life contexts. Studies in Norway and Finland have shown that project-based approaches that combine movement and cultural experiences improve students' scientific literacy and learning motivation(Bolick et al., 2024; Hansen et al., 2023; Sormunen et al., 2023). The integration of local wisdom into this project-based model encourages deeper learning, cultural relevance, and preservation of cultural heritage while fostering collaboration, problem-solving, and creativity (Zaki et al., 2024). This is in line with Indonesia's independent curriculum, where project-based learning enhances conceptual understanding, 21st-century skills, and engagement through meaningful real-life projects (Rosmiati et al., 2025).

Conceptually, Bantengan arts-based science learning has multidimensional value (Boakye-Yiadom et al., 2025). Scientifically, this learning contextualizes the laws of physics in an applicable and concrete way; pedagogically, it encourages active, reflective, and collaborative learning experiences; and culturally, it strengthens local cultural identity and preservation (Kasi et al., 2022). However, the implementation of this model requires systemic support, both in the form of cross-disciplinary curriculum development and further research testing its effectiveness at various levels of education (Rosmiati et al., 2025). This can be enhanced through a project-based learning model integrated with local wisdom, which enhances problem-solving, collaboration, creativity, and cultural relevance, as demonstrated in recent studies in Indonesia (Zaki et al., 2024). Empirical evaluation of teacher readiness, student engagement, and scalability across contexts will further validate and refine this approach for wider adoption (Sari et al., 2025). Thus, Bantengan art is not only a cultural heritage but also a strategic pedagogical instrument for building scientific literacy rooted in national identity.

CONCLUSSION | خاتمة

This study shows that the Bantengan art form contains rich and relevant physics concepts for analysis in science learning. Through an ethnographic approach, it was found that the main movements in Bantengan, such as foot stamping, running and heading, body rotation, static jumps, and extreme flexion, represent various basic principles of physics, including Newton's laws, momentum, impulse, mechanical energy, torque, and rotational dynamics. The integration of scientific concepts and cultural meanings results in a more holistic understanding, where science is not only seen as abstract knowledge, but also as part of the cultural practices that live in society.

These findings confirm that Bantengan has great potential as an ethnoscience-based learning context that can enhance students' conceptual understanding, engagement, and scientific literacy through cultural experiences close to everyday life. Movement-based learning and cultural contexts have been shown to strengthen the connection between physical experiences and students' theoretical understanding. For further development, it is recommended that teachers integrate Bantengan into project-based or inquiry-based learning models and develop local wisdom-based teaching modules that emphasize the relationship between culture and science. Support for teacher training and contextual curriculum development is needed so that ethnoscience integration can be implemented authentically, deeply, and sustainably. Ultimately, by demonstrating that the mechanics of Newtonian physics and the spiritual meanings attributed to the Bantengan performance can be examined side by side without one negating the other, this study deconstructs the rigid dichotomy between "modern science" and "traditional belief," showing that the two can engage in a harmonious dialogue within science education.

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