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An Ethno-Pedagogical Study of the Ketoprak Wahyu Manggolo Traditional Performing Arts: A Scientific Approach to the Physics Concepts of Force and Motion

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A B S T R A C T

In an era of globalization that threatens the loss of local cultural identities, this study explores Ketoprak as a traditional Javanese dramatic art in Pati and Rembang, positioning it as a form of ethno-pedagogy that conveys character education through moral narratives and improvisational performance, with an urgent need for preservation due to the degradation of its practices. The main purpose is to reveal the local wisdom embedded in Ketoprak performances by addressing questions related to the representation of Javanese moral values, the challenges of safeguarding the tradition, and its potential use as learning material. Using a qualitative ethnographic design, the research employed participatory observation in two groups (Cahyo Mudo and Wahyu Manggolo) in October 2025, semi-structured interviews with ten informants, and thematic analysis. The findings show that Ketoprak serves as a medium of social cohesion through elements such as ontowencono, humorous dialogues, and messages of karma, while facing the challenge of declining interest among younger generations, which is addressed through adaptive strategies such as modern staging and community-based revitalization. These efforts contribute to the integration of traditional arts into formal education in the form of the results of the reconstruction of scientific knowledge of ketoprak for science learning (physics concepts: force and motion).

INTRODUCTION

Modern science strives to be relevant to life, especially in Indonesia with its rich multiculturalism. Local wisdom and ethnoscience can bridge this relevance (Handoyo et al., 2021). Ethnoscience, as a study of indigenous peoples' knowledge systems about nature, has the potential to enrich formal science curricula and improve understanding of scientific concepts through context (Wardani et al., 2020). The integration of ethnoscience in science education not only introduces traditional knowledge but also fosters cultural appreciation and creates meaningful learning (Purwanto et al., 2021), in line with 21st-century education that emphasizes critical thinking, creativity, and interdisciplinary connectivity.

Local wisdom embodies ethnoscience and serves as both a cultural identity and a guide for life (Rahmadani et al., 2022). Globalization poses a threat to local wisdom if it is not properly preserved (Wulansari et al., 2023). The adoption of ethnoscience in science education is therefore crucial (Ardiyanti & Fitriani, 2020) as a pedagogical strategy to bridge scientific concepts with students' real-life experiences while preserving the nation's intellectual heritage. Learning based on local wisdom has been proven to significantly enhance students' motivation and learning outcomes (Sudjatmiko et al., 2021).

Ketoprak, a traditional performing art rooted in Javanese culture, functions not only as entertainment but also as a medium for transmitting moral, social, and natural knowledge values (Astika et al., 2020). Ketoprak stories often contain metaphors about life and human–nature relationships, reflecting the worldview of the local community (Yana & Susilaningsih, 2022). These narratives have the potential to embed ethnoscientific concepts relevant to science education, such as traditional agricultural systems, herbal medicine, and understandings of natural phenomena (Pradana & Sutanto, 2023), thereby revealing rich pedagogical resources that remain underutilized in formal education.

THEORETICAL REVIEW

Pati, as a center of Javanese culture, possesses a strong Ketoprak tradition (Wahyudi et al., 2020). Ketoprak performances in Pati, characterized by distinctive plots and staging, preserve information about community values, history, and interactions with the environment (Suprapto & Susanto, 2021). Their educational potential lies in illustrating abstract scientific concepts in a concrete manner for students who are familiar with local culture (Santoso et al., 2022). However, research on reconstructing scientific concepts and pedagogical values from Ketoprak Pati into science learning remains limited, indicating a significant research gap.

Failure to utilize local wisdom and ethnoscience embedded in Ketoprak within science learning may result in several negative impacts. First, science learning becomes less relevant and appears unfamiliar, leading to decreased student motivation and understanding (Hidayah et al., 2020). Second, cultural erosion and the loss of local wisdom may occur due to a lack of regeneration and appreciation (Anggraini et al., 2023). Third, education misses the opportunity to foster holistic thinking that integrates science with the humanities and socio-

cultural contexts (Sari & Setyarsih, 2021). Fourth, such neglect may produce graduates who are academically competent but lack a strong cultural identity.

Ketoprak can serve as an effective medium for science learning through an ethnoscience-based approach. Storylines, dialogues, and characters in Ketoprak often imply traditional knowledge of natural phenomena, such as planting cycles, traditional medicine, or basic astronomy (Nuraini et al., 2022). Agricultural-themed performances can be linked to science topics such as ecosystems, plant nutrition, and the water cycle (Wijaya & Wahyuni, 2020). The use of traditional herbal remedies can serve as an entry point for discussing natural chemical compounds or biological principles (Setiawan et al., 2023). Reconstructing these concepts enables science learning to become more contextual, engaging, and deeply rooted in local culture.

This study is grounded in constructivist theory, which posits that knowledge is actively constructed through experience and interaction with the environment (Dewi et al., 2021). Local wisdom and ethnoscience embedded in Ketoprak function as a "bridge" that enables learners to construct new scientific understanding by connecting it to their existing cultural knowledge schemas (Rahayu et al., 2020). In addition, this research draws on the principles of Culturally Responsive Teaching, which recognize students' cultural backgrounds as primary educational resources (Astuti et al., 2022). Accordingly, Ketoprak serves both as a source of learning content and as an effective pedagogical strategy.

Based on this context and urgency, the present study is of significant importance. The exploration of Ketoprak Pati to reconstruct scientific concepts and pedagogical values is expected to contribute to the preservation of local wisdom, the enrichment of ethnoscience, and the development of innovative science learning models (Suryani et al., 2021). The findings are anticipated to provide guidance for educators and curriculum developers in integrating local culture into science education, thereby fostering meaningful and contextual learning while nurturing environmental awareness and a strong sense of national identity.

METHODOLOGY

Observation Design

This study employed a qualitative observational design with an ethnographic approach, emphasizing an in-depth understanding of cultural contexts and pedagogical implications within traditional performing arts. A qualitative approach was selected due to the exploratory nature of the research, which aims to identify implicit physics concepts embedded in artistic movements rather than to measure numerical variables rigorously. The design incorporates participatory elements to capture spontaneous dynamics such as *ontowencono*, aligning with ethnopedagogical principles that position culture as a primary data source (Creswell & Poth, 2018, adapted from ethnographic studies of Indonesian traditional arts).

Location and Time of Observation

Observations were conducted on October 10, 2025. The initial observation took place in the afternoon (15:45–17:15) in Kaliombo Hamlet, Kaliombo Village, Sulang District, Rembang Regency, featuring a performance by *Ketoprak Cahyo Mudo*. On the same date, evening observations were continued (20:50–01:00) in Gedangan Village, Rembang City District, to observe a performance by *Ketoprak Wahyu Manggolo*. Although this group originates from Juwana District, Pati Regency, its performance in Sulang reflects the mobility of Ketoprak troupes and sustained community demand for this traditional art form.

Subjects and Objects of Observation

The subjects of observation included key artistic practitioners, notably Mbah Mogol (founder and director). Additionally, purposive sampling was applied to select Mbak Arum (portraying *Mbok Emban* in the *Taman Sari* scene) and Rega (an 11 year old child performer). The primary objects of observation were performance elements, including *serimpi* dance movements, comedic battle scenes (*dagelan*), *ontowencono* improvisation, and performer–audience interactions. Observations also encompassed the social environment, particularly Javanese cultural norms influencing movement, to contextualize findings within an ethnopedagogical framework.

Data Collection Techniques

Data were collected through non-intrusive participatory observation, in which the researcher observed and documented movements directly without disrupting the flow of the performance. Supporting techniques included semi-structured interviews with key participants (30–45 minutes per session), visual documentation (photographs and motion videos), and secondary literature review on ethnopedagogy and the physics of art. This multi-method approach ensured data triangulation by integrating verbal narratives with visual observations to validate implicit findings, such as the manifestation of Newton's laws in improvisational movements (Yin, 2018).

Observation Instruments

The primary instrument was a structured observation sheet comprising three categories: (1) movement descriptions (speed, direction, interaction forces); (2) cultural context (e.g., *ontowencono* improvisation); and (3) pedagogical implications (moral values). Audio-video recording devices (HD-resolution smartphones) were used to document dance and battle movements, while digital field notes captured direct quotations and narrative patterns. These instruments were designed to be adaptive and ethically grounded, adhering to qualitative research ethics to respect participant privacy.

Data Analysis Techniques

Data analysis was conducted inductively using qualitative procedures, including: (1) transcription of interviews and observational records; (2) thematic coding to identify patterns such as uniformly accelerated motion (GLBB) in *serimpi* dance movements; (3) contextual interpretation through comparison of primary data with ethnophysics literature; and (4) triangulation to enhance validity. Findings were presented using descriptive-narrative techniques, followed by thematic analysis based on Miles and Huberman (2014) to link physical movement phenomena with ethnopedagogical principles. This iterative process ensured coherence between empirical data and the research objectives.

RESULTS AND DISCUSSION

Description of Local Wisdom

Ketoprak is a traditional Javanese theatrical art form. Performances are typically accompanied by Javanese *gendhing* with distinctive rhythms, commonly referred to as *Ketoprak Gendhing*. The stories presented in Ketoprak vary widely, ranging from historical chronicles (*babad*) and legends to fictional narratives. Ketoprak plays a significant role in Javanese society, not only as a form of entertainment but also as a medium for conveying moral messages and social criticism. As noted by Asnimawati (2025), Istiningsih (2025), and Suanda (2024), local wisdom such as Ketoprak holds substantial potential as an approach for developing instructional materials and preserving cultural values.

An in-depth observation of Ketoprak as local wisdom was conducted at two main locations in Pati and Rembang Regencies, focusing on two performing art groups: *Ketoprak Cahyo Mudo* in Juwana District, Pati, and *Ketoprak Wahyu Manggolo* in Jakenan District, Pati. Additionally, interactions with Ketoprak artists were carried out in Kaliombo Hamlet, Kaliombo Village, Sulang District, and Gedangan Village, Rembang City District. These locations were selected due to the richness and continuity of Ketoprak traditions that remain actively practiced and developed, enabling a comprehensive capture of the essence of local wisdom.

1) Field Observation Process

Field observations employed participatory methods and in-depth interviews, complemented by audio-visual documentation and field notes. The focus encompassed all aspects of the performance, from backstage preparations, makeup, and costumes to rehearsals and the main performance. Dialogues among performers, non-verbal expressions, spontaneous interactions with the audience, and the overall atmosphere of the performance were closely observed to capture Ketoprak as a reflection of socio-cultural life (Suanda, 2024; Asnimawati, 2025).

Observations of *Ketoprak Cahyo Mudo* were conducted on October 10, 2025, from 15:45 to 17:15, in Kaliombo Hamlet, Kaliombo Village, Sulang District. Although originating from Juwana, the group demonstrated high mobility and strong community demand for Ketoprak performances. Observations highlighted stage preparation, costume changes, and interactions among three main performers.

Meanwhile, *Ketoprak Wahyu Manggolo* was observed later that evening in Gedangan Village, Rembang City District, from 20:50 to 01:00. This observation was more comprehensive, covering the entire performance sequence from the opening *gendhing*, the main storyline, battle scenes, comedic interludes (*dagelan*), to the *Taman Sari (Emban)* segment.

Observations revealed intense backstage activity, strong communal cooperation, and performer cohesion, reflecting core Javanese socio-cultural values. The prominent storyline depicted competition among Ketoprak groups and efforts to attract audience attention. Dialogic interactions between performers and audiences indicated that Ketoprak is not merely one-way entertainment but functions as a social bond that creates shared cultural experiences (Naden, 2023; Talan, 2025).

2) Interview Results with Ketoprak Performers

Interviews were conducted with group leaders, senior performers, and child performers to obtain holistic perspectives on challenges, expectations, and core values upheld within Ketoprak practice. Mbah Mogol, founder of *Ketoprak Wahyu Manggolo*, explained that the group was established in 2007 with a philosophical meaning: "*Wahyu*" signifies divine guidance, while "*Manggolo*" refers to leadership or pioneering spirit. The group has been based in Jakenan, Pati, since 2009. His motivation lies in preserving cultural heritage while providing entertainment imbued with moral and spiritual values (Hidayati, 2025). Training is conducted spontaneously (*ontowencono*), without fixed scripts, fostering creativity, verbal adaptability, and memory skills. Performances emphasize moral messages, particularly the concept of "*tumindak'e elek*" (wrongdoing), which inevitably results in consequences, while good deeds lead to positive outcomes (Suanda, 2024). He also highlighted challenges such as managing over 100 crew members, maintaining harmony, and preserving the structural integrity of performances from opening to closing *dagelan*.

Mbak Arum, a senior performer portraying *Mbok Emban*, emphasized her role in the *Taman Sari* segment, which provides light entertainment between the main storyline. Having joined the group in 2017, she stressed dedication, stamina, and professionalism. The performance structure includes opening dances, standard or humorous narratives, *Taman Sari* scenes, battle sequences, and closing *dagelan*. Challenges include makeup issues, weather conditions, and uncertain audience size; however, performers gain a strong sense of

togetherness, entertainment, and financial support for daily life. Mbak Arum also highlighted moral values and historical learning embedded in Ketoprak, including language development and improvisational skills (Septina, 2025; Munawwarah, 2025).

Rega, an 11-year-old child performer, represents the regeneration of young Ketoprak artists. He balances school and performances and perceives Ketoprak as an enjoyable experience. The spontaneous nature of performances trains acting skills, quick thinking, adaptability, and creativity competencies relevant to 21st-century skills development (Mukti, 2022).

Educational and Ethno-pedagogical Values Embedded in Ketoprak

Ketoprak performing arts extend far beyond their function as entertainment, serving as a repository of educational and ethno-pedagogical values that are essential for character formation. Ethno-pedagogy is understood as ethnically based learning, functioning both as a source and a medium of instruction (Fatmi, 2022); thus, Ketoprak can serve as an effective instrument for transmitting noble cultural values to younger generations. As a form of local wisdom, Ketoprak contains rich educational and ethno-pedagogical dimensions, in which learning approaches integrate local cultural values with scientific concepts and offer the potential to bridge the gap between traditional and modern knowledge systems (Septina, 2025; Asnimawati, 2025).

The first dimension is character education, as Ketoprak narratives frequently convey moral messages concerning good and evil, honesty, and justice. The concept of "*tumindak'e elek*" (wrongdoing) leading to punishment, while virtuous actions result in positive rewards, implicitly teaches ethical and moral values to audiences of all ages (Hidayati, 2025). Second, Ketoprak enhances historical and cultural literacy through stories of kingdoms, legends, and wayang figures that constitute an integral part of Javanese history, enabling audiences to learn about customs, value systems, and cultural heritage (Suanda, 2024). For children such as Rega, this approach provides an engaging and enjoyable medium for becoming familiar with their cultural roots. Third, Ketoprak develops language and communication skills through the rich use of the Javanese language, ranging from everyday speech to *krama inggil*, as well as improvisation (*ontowencono*), which sharpens rapid thinking and verbal adaptability (Munawwarah, 2025). Fourth, Ketoprak instills collaboration and teamwork, as performances involve various roles such as actors, makeup artists, costume designers, and gamelan musicians, thereby teaching the importance of collective responsibility and cooperation (Putra, 2025a). In addition, Ketoprak encourages creativity and adaptability through dynamic stage improvisation (Mukti, 2022). Finally, it fosters social sensitivity and empathy by inviting audiences to understand diverse perspectives and emotional expressions embodied by the characters.

Interviews with Ketoprak practitioners further reinforce these values. Mbah Mogol, a senior Ketoprak figure, emphasized that each performance

contains profound philosophical teachings, particularly *pitutur* (moral guidance) regarding the consequences of "*tumindak'e elek*" and the importance of virtuous behavior. These implicitly conveyed moral messages constitute the essence of character education. He also highlighted preservation challenges, such as crew management and performer regeneration, which require managerial competence within the context of traditional arts an issue that aligns with Suanda's (2024) view of ethno-pedagogy as a medium for preserving local wisdom. Meanwhile, Mbok Emban Mbak Arum emphasized the entertainment aspect, togetherness, and Ketoprak's function as a medium for historical learning through narratives of kingdoms, heroic struggles, and past events that cultivate patriotic values. She also acknowledged the dynamics of two-way communication between performers and audiences, which can influence storylines and improvisation, consistent with Handayani et al.'s (2022) perspective on ethno-pedagogy as an adaptive learning model..

Additional perspectives were provided by Rega, an 11-year-old Ketoprak performer, who illustrated the balance between formal education at school and non-formal learning through his involvement in Ketoprak. For him, Ketoprak fosters improvisation skills, creativity, and self-confidence, serving as a concrete example of how learning can occur through cultural practice. This aligns with the definition of ethno-pedagogy as ethnically based learning that functions both as a source and a medium of instruction (Handayani et al., 2022). Rega's experience demonstrates that traditional arts can effectively develop life skills while simultaneously nurturing a sense of love for local culture from an early age. Such local wisdom-based approaches, as explained by Fatmi (2022), are highly relevant in thematic learning because they enable the integration of multiple disciplines within the socio-cultural context of the community.

Student's Personal Reflection on the Relevance of Local Wisdom in Contemporary Education

Conducting an in-depth observation of Ketoprak performances in Pati and Rembang Regencies has broadened my understanding of the richness and relevance of local wisdom within the context of modern education. Amid the forces of globalization that tend to homogenize cultures, Ketoprak emerges as a stronghold of cultural identity that not only entertains but also provides profound educational value.

This traditional art form demonstrates that learning is not confined to formal educational institutions. Through its narrative structures, dialogues rich in subtle yet meaningful social critique, and characters that represent diverse human traits, Ketoprak organically conveys moral, ethical, and social values. Witnessing firsthand how Mbah Mogol patiently leads more than one hundred crew members, and how Mbak Arum passionately shares both the joys and challenges of her artistic journey, reflects the extraordinary dedication of Ketoprak practitioners in preserving cultural heritage. Even Rega, a child performer, illustrates that appreciation for traditional arts can develop from an early age and become an integral part of personal growth.

In the context of contemporary education, local wisdom such as Ketoprak holds significant potential for curricular integration. The ethno-pedagogical

approach embodied in Ketoprak offers a solution for creating learning experiences that are more contextual and meaningful for students. For instance, historical narratives presented in Ketoprak can be utilized as interactive learning materials in history education. The improvisational nature of Ketoprak performances can also cultivate students' critical thinking, creativity, and collaboration skills competencies that are essential in 21st-century learning. Moreover, learning moral values such as "*tumindak'e elek*" (wrongdoing) and virtuous behavior through performing arts may be more effective in shaping Pancasila character than conventional classroom lectures.

Nevertheless, the preservation of Ketoprak in the modern era faces considerable challenges. Declining interest among younger generations, limited regeneration of artists, and competition with instant digital entertainment pose serious threats to its sustainability. Therefore, collective efforts from various stakeholders including government institutions, academics, communities, and art practitioners are essential to support and develop this traditional art form. Innovative revitalization and promotional programs, as discussed by Prasetyo and Darmaningtyas (2022) in their study on strategies for preserving traditional theater arts, are crucial to ensuring that Ketoprak not only survives but also continues to evolve and gain wider recognition.

As a university student, I feel a personal responsibility to contribute to these preservation efforts. Based on this observation, I believe that creative and adaptive approaches are essential for example, presenting Ketoprak performances with modern elements without compromising their core values, or utilizing social media as a platform for promotion and education about Ketoprak's cultural significance. Through such efforts, Ketoprak as a form of local wisdom can remain relevant and make a meaningful contribution to shaping future generations who are culturally grounded and possess strong character.

Results of the Reconstruction of Science Concepts and Learning Outcomes (CP) for Phase D Science

The results of observation and reconstruction analysis indicate that Ketoprak local wisdom can be comprehensively integrated with junior secondary school Science Learning Outcomes (Capaian Pembelajaran/CP), the STEM approach, 21st-century learning, and the eight dimensions of Deep Learning. In the first CP, related to the identification of living organisms, taxonomic concepts are reconstructed through Ketoprak narratives featuring animals or plants, such as the story of Raden Kajeng rescuing a peacock. Students create a "Biodiversity Script" as a form of project-based learning, demonstrating creativity and collaboration through science-based performances.

In the second CP concerning the classification of matter, students demonstrate chemical reactions through the "Ketoprak Color Potion," using natural materials such as indigo leaves. This activity fosters critical reasoning and creativity within a cultural context. For the third CP on levels of biological organization, Ketoprak presents scenes depicting characters experiencing shortness of breath, enabling students to simulate respiratory disorders and measure breathing frequency, integrated with community-based learning.

The fourth CP, related to interactions among living organisms and climate change mitigation, reconstructs the Tanjung Sari village ecosystem through a "Forest Restoration" scene enhanced with LED visual effects. In this activity, students practice temperature measurement and critical thinking. The fifth CP on heredity is represented through the drama "Color Inheritance," illustrating dominant–recessive genetic patterns through costumes and dialogue, thereby strengthening creativity and scientific reasoning.

In the sixth CP on conventional biotechnology, the fermentation process of *tapai* is integrated into the "Harvest Festival" scene, emphasizing collaboration and the role of microorganisms. The seventh CP, focusing on physical measurements, is realized through measuring performers' body temperature before and after Ketoprak rehearsals using digital thermometers to understand metabolism. The eighth CP, addressing force and pressure, invites students to analyze centripetal force in the Serimpi dance using accelerometer sensors attached to dancers' costumes.

Subsequently, the ninth CP on work and energy is translated into Ketoprak battle scenes, where students use pedometers or accelerometers to calculate players' kinetic energy during running activities. In the tenth CP on heat transfer, students measure stage temperature changes before and after lighting installation and compare heat conduction in wood and plastic to understand thermal insulation. The eleventh CP on sound waves is integrated through frequency analysis of gamelan music using digital oscilloscope applications.

For the twelfth CP, students explore magnetism and electricity by assembling a simple generator (dynamo) to power LED lights as part of the storyline "The Light of the Hero." The thirteenth CP, concerning the relative positions of the Earth, Moon, and Sun, is explored through the creation of eclipse animations using Processing software as a performance backdrop. Finally, the fourteenth CP on decision-making to avoid addictive and harmful substances is evaluated through chemical composition analysis of traditional costume dyes, comparing natural and synthetic materials using a Life Cycle Assessment approach.

Overall, this reconstruction demonstrates that Ketoprak can serve as a contextual STEM learning platform that strengthens students' creativity, collaboration, critical reasoning, and independence. The integration of constructivist principles, contextual learning, and project- and community-based learning generates active learning experiences rooted in local culture while remaining aligned with 21st-century learning frameworks and Deep Learning principles.

The Most Suitable and Promising Learning Topics for Further Development

Based on the results of reconstructing the relationship between science concepts and Ketoprak, the learning topic of **Force, Motion, and Pressure** emerges as the most appropriate and promising for further development. This topic encompasses various types of forces, Newton's Laws of Motion (I, II, and III), physical quantities involved in motion (distance, displacement, speed, velocity, and acceleration), Uniform Linear Motion (ULM), Uniformly Accelerated Linear Motion (UALM), as well as the concept of pressure ($P = F/A$).

The selection of force and motion over other Phase D Science Learning Outcome topics such as levels of biological organization, interactions among living organisms, or energy and its transformations is based on the strong and recurring presence of force and motion concepts, both explicitly and implicitly, throughout the Ketoprak Wahyu Manggolo performances. Dance movements, battle scenes, and improvisational *ontowencono* sequences represent direct manifestations of applied force and motion. These elements provide authentic and tangible contexts that enable students to comprehend abstract physics concepts through concrete experiences closely connected to their cultural background.

This strong alignment corresponds with the Phase D Science Learning Outcomes (CP), particularly within the element *Understanding Science* for Grade VII, which includes the competency to "analyze various forms of motion, force, and pressure" (Science Subject Guidelines, 2025, p. 69, Ministry of Education and Culture, 2025).

Furthermore, social challenges such as maintaining harmony among performers and managing interactions with the audience highlight the importance of community management aspects in the preservation of traditional arts. These issues offer additional avenues for further investigation, particularly in developing sustainable ethno-pedagogical models within the context of arts based community learning.

Table 1. Observation Results and Reconstruction of Ketoprak Local Wisdom into Physics Concepts

Theme / Sub-theme (Interview-Based))	**Themes / Sub-themes (Based on Interviews)**	**Konsep Fisika (Gaya & Gerak) yang Dihubungkan**
Group Preparation and Organization: preparation of props, performers, and musical instruments (Mbah Mogol).	All elements are prepared prior to the performance; performers learn and understand their roles autodidactically (ontowencono).	Force: pushing/pulling forces applied to props (e.g., sticks, drums) → Newton's First Law; inertia observed when performers change positions.
Force: pushing/pulling forces applied to props (e.g., sticks, drums) → Newton's First Law; inertia observed when performers change positions.	Body movements, jumps, and dramatic gestures involving acceleration and changes in direction.	Newton's Second Law (F = ma) and momentum (p = mv) in jumping motions and hand movements.
Moral Values and the 'Tumindak e Elek/Baik' Narrative: moral messages about cause and effect.	The narrative teaches cause-and-effect relationships (action–reaction).	Potential energy → kinetic energy, where 'good' actions lead to positive outcomes and 'bad' actions lead to negative outcomes (energy conservation).
Taman Sari (Interactive Traditional Games): entertainment segments, dance, and traditional games.	Repetitive movements (Serimpi dance) demonstrate circular motion and centripetal force during rotations.	Circular motion: $v = \omega r$; centripetal force $F_c = mv^2/r$.

Conflict and Resolution (Members' Well-being): social dynamics of "collaborative movement.	Conflict resolution requires cooperative pulling forces, in contrast to repulsive forces associated with conflict.	Analogy of frictional forces in social interactions; the concept of equilibrium (ΣF=0).
Children's Roles (Ages 8–12): the "Rega" concept simultaneous participation in learning and the arts..	Children "transition" between the classroom and the stage, altering their speed (acceleration) as they shift roles.	Acceleration $a = \Delta v/\Delta t$ during rapid transitions; momentum during running onto the stage.
Use of Musical Instruments (kendang, gong): rhythmic striking patterns.	Percussive beats generate mechanical waves that propagate through the air and the instrument membranes.	Frequency and amplitude; the relationship F = acting on the membrane.
Development of Ethno Physics Based Teaching Materials: integration into the senior high school curriculum.	Observation reveals the need for ketoprak-based physics learning modules.	Newton's Second Law and projectile motion (e.g., mask throwing).
Evaluation of Socio Cultural Impact: increased interest among younger generations.	Increased engagement indicates social learning effects (Bandura's model) triggered by social forces (interaction).	Social forces as an analogy for attractive forces between particles.
Integrated Pedagogical Model: the "Ketoprak Physics" framework.	Integration of ketoprak narratives with force-based experiments (e.g., mask throwing) in classroom activities.	Laws of projectile motion to explain the trajectory of a thrown mask.

With its rich cultural heritage and long standing traditions, Ketoprak has consistently captivated audiences through its epic narratives and dynamic performances. However, have we ever realized that behind the beauty of dance movements, the resonance of gamelan music, and the dramatic staging of scenes, there are fundamental principles of physics that underpin every element of the performance?

The table below provides insight into how fundamental physics concepts such as force (types of forces and Newton's laws), motion (kinematic quantities, uniform linear motion, uniformly accelerated motion), and pressure ($P = F/A$) are deeply integrated into Ketoprak performances. Beyond theoretical explanations, this exploration highlights their practical applications in performers' movements, interactions with stage props, and the production of sound by musical instruments, accompanied by analytical explanations of their physical implications and relevant formulas.

Let us delve into how physics, often unconsciously, plays a crucial role in shaping this masterpiece of traditional performing arts.

1. Application of Force Concepts in Ketoprak Performing Arts

Table 2. Application of Force in Ketoprak Performing Arts

Physics Concepts	Application in Ketoprak Performing Arts	Relevant Physics Formulas
Muscular Force	Performers' movements such as raising hands, stepping, or executing martial arts motions; also applied when playing gamelan instruments, striking gongs, or plucking the siter.	F_{otot}
Frictional Force	Friction between performers' feet and the stage during movement, especially in dance or combat scenes; friction in bowed instruments such as the rebab.	$f_s \leq \mu_s N, f_k = \mu_k N$
Gravitational Force	Performers jumping or falling; seated positions of gamelan players.	$W = mg$
Normal Force	Performers standing upright on the stage; musical instruments placed on the floor.	N ((opposite in direction to W on a horizontal surface)
Newton's First Law (Inertia)	A stationary performer tends to remain at rest, and a moving performer tends to continue moving unless acted upon by another force.	$\Sigma F = 0 \implies a = 0$
Newton's Second Law (F = ma)	Changes in speed or acceleration of performers' movements during combat scenes (e.g., accelerated sword movements).	$F = ma$
Newton's Third Law (Action–Reaction)	When a performer steps forward, the foot pushes the floor backward (action), and the floor pushes the foot forward (reaction), enabling forward motion.	$F_{aksi} = -F_{reaksi}$

1. Application of Motion Concepts in Ketoprak Performing Arts

Table 3. Application of Motion Concepts in Ketoprak Performing Arts

Physics Concepts	**Application in Ketoprak Performing Arts**	**Relevant Physics Formulas**
Kinematic Quantities (Position, Displacement, Distance)	Determining performers' positions on the stage, movement from one point to another, and the total distance traveled during the performance.	x (posisi), Δx (perpindahan), s (jarak)
Kinematic Quantities (Velocity, Speed)	The velocity of performers as they move across the stage; the speed of dancers' hand movements.	$v = \frac{\Delta x}{\Delta t}$ (kecepatan), $v = \frac{s}{\Delta t}$ (kelajuan)
Kinematic Quantities (Acceleration)	Changes in performers' velocity when starting, stopping, or suddenly changing the direction of movement.	$a = \frac{\Delta v}{\Delta t}$
Uniform Linear Motion (ULM)	Performers moving from one side of the stage to the other at a constant speed during calm scene transitions.	v = konstan, $x = x_0 + vt$
Uniformly Accelerated Linear Motion (UALM)	Performers moving with acceleration or deceleration, such as during dramatic entrances or action scenes.	*+-87$v_t = v_0 + at$, $x_t = x_0 + v_0 t + \frac{1}{2}at^2$, $v_t^2 = v_0^2 + 2a\Delta x$

1. Application of Pressure Concepts in Ketoprak Performing Arts

Table 4. Application of Pressure Concepts in Ketoprak Performing Arts

Konsep Fisika	**Penerapan dalam Kesenian Ketoprak**	**Rumus FIsika yang Relevan**
Air Pressure	Sound production in wind instruments such as flutes or bamboo recorders.	(No single simple formula; involves fluid dynamics principles)
Contact Pressure ($P = F/A$)	Finger pressure on gamelan keys or siter strings; pressure applied when striking a gong; pressure exerted by the tip of a prop spear on the stage surface.	$P = \frac{F}{A}$
Psychological Pressure	Emotional tension experienced by performers when portraying characters with internal conflict.	No physical formula

The findings of this study clearly demonstrate that dance movements, battle performances, and improvisational actions in Ketoprak Wahyu Manggolo embody the concepts of Uniform Linear Motion (ULM), Uniformly Accelerated Linear Motion (UALM), and adhere to Newton's Laws of Motion. These results are consistent with previous studies, such as Rahmawati (2021), who analyzed the application of Newton's Laws in the Dadhak Merak dance. Similarly, studies on physics concepts embedded in traditional dances and spiritual cultural practices, as reported by Suryani and Setiawan (2025), reveal how physical principles are integrated into cultural performances paralleling the findings of the present ketoprak study. Furthermore, Nadzirin (2024) emphasizes that through ethnoscience analysis of local wisdom such as *Ancak Robyong*, hidden dynamic physics concepts can be identified. Therefore, there is a strong alignment between traditional artistic practices and fundamental scientific physics concepts.

One distinctive characteristic of Ketoprak Wahyu Manggolo is its "ontowencono" or spontaneous nature, which differentiates it from other traditional performing arts that rely heavily on scripted choreography. This spontaneity allows for direct observation of internal forces, such as the impulses generated by performers, as well as environmental reactions, including audience responses. This phenomenon aligns with recent studies proposing a Newtonian–cultural movement approach, which integrates Newton's laws with cultural contexts to better understand motion (Putro et al., 2025). In this sense, cultural context not only enriches the artistic meaning but also serves as a bridge for understanding physics through empirical experiences in performance arts.

This study further demonstrates that ethnophysics is not merely analogical in nature, but can be treated as empirical data that may be codified into simplified physical models, such as equations of motion. This contribution enriches the limited body of literature on the "ethnophysics of performance," a field that remains underrepresented in reputable academic journals. Consequently, the present research expands the theoretical foundation of ethnopedagogy and offers new perspectives for the development of physics education grounded in local cultural contexts.

CONCLUSIONS AND RECOMMENDATIONS

This study comprehensively confirms that Ketoprak, as a form of Javanese local wisdom, functions not only as an entertainment-oriented performing art but also plays a crucial role as a medium for transmitting moral values, social criticism, and strengthening collective cultural identity. In-depth observations of Ketoprak Cahyo Mudo and Ketoprak Wahyu Manggolo in Pati and Rembang demonstrate the vitality of this traditional art form, which continues to live on and adapt to changing social contexts. Key findings from interviews with Mbah Mogol, the leader of Ketoprak Wahyu Manggolo, enhance the understanding of the deep philosophical meaning behind the group's name, the morally oriented motivation for cultural preservation, and the implementation of the distinctive *ontowencono* training system, which emphasizes improvisation and responsiveness. Implicit character education teaching the consequences of

actions (karma) through narrative performances (*tumindak'e elek*) is shown to be the core moral message conveyed through Ketoprak.

FURTHER STUDY

Furthermore, Ketoprak exhibits strong potential as an innovative approach to the development of relevant and contextual teaching materials, particularly through the integration of scientific knowledge such as physics concepts (force and motion) into science education. At the same time, it reinforces cultural identity and serves as an effective ethno-pedagogical practice within multicultural societies.

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