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Analysis Of Newton's Laws Concepts In Besei Kambe, A Traditional Sport Of Central Kalimantan

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Abstract

Besei Kambe is a traditional Dayak game from Central Kalimantan in which two teams compete by pulling a jukung on the water. Beyond its cultural significance, this activity embodies various physics concepts that can be utilized as contextual learning resources. This study aims to identify and analyze the physical principles that emerge during the practice of Besei Kambe, particularly those related to Newton's laws, action–reaction forces, and resultant forces. Through qualitative analysis based on illustrative observation and literature review, the study reveals that the motion dynamics of the boat and the interactions between the paddlers and the water reflect direct applications of these fundamental physics concepts. These findings indicate Newton's First Law appears when the boat remains still under balanced forces, Newton's Second Law when an unbalanced force causes acceleration, and Newton's Third Law in the action–reaction interaction between the paddle and the water. These findings demonstrate that Besei Kambe naturally represents fundamental mechanics principles and can serve as an effective contextual resource for physics learning grounded in local wisdom.

Keywords: Besei Kambe, Central Kalimantan, Local Wisdom, Newton's Laws, Physics Education

INTRODUCTION

Physics is deeply embedded in everyday human experiences, as numerous routine phenomena can be understood through fundamental physical principles (Safitri et al., 2023). This inherent relevance suggests that physics learning should be delivered through interactive, engaging, and intellectually stimulating experiences that encourage active participation, foster creativity, and support learner autonomy while accommodating students diverse interests and developmental needs (Isnaniah & Masniah, 2023; Pingkan et al., 2021). Nevertheless, despite its close connection to real-life contexts, many students continue to perceive physics as abstract and difficult due to its strong mathematical orientation and the persistent dominance of teacher centered instructional practices (Julisma, 2022). Given these challenges, it is essential to rethink how physics is designed so that learners can experience the subject as meaningful, intuitive, and relevant rather than distant and formula driven.

An effective alternative approach to addressing these challenges is to connect physics learning with local wisdom that is inherently close to students' lived experiences (Hikmawati et al., 2021; Dani et al., 2022). Martawijaya and Mahir (2024) state that local wisdom refers to forms of local knowledge consisting of community rooted ideas, values, and cultural practices that are considered wise, meaningful, and ethically grounded, and that continue to be preserved and followed by local communities. According to Jufrida et al., (2022), local wisdom based learning is particularly well suited to the Indonesian educational context, given the nation's rich cultural, linguistic, and traditional diversity.

Numerous studies across Indonesia have examined the integration of local wisdom into physics education and consistently demonstrate its positive impact on students conceptual understanding, learning motivation, scientific literacy, and even cultural literacy (Eko Wahyudi et al., 2025; Kusuma et al., 2023; Rusilowati et al., 2021; Sae et al., 2021). This approach has been successfully applied across various physics topics, including fluid mechanics, waves, rotational dynamics, temperature and heat, and Newton's Laws (Safitri et al., 2023). However, despite these advances, the application of local wisdom in physics instruction remains uneven across regions and topics.

Central Kalimantan is one of the provinces on the island of Kalimantan, consisting of 13 regencies and one municipality, with the majority of its population belonging to the Dayak ethnic group (Novika Lestari, 2023). Central Kalimantan strongly shaped by its network of major rivers such as the Kahayan, Kapuas, and Barito (Usop, 2020). These rivers have long supported the daily lives of the Dayak community, serving as routes for transportation, fishing, and trade, traditionally using wooden boats. One cultural practice that continues to preserve this river based tradition is Besei Kambe, a traditional Dayak sport.

In Besei Kambe, two teams sit in the same long boat (known as jukung), positioned back-to-back, and paddle in opposite directions to test strength, coordination, and endurance (Widen et al., 2025). This activity not only reflects the community's close relationship with river culture but also provides a meaningful context for physics learning, especially when exploring concepts related to forces, motion, and Newtonian dynamics.

Despite its rich cultural heritage, research integrating Central Kalimantan's local wisdom into physics learning remains scarce. Existing studies often highlight only isolated aspects of Dayak traditions. For instance, Makhmudah et al. (2019) developed a module on momentum and impulse based on local cultural practices, and Novika Lestari (2023) incorporated the traditional Sipet into ethnophysics instruction. These limited efforts underscore a broader gap and reveal substantial untapped potential, particularly in utilizing river-based traditions such as Besei Kambe to develop culturally grounded physics learning materials that can strengthen students' conceptual understanding and contextual relevance.

This study aims to identify and analyze the concepts of Newton's laws of motion embedded in Besei Kambe as a potential foundation for contextualized physics learning. The outcomes of this study are expected to support the development of culturally responsive instructional materials that enhance student engagement, deepen conceptual understanding, and strengthen the relevance of physics to students' lived experiences, particularly within the cultural setting of Central Kalimantan.

METHOD

This study used a qualitative descriptive design to identify the concepts of Newton's laws of motion represented in Besei Kambe. The data sources consisted of secondary materials such as videos, photographs, and literature documents describing Besei Kambe. Data were collected through careful observation of these materials to capture movements, interactions, and force directions that reflect physical phenomena. Subsequently, animations were created to visually represent these phenomena and facilitate a clearer understanding of the observed physics concepts.

The data analysis was carried out using a qualitative descriptive approach, consisting of three main stages, data reduction, data display, and conclusion drawing (Rizaldi et al., 2024). First, data reduction was conducted by condensing, summarizing, and focusing on the most relevant aspects of the data. This step highlighted key observations and allowed the researcher to manage the data more effectively, making it easier to retrieve and review when necessary. Second, data display involved organizing the reduced data and animations systematically, providing a clear visual and descriptive representation of the physics concepts. Finally, conclusion drawing was performed, where the observed phenomena were categorized according to specific Newtonian concepts, such as inertia, action–reaction interactions, and the relationship between force and acceleration.

RESULT AND DISCUSSION

Besei Kambe is a traditional sport of the Dayak community that combines physical strength and teamwork. The game is played on a river using a long boat (jukung) and paddles, and it can be participated in by both men and women. In the Dayak Ngaju language, besei means "to paddle," while kambe means "spirit". Therefore, this tradition is also referred to as "Bekayuh Hantu" (paddling of the spirits). According to oral tradition, Besei Kambe originated from an event during the Tiwah ceremonial procession, a Dayak funeral ceremony to honor the deceased. During the ceremony, the community heard a commotion on the river, which was said to have been caused by two spirits paddling so fiercely that their boat broke in the middle of the river.

Before the game begins, participants are divided into two teams, each consisting of two members. The teams sit back-to-back in a jukung and start paddling in opposite directions. The match requires full energy and strategy to move the boat past a designated boundary (andang) set by the judges. The team that crosses the marker first is declared the winner.

Figure 1. Traditional Dayak sport Besei Kambe

Besei Kambe involves coordinated body movements, strategic positioning, and dynamic physical interactions that naturally embody several fundamental laws of physics, particularly Newton's laws of motion. These concepts are evident in the observable actions and reactions of the players and the boat, highlighting the potential of Besei Kambe as a culturally relevant medium for learning physics. A detailed identification of the physics concepts manifested during the game is summarized in Table1.

Table 1. Identification of Newton's laws of motion concepts in Besei Kambe

Physics Concept	**Activity in Besei Kambe**	**Explanation**
Newton's First Law (Inertia)	Before the race commences, the two teams are seated inside the jukung (boat) in a back-to-back position, with paddles ready but not yet exerting force on the water.	The *jukung* remains at rest because no net force acts on it. The system's inertia maintains its state of rest until an unbalanced external force is applied by the paddles.
Newton's Third Law (Action–Reaction)	As the race starts, both teams simultaneously dip their paddles into the water and push backwards.	When the paddle pushes the water backward, the water exerts an equal and opposite reaction force that pushes the *jukung* forward. This reaction force initiates the motion of the *jukung*.
Newton's Second Law (Net Force and Acceleration)	Teams paddle in opposite directions, competing to shift the *jukung*.	The motion is governed by the net force. $\Sigma \boldsymbol{F} = \boldsymbol{F}_A - \boldsymbol{F}_B$ The jukung accelerates in the direction of the larger force. A greater imbalance between the opposing forces results in a larger net force, which, according to $\boldsymbol{a} = \frac{\Sigma \boldsymbol{F}}{m_{total}}$

Newton's First Law in the Initial Stability of the Jukung

The initial phase of the Besei Kambe, before the commencement of paddling, presents a quintessential demonstration of Newton's First Law of Motion, also known as the law of inertia. In this state, the jukung crew system is in a condition of static equilibrium, where the vector sum of all external forces acting upon the system is precisely zero. This is mathematically expressed as:

$$\Sigma \boldsymbol{F} = 0 \quad (1)$$

This equilibrium is evident in both the vertical and horizontal direction. This balance is particularly evident in the vertical direction, where two primary forces interact, the gravitational force and the buoyant force. The gravitational force (w), acting downward, results from Earth's gravitational attraction on the total mass of the system and is calculated as:

$$\boldsymbol{w} = m_{total}\,\boldsymbol{g} \qquad (2)$$

Where:

m_{total}	:	the combined mass of the boat and crews (kg)
g	:	the acceleration due to gravity (m/s^2)
w	:	the gravitational force (N)

Simultaneously, the buoyant force (F_B), acting upward, arises from the water displacement according to Archimedes' principle and is expressed as

$$\boldsymbol{F}_B = \rho \boldsymbol{g} V_{dis} \qquad (3)$$

Where:

ρ	:	the fluid density (kg/m^3)
g	:	the acceleration due to gravity (m/s^2)
V_{dis}	:	the submerged volume of the jukung (m^3)
F_B	:	the buoyant force (N)

These two forces exactly counterbalance each other, resulting in zero net vertical force, as described by the equation

$$\Sigma F_y = F_B - w = 0$$

$$F_B = w \quad (4)$$

This equilibrium, clearly illustrated in the free-body diagram of Figure 2, confirms that the system's inertia maintains the jukung at rest until an external unbalanced force, initiated by paddling to disrupts this state.

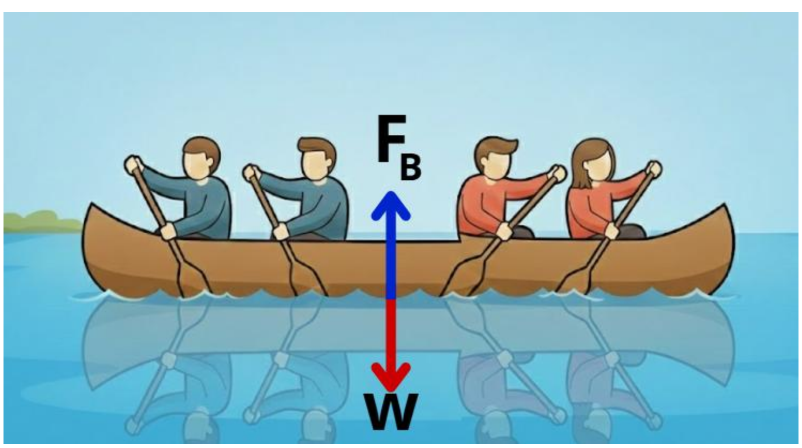

Figure 2. Free body diagram of the jukung in a state of static equilibrium before the race begins.

In the horizontal plane, the absence of paddling and the assumption of calm conditions mean that forces such as water resistance and air drag are negligible, leading to a net horizontal force of zero ($\Sigma F_x = 0$). The convergence of these balanced force components confirms the state of static equilibrium, and the system's inertia maintains the jukung at rest.

Action–Reaction Interaction Between Paddle and Water

The interaction between the paddle and the water in *Besei Kambe* provides a clear and authentic representation of Newton's Third Law of Motion. This fundamental principle states that for every action force, there exists a simultaneous reaction force that is equal in magnitude and opposite in direction. The mathematical expression of this law is given by:

$$\boldsymbol{F}_{action} = -\,\boldsymbol{F}_{reaction} \qquad (5)$$

In Besei Kambe, when a paddler executes a stroke, they exert a backward-directed force on the water (F_{action}). According to Newton's Third Law, the water simultaneously exerts an equal and opposite forward-directed force on the paddle ($F_{reaction}$). This reaction force is transmitted through the paddler's arms to the jukung, constituting the net external force responsible for its forward propulsion, as clearly illustrated in Figure 3.

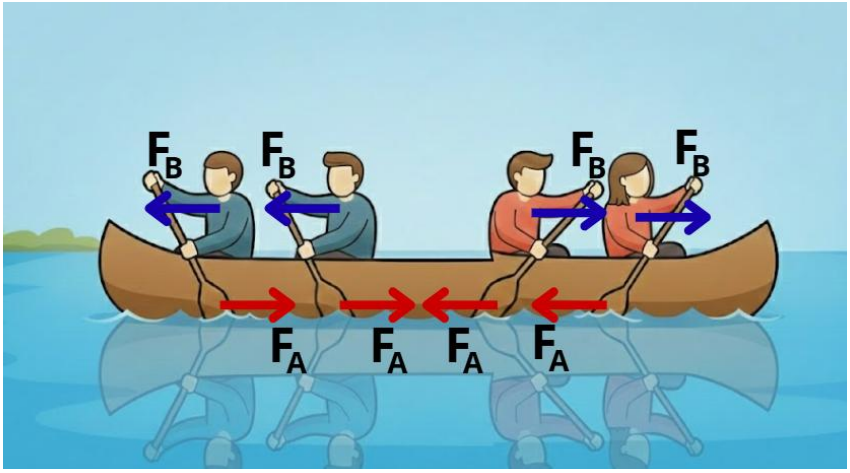

Figure 3. Free body diagram of Newton's Third Law during the paddling motion.

The vector notation confirms that these two forces act in opposite directions. It is critical to emphasize that these two forces act on different objects, the action force acts on the water, accelerating it backward, while the reaction force acts on the jukung paddler system, accelerating it forward.

Therefore, a more powerful and deeper stroke, which imparts a greater backward acceleration to a larger mass of water, results in a stronger reaction force and a greater forward acceleration of the jukung.

Newton's Second Law: Net Force and Resulting Acceleration in Besei Kambe

The competitive interaction between the two opposing teams in Besei Kambe provides a clear and dynamic illustration of Newton's Second Law of Motion. The motion of the jukung is governed not by the individual forces exerted by each team, but by the vector sum of these forces, known as the net external force. This fundamental relationship is encapsulated by the equation:

$$\Sigma \boldsymbol{F} = m_{total}\,\boldsymbol{a} \qquad (6)$$

Where:

m_{total}	:	the combined mass of the boat and crews (kg)
a	:	the acceleration (m/s^2)

ΣF : the net external force (N)

To analyze the competition, we define the force generated by Team A as F_A (acting to the right) and the force generated by Team B as F_B (acting to the left).

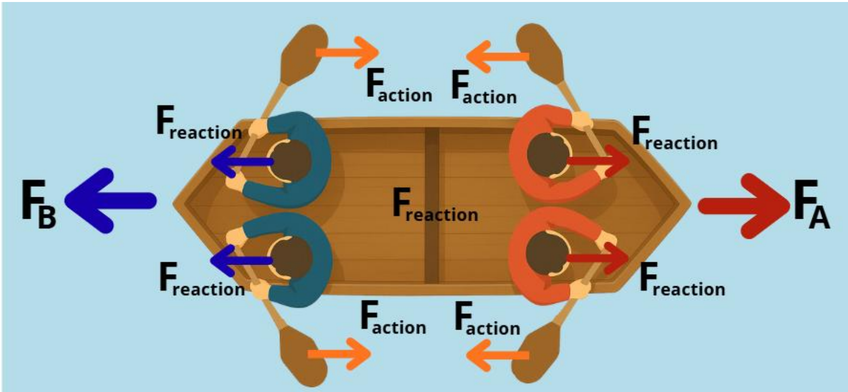

Figure 4. Schematic diagram illustrating the net force and resulting acceleration in Besei Kambe.

The net force acting on the boat is therefore the vector sum:

$$\Sigma F_x = F_A - F_B \quad (7)$$

and its direction depends on which force is larger. The resulting motion is determined as follows:

- If $F_A > F_B$, then $\Sigma F > 0$, and the *jukung* accelerates in the positive direction (towards Team A).
- If$F_A < F_B$, then $\Sigma F < 0$, and the *jukung* accelerates in the negative direction (towards Team B).
- If $F_A = F_B$, then $\Sigma F = 0$, according to Equation (3), this results in zero acceleration ($a = 0$).

This phenomenon vividly demonstrates how the competition between two force vectors dictates the system's motion. A greater imbalance between the opposing forces results in a larger net force producing a greater acceleration, which according to:

$$\boldsymbol{a} = \frac{\Sigma F}{m_{total}} \quad (8)$$

This integrated analysis shows that Besei Kambe serves as an ideal natural laboratory for observing Newton's Second Law in action. The visible acceleration of the jukung provides immediate feedback about the relative force difference between the teams, while the mass-dependent response illustrates the concept of inertia, making this traditional game a valuable context for physics education.

CONCLUSION

Traditional games represent an important form of local wisdom that must be preserved, and Besei Kambe is one of the traditional games from Central Kalimantan that carries strong cultural value. The analysis reveals that principles such as Newton's laws of motion, action–reaction forces, and resultant forces naturally emerge from the coordinated movements and interactions between the teams, the paddles, and the water. These embedded physical principles show that Besei Kambe is not only a cultural heritage activity but also a meaningful contextual resource for learning physics. Integrating such local wisdom into physics instruction can strengthen students' conceptual understanding by linking scientific ideas with experiences that are familiar, culturally relevant, and engaging. Through this connection, traditional practices like Besei Kambe can serve as effective educational bridges between abstract physics concepts and real world phenomena.

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