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Exploration of physics principles in bola rai' design based on local knowledge

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Abstract

Exploration of Physics Principles in Bola Rai' Design Based on Local Knowledge. This study aims to explore the application of physics principles in the design of *Bola Rai'*, a floating house constructed based on local knowledge of the community around Lake Tempe. The research employs a qualitative descriptive approach, utilizing interviews, observations, and documentation techniques in Dusun Salomate, Limpomajang Village, Soppeng Regency. Primary data from interviews and observations were supplemented with secondary sources from literature. The analysis reveals that the design of *Bola Rai'* applies physics principles such as Archimedes' principle, hydrostatic pressure, weight, and pressure within the raft structure. Additional physics concepts are applied to the house's pillars, including weight, Newton's laws, and pressure. The walls demonstrate principles of aerodynamics, heat transfer, thermal conductivity, and Pascal's law, while the roof structure incorporates principles of pressure, weight, and thermal conductivity. The study concludes that physics principles have been effectively integrated into the design of Bola Rai' through the adaptation of local knowledge, suggesting its potential as a source for contextual physics learning.

Keywords: Bola Rai'; physics; local knowledge; floating house; learning resource

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INTRODUCTION

Physics is a science that is highly relevant to everyday life, as many natural phenomena can be explained through its concepts. This discipline is particularly appealing because numerous physics concepts are directly connected to real-life situations (Oktaviani & Gunawan, 2017). However, in practice, many students perceive physics as a difficult and less enjoyable subject. They often struggle to relate the material being studied to its application in daily life. Like mathematics, physics involves the use of principles and concepts to solve problems, which may cause students to lose interest, as they view it as too challenging (Siyati & Kamariyah, 2022). One strategy to address this issue is to use local phenomena familiar to students as teaching materials. Students tend to show greater interest and enthusiasm when they are actively involved in learning that is closely related to their everyday experiences. Integrating ethnoscience into science education can enhance students' interest and motivation, ultimately leading to better learning outcomes (Sartika et al., 2023). This is supported by research conducted by Mukti et al., (2022), which demonstrates that ethnoscience can be incorporated into learning through various components such as instructional tools, teaching materials, approaches, methods, models, and media. The integration of ethnoscience has been proven effective in improving students' conceptual understanding, scientific process skills, character development, learning interest, academic achievement, and critical thinking abilities. For example, research on Rejang traditional houses known as "earthquake-resistant houses" in Bengkulu has shown that incorporating such local wisdom into science lessons, particularly on the topic of force, can improve student learning outcomes (Sartika et al., 2023). Similarly, the development of contextual-based physics teaching materials that incorporate local wisdom is considered highly feasible and has been shown to enhance students' comprehension of physics concepts (Satriawan & Rosmiati, 2016).

Exploring culture and traditions integrated with physics concepts has become an effective and engaging approach to science education. Various cultural elements ranging from traditional games (Gifani et al., 2023; Nurianti et al., 2023; Nurmasyitah et al., 2022; Rumiati et al., 2021), traditional dances (Asbanu, 2023; Nurhidayat et al., 2020), traditional foods (Damasari et al., 2022; Ulya et al., 2023), to traditional houses (Fajriyani, 2023b, 2023a; Jefriyanto et al., 2022; Latif et al., 2019) have been explored as media for conveying physics concepts in everyday contexts.

Traditional games, such as the one studied by Rumiati et al., (2021), reveal mechanical energy principles in the traditional Egrang game. This study shows that the game incorporates physics concepts that bridge modern science with ethnoscience. Likewise, the Acehnese traditional game Geulengkue Teu Peu Poe, which can be played in schools, involves concepts of parabolic motion (Nurmasyitah et al., 2022). The Mojang Priangan traditional dance illustrates heat transfer, while the Okomama dance from the Amanuban tribe involves changes in potential energy, especially during the entry, preparation, and handover phases (Asbanu, 2023; Nurhidayat et al., 2020). Traditional houses also offer opportunities to teach physics by analyzing the physical principles embedded in their design. For instance, Jefriyanto et al., (2022) examined the Tongkonan house of the Toraja tribe, which demonstrates principles of force and pressure through its structural pillars. In addition to the Tongkonan house, there is home to a unique architectural design known as the Bola Rai' a floating house used by the Bugis community in Lake Tempe, South Sulawesi. These raft houses serve as temporary residences for locals who primarily work as fishermen. The Bola Rai' is unique in its ability to float on water, showcasing the community's indigenous understanding of static fluid concepts such as hydrostatic pressure and buoyancy (Fajriyani, 2023b). However, the previous study was limited to a literature-based approach and served only as an initial identification of potential physics concepts, without direct field verification. In the present study, the researchers conducted on-site observations of several floating houses in Lake Tempe and carried out interviews with multiple owners, who were also the builders of these houses. And others number of studies explicitly connected the structural characteristics of the Bola Rai' floating house to a comprehensive analysis of physics concepts.

Existing research that addresses its physical dimension tends to focus narrowly on Archimedes' principle or buoyancy (Beddu, 2017; Beddu et al., 2019; Fajriyani, 2023a). Broader mechanical aspects such as force, weight, pressure, and surface tension which are inherently embedded in the Bola Rai' design, remain largely unexplored in the literature, leaving a significant gap for investigation. This study is particularly urgent in the broader context of science education and community development. Integrating local architectural phenomena like the Bola Rai' into physics instruction not only enhances relevance and student engagement, but also fosters preservation of traditional knowledge systems at risk of erosion due to modernization. Ethnoscience-based learning where indigenous knowledge is reconstructed as scientific knowledge has been shown to significantly improve student motivation, conceptual understanding, and cultural identity (Mukti et al., 2022). Moreover, context-based physics teaching materials grounded in local wisdom have demonstrated positive effects on student achievement and learning activities (Satriawan & Rosmiati, 2016). In regions with extreme thermal conditions such as South Sulawesi traditional building designs like Bugis houses already exhibit principles of thermal comfort, exemplifying how local architecture intuitively incorporates scientific principles (Latif et al., 2019). Therefore, this research not only fills a theoretical gap but also offers practical insights for developing culturally responsive and environmentally adaptive physics learning resources.

Despite growing interest in ethnoscience-based physics education, there remains a clear lack of studies that comprehensively identify and analyze the full range of physics principles embedded in the design of traditional floating houses such as the Bola Rai', and explicitly connect these principles to the science curriculum and classroom learning in schools. This research addresses these gaps by providing a detailed physics-based examination of the Bola Rai' design and evaluating its applicability as a culturally grounded learning resource. Specifically, this study aims to explore the physics concepts embedded in the Bola Rai' and analyze its potential use as teaching material or a learning resource in physics or science education. The investigation focuses on everyday physics concepts such as pressure, force, weight, hydrostatic pressure, buoyancy, and fluid equilibrium. By examining this local structure, the research contributes to the development of more contextual and relevant teaching materials, thereby promoting physics learning that is more meaningfully connected to students' environments. It is further expected to serve as a reference for developing instructional resources that are both theoretically sound and inspired by real-world phenomena surrounding students.

METHODS

Types of Research

The method used is a descriptive qualitative research method aimed at gaining an in-depth understanding of the phenomenon through the interpretation of data collected from various sources. This method allows researchers to obtain a more comprehensive and detailed picture of the subject under study.

Research Objects and Locations

The object of this research is the Bola Rai' floating house on Lake Tempe, specifically in the Salo Mate area, Limpomajang Village, Marioriawa District, Soppeng Regency, South Sulawesi, which serves as an integral part of the local community's way of life.

Sampling and Informants

This study employed purposive sampling to select informants with extensive knowledge and direct experience of Bola Rai' floating houses. Informants were classified into three categories for the purpose of source triangulation. Key informants were the housebuilders, who also served as the owners of their respective Bola Rai’. In total, six such builder-owners were interviewed, as they provided the most direct insights into construction techniques, material selection, and practical use. Main informants consisted of individuals who owned a Bola Rai’ but were not involved in its construction (3 people), community members currently living in Bola Rai’ (3 people), and two local leaders who offered contextual perspectives on the cultural and social functions of the floating houses. Supporting informants included five community members from Limpomajang, supplemented with relevant written documents that provided additional perspectives on the historical and cultural significance of Bola Rai’.

Data Collection Techniques

Data collections were conducted using two types of sources: primary data and secondary data. The data was gathered through direct field observations, in-depth interviews with relevant informants, and documentation from related sources.

1. Interview: Semi-structured interviews were carried out with the Salomate community members, houseboat owners and builders, also the local leaders to obtain detailed information regarding the traditional knowledge employed in the construction and upkeep of houseboats, as well as the embedded physics principles. Interviews lasted 30–60 minutes, were audio-recorded with consent, and transcribed verbatim.
2. Observation: Direct observation was conducted on the structure of the Bola Rai’ floating house and its interaction with the water environment in Lake Tempe, including construction techniques, repair activities, and adaptations to changes in water levels. Observations were documented through detailed field notes, photographs, and short video recordings.
3. Documentation: The documentation stage involves collecting data related to the development process of the Bola Rai', from the initial to the final stages.

The triangulation was applied across sources (owners, builders, community members, leaders) and methods (interviews, observations, documentation) for the trustworthiness of the result. Member checking was conducted by sharing interview summaries with participants for verification. In this research, we used peer debriefing with academic colleagues to helped refine interpretations, and maintaining comprehensive field notes ensured transparency and replicability.

Data Analysis Techniques

Data analysis in this study employs source triangulation. Therefore, key informants, main informants, and supporting informants are identified for each aspect being investigated. The data analyzed refers to the structure and activity of the Bola Rai' floating house and its relation to physics concepts. The data analysis process includes data collection, data reduction, data presentation, and drawing conclusions or verification.

1. Data Collection: The process by which researchers objectively and accurately record all necessary data based on the results of observations, interviews, and documentation.
2. Data Reduction: A type of analysis that refines, categorizes, directs, and eliminates irrelevant data, organizing it in a way that allows for meaningful extraction and verification, thus providing a clearer picture and facilitating the research process.
3. Data Presentation: A collection of information organized in a way that allows conclusions to be drawn and actions to be taken, making the data easy to understand and revealing patterns of relationships.

4. Data Verification: The results of the data analysis conducted by the researchers, which is then accurately verified using various techniques, including:
   a. The collected data is compared with other supporting data to accurately clarify the problem.
   b. After being described, the data is discussed, critically analyzed, or compared with the opinions of others.
   c. Finally, the data is focused on the core of the research problem.

Research Procedures

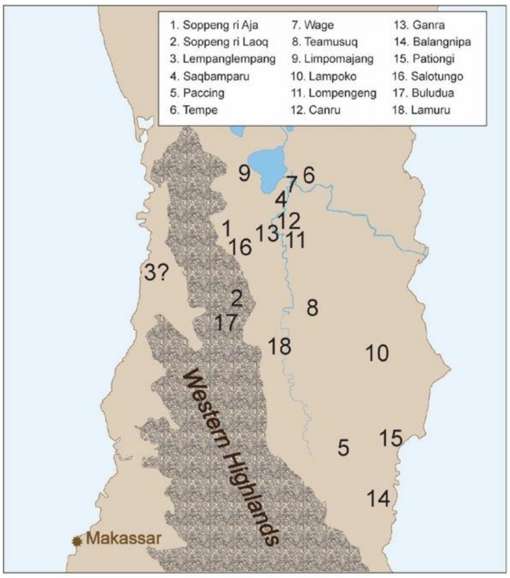
Includes the stages of defining the research scope, selecting and determining informants, conducting interviews, recording and documenting data, and analyzing the collected information.

RESULTS AND DISCUSSION

Research Result

1. Site and Environmental Context

Field observation in Salo Mate, Limpomajang Village, Marioriawa District, Soppeng Regency (South Sulawesi) shows that the area is regularly inundated, especially during the rainy season when the discharge from Lake Tempe exceeds its capacity. This seasonal flooding directly affects the daily life of the community, forcing them to adapt to changing water levels. Interview data confirm that most families in Limpomajang maintain two houses: a main house built on stilts on land and a secondary house in the form of a Bola Rai'. The stilt house functions as the family's permanent dwelling, while the Bola Rai' serves as a temporary refuge or evacuation house during periods of lake overflow.



Source: https://id.wikipedia.org/

Figure 1. A View of Lake Tempe and Its Surrounding Areas

Community members emphasized that this dual-house strategy has been practiced for generations to ensure safety and continuity of daily activities. This finding aligns with Naing(2019), who notes that seasonal water overflow from Lake Tempe inundates the Limpomajang area and necessitates adaptive architectural strategies by the community. Moreover, according to the Head of Limpomajang Village, during the rainy season when the lake overflows, residents also adapt their livelihoods by shifting from farming to fishing, illustrating a flexible socio-economic response to environmental conditions.

2. Overview of The Bola Rai’

Bola Rai’ refers to the floating houses used by residents of Limpomajang, the concept was first popularized by the fishing community of Wajo Regency (Beddu, 2017). Structurally, Bola Rai’ comprises pillars (*aliri*), floors (*dapara*), walls (*renring*), and roofs (*pabbingeng*). The house resembles the Bugis stilt house in form but differs in pillar height—approximately 30–45 cm for Bola Rai’ compared with around 5 m for land-based Bugis houses (Hatta & Sudrajat, 2020). Its gable roof is commonly employed not only for weather adaptation but also as an expression of the Bugis cultural philosophy Sulapa Eppana OgiE, symbolizing balance and harmony.

The choice of materials is strongly shaped by economic and environmental considerations. However, the Bugis people more broadly are familiar with and utilize a variety of traditional building materials such as bitti wood (*aju betti*), ipi wood (*aju ippi*), amara wood (*aju amara*), sandalwood (*aju sandalwood*), tippulu wood (*aju tippulu*), durian wood (*aju durian*), panasa wood (*aju panasa*), ironwood (*aju seppu*), palm trunks, coconut trunks, bamboo, sugar palm trunks, pindang trunks, reeds, and ijuk (Rusdianto, 2021). The selection of materials in each Bola Rai’ depends not only on their availability in the local environment but also on the financial capacity and preferences of the homeowner.

Interview data with one house owner who also serves as a builder revealed that constructing a Bola Rai’ is considered easier than building a main stilt house, primarily because it uses lightweight materials (bamboo and softwoods) and has fewer internal partitions. While the house is divided into basic functional zones such as a living area, bedroom, kitchen, and family space, these sections are separated only by minimal partitions. Builders also noted that construction techniques are passed down through generations, ensuring continuity of local knowledge and cultural practice.

Source: Documentation research

Figure 2. A view of one of the floating houses in Salomate

Direct field observations further showed that the height of Bola Rai’ pillars varies between 20 cm and 65 cm, depending largely on the preferences of the house owner and the availability of construction materials. The roof is generally constructed from zinc sheets or palm leaves, but maintains a triangular gable form typical of Bugis houses on land. This reflects both cultural continuity and practical adaptation to aquatic environments. Based on direct observation, almost all Bola Rai’ houses in Limpomajang predominantly use bamboo as the main construction material particularly for the raft, floor, walls, and roof frame with woven bamboo panels or wooden planks occasionally employed as complementary materials.

3. Raft System and Layering

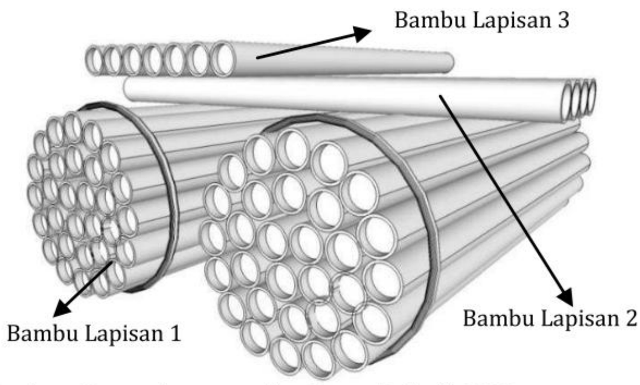
The raft is the core structural foundation that enables the Bola Rai' to float on the water. Field observations revealed that the raft is constructed using multiple layers of bamboo arranged carefully to provide buoyancy and stability (see Figure 3).

Source: Documentation research

Figure 3. Raft layers of a community Bola Rai' floating house.

The raft assembly is carried out with great care and precision. Based on observations shown in figure 3, field observations and interviews with builders revealed that the raft is constructed using three main layers of bamboo. The first layer typically consists of bundles of around 50 bamboo poles tied together, functioning as the primary floating base. The second layer, laid in the opposite direction, usually contains three to four bamboo poles tied crosswise to support the house pillars, with each intersection reinforced by rope for stability and flexibility. The third layer functions as a terrace (*dapara*) surrounding the house, providing access for mooring boats, storing fishing equipment, and daily tasks such as washing and bathing. Both community members and field notes emphasized that this design not only ensures structural durability but also allows for easy replacement of damaged bamboo poles without dismantling the entire raft.

Interview data with several house owners and builders further emphasized that bamboo was deliberately chosen because it is lightweight, buoyant, readily available, and economical compared to alternatives such as empty oil drums. Builders explained that raft bamboo is generally replaced every 2–3 years, although in recent years the frequency has increased as many Bola Rai' also serve as tourist attractions, exposing them to heavier use.



Source: Nain dan Halim (2013)

Figure 4. Illustration of the layers forming the Bola rai' raft.

Documentation data (Naing & Halim, 2013) as pictured in figure. 4, confirm this layered raft design and its functional role in distributing weight evenly across the structure while adapting to water movement. This system illustrates how local empirical knowledge of material properties and fluid interaction has been embedded into construction practices over generations.

Interview data with the Head of Limpomajang Village also revealed that since road access to Limpomajang has improved and Bola Rai' has gained visibility through social media, tourists increasingly visit to observe and experience life on the water. Some Bola Rai' owners have even adapted their houses into small family-run restaurants specializing in local fish dishes. However, the number of tourists remains limited because the raft has a finite load capacity. If this capacity is exceeded, the house can become unstable and risk sinking. This finding underscores both the cultural-economic adaptation of Bola Rai' and its physical limitations, directly tied to the principles of buoyancy and stability.

4. Pillar and Frame Connection

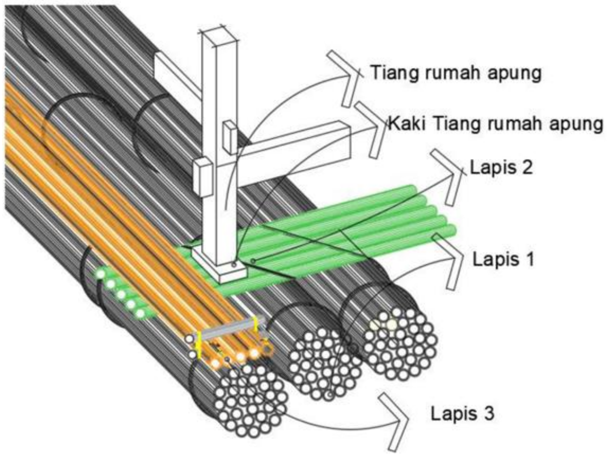
Direct field observations revealed that the height of Bola Rai' pillars varies between 20 cm and 65 cm, largely depending on the preferences of the house owner and the availability of materials. However, variation in height also influences the use of additional structural supports. Houses with shorter pillars (approximately 20–25 cm) are generally constructed without diagonal bracing at the base, as their lower center of gravity already provides sufficient stability. By contrast, houses with taller pillars (40–60 cm) typically include diagonal braces installed at an angle to reinforce the legs of the structure. This additional support minimizes lateral movement caused by wind or waves, thereby reducing the risk of instability. This distinction was clearly visible during observation and is illustrated in Figure 5.

Source: Documentation research

Figure 5. A view of the pillar structure of the Bola rai'.

Interviews with community members familiar with the structure further confirmed that keeping pillar height below ~1 m improves stability against wind and waves. They also noted that pillar spacing is carefully considered: a maximum span of about 3 m is observed to prevent over-burdening the raft with excessive loads (Naing & Halim, 2013).

According to documentation data from (Naing, 2019a), the construction process involves a sequence of connection stages. At the *mappatama arateng* stage, long flat beams (*arateng*) are inserted through mortise-like holes in the poles and pegged to connect them. Upper beams (*bare')* run parallel, while the *barakapu* serves as the ceiling base (*rakkeang).* This pegged joinery system provides both strength and limited flexibility, allowing the house structure to adjust to wind-induced motion without compromising stability. This description aligns with their findings and is illustrated in Figure 6, which depicts the pillar and joinery design of the Bola Rai'.



Source: Naing (2019)

Figure 6. Illustration of the Pole Structure and Its Installation on the Raft Section of the Bola Rai'.

5. Wall and Ventilation

According to Sari et al. (2023), the walls of Bola Rai' are generally lightweight constructed from bamboo, thin boards, or zinc to reduce the load on the frame. Houses typically omit windows but include regularly spaced vents to regulate airflow, maintaining comfortable indoor temperatures in the open-water setting. Two bamboo wall techniques are identified: (i) *renring awo tetta* which split bamboo clamped together; and (ii) *renring tabba'* which bamboo shaved into thin strips, woven, then secured with small wooden battens. Wooden-plank walls use tongue-and-groove with blocking, while zinc walls are nailed and supported by horizontal battens.

Field observations further confirmed that most Bola Rai' walls in Limpomajang rely on bamboo either woven bamboo panels or horizontally arranged split bamboo. A smaller proportion of houses use zinc sheets, while the rest employ wooden planks. Wall design also varies: some houses include small windows, while others rely solely on vertical slits for ventilation. Nevertheless, all observed houses incorporated designated air vents, underscoring the community's consistent prioritization of airflow regulation within the structure.

Interview data with local residents emphasized that Limpomajang's open location on Lake Tempe exposes houses to strong winds. For this reason, ventilation is considered essential not only for cooling but also for stabilizing the Bola Rai'. As one community member explained, the controlled airflow helps reduce the impact of strong winds, so the house does not sway excessively when floating on the lake.

6. Plan, Footprint, and Functional

As noted by Sari et al. (2023), the house footprint is intentionally smaller than the raft to improve stability and circulation. Typical overall sizes of Bola Rai' on Lake Tempe are categorized as small (≈42 m²), medium (≈48 m²), and large (≈60 m²). While interior zoning resembles the Bugis house, the room dimensions are notably smaller than in land-based stilt houses.

Field observations confirmed this minimalist approach: the raft is deliberately constructed wider than the house itself, with extensions at the front and rear that enhance both stability and functionality. According to housebuilders and community members living in Bola Rai', this design not only allows residents to move more easily around the house but also increases the house's stability on the water. The front section typically functions as a terrace and a storage space for fishing gear. The sides of the house facilitate daily mobility when guests are present inside the house, they can pass along the side paths to access both the front and rear areas. Since most Limpomajang residents are fishermen, the side areas also serve as docking spaces for boats. The rear section is commonly used for washing activities such as cleaning dishes and clothes.

This functional zoning illustrates how the Bola Rai’ not only adapts to aquatic environmental conditions but also integrates cultural practices and daily livelihoods, demonstrating a strong connection between form, function, and context.

7. Roof Material and Framing

Roofs are generally made from zinc sheets or thatch over timber or bamboo rafters. The gable form simplifies construction while keeping the roof lightweight to avoid overloading the pillar frame and to distribute weight more evenly onto the raft. Interviews emphasized material choices that balance durability, ease of replacement, and minimized mass.

Based on interviews with housebuilders, the roof construction of Bola Rai’ is intentionally designed in a simpler and lighter form compared to the main stilt houses on land. In permanent houses, builders typically select hardwoods with dense textures and greater weight, combined with more complex roof frames and additional supports, often including ceiling panels beneath the roof. In contrast, the Bola Rai’ employs lighter woods or bamboo with a simpler framing system. While lighter, this roof design is still considered sufficiently strong to withstand weather conditions, while ensuring the house remains stable and does not overburden the raft foundation.

Table 1. Summary of Results and Data Sources

No	Research Focus	Summary of Findings	Data Sources
1	Site and Environmental Context	Seasonal flooding from Lake Tempe regularly inundates Limpomajang. Families maintain two houses: a main stilt house and a Bola Rai’ (secondary floating house) for refuge during overflow. This dual-house strategy has been practiced for generations to ensure safety and continuity of daily activities. Based on information from the local leader, during the rainy season when the lake overflows, residents of Limpomajang also adapt their livelihoods by shifting from farming to fishing.	Field observation; Interviews with house owners; Interview with local leader; Naing, (2019b); Documentation (Wikipedia, Fig. 1)
2	Overview of the Bola Rai’	Bola Rai’ resembles Bugis stilt houses but with shorter pillars (30–65 cm). Materials mainly bamboo and light wood; material selection depends on availability and financial capacity. Construction considered easier than stilt houses due to lighter structure and fewer partitions. Knowledge is transmitted across generations.	Field observation; Interviews with house owner-builder; Rusdianto (2021); Hatta & Sudrajat (2020); Beddu (2017); Fig. 2
3	Raft System and Layering	Raft consists of 3 bamboo layers: base (≈50 poles tied), cross-supports, and terrace. Easy to repair by replacing damaged bamboo. Bamboo replaced every 2–3 years, more frequently due to tourism use. Raft ensures buoyancy, stability, and weight distribution. Some houses adapted into	Field observation; Interviews with builders & house owners; Naing & Halim (2013); (Fig. 3–4); Interview with Head of Limpomajang

No	Research Focus	Summary of Findings	Data Sources
		small restaurants for tourists, though limited by raft load capacity.	
4	Pillar and Frame Connection	Pillar height 20–65 cm. Shorter pillars (<25 cm) usually without diagonal braces; taller ones (40–60 cm) reinforced with angled supports. Stability improved by keeping pillars <1 m and spacing ≤3 m. Connection uses pegged joinery (mappatama arateng, bare', barakapu), allowing limited flexibility under wind.	Field observation (Fig. 5); Interviews with community members; Naing & Halim, (2013); Naing (2019a); (Fig. 6)
5	Wall and Ventilation	Walls mainly bamboo (woven panels or split bamboo), some zinc or wooden planks. Variations include small windows or vertical slits. All houses include air vents for airflow. Ventilation reduces wind impact, preventing excessive swaying.	Field observation; Interviews with community members; Sari et al. (2023)
6	Plan, Footprint, and Functional Zoning	House footprint smaller than raft, raft extends front/back for stability. Front = terrace + storage; sides = access paths + docking boats; rear = washing. Design ensures stability and ease of movement. Sizes: small (42 m²), medium (48 m²), large (60 m²)	Field observation; Interviews with housebuilders & residents; Sari et al. (2023)
7	Roof Material and Framing	Roofs made of zinc or thatch with timber/bamboo rafters in gable form. Bola Rai' roof simpler and lighter than main stilt house, avoiding overload while maintaining durability. Permanent houses use hardwoods and complex framing; Bola Rai' uses lighter bamboo/softwood.	Interviews with housebuilders; Field observation

To deepen the interpretation of these findings, it is necessary to relate the local knowledge identified in the construction of Bola Rai' to the underlying principles of physics. While the results section has outlined the structural characteristics and cultural practices surrounding the raft, walls, pillars, and roof, the following section provides a validation and verification process. This step systematically compares community practices with established physics concepts, ensuring that local empirical knowledge is not only documented but also scientifically contextualized.

Table 2. Validation and Verification of Local Knowledge with Physics Principles

Component	Local Knowledge (from the informants)	Validation Source (Observation / Documentation / Interview)	Physics Principle	Verification Outcome
Raft	• Raft made from layered bamboo bundles (≈50 poles) because bamboo is lightweight, buoyant, and easy to replace.	Direct observation of raft layering; Interviews with builders & house owners, and local leaders; Documentation	Archimedes' Principle (buoyancy), Hydrostatic Pressure, Weight, Density, Pressure	**Verified**: • Bamboo density < water density, explaining buoyancy. • Hollow nodes add flotation and the hydrophobicity of bamboo.

Component	Local Knowledge (from the informants)	Validation Source (Observation / Documentation / Interview)	Physics Principle	Verification Outcome
	• There are 3 layers of bamboo with specific design • Raft replaced every 2–3 years. • The raft is constructed wider than the house to provide space for fishing activities and to facilitate the mobility of the house's occupants.	Naing & Halim (2013).	distribution, Static fluids.	• Over time, capillarity causes water absorption into bamboo fibers, increasing mass and reducing buoyancy, • Field confirms layered system improves stability. • Replacement cycle due to water absorption matches empirical practice.
Pole/Pillars	• The pattern of the house poles is designed according to the area of the bola rai', with equal spacing between each pole; • Pillar height is kept short (20–65 cm) to ensure stability against wind and waves; • Taller pillars are braced diagonally	Field observation (Fig. 5); Interviews with community members; Naing & Halim, (2013); Naing (2019a); (Fig. 6)	Newton's First & Third Laws; Pressure Distribution; Structural Mechanics	**Verified:** • Bracing improves stability, consistent with mechanical principles. • Joinery system provides flexibility under wind force, aligning with structural physics. • Shorter pillars (<0.5 m) lower the center of gravity, improving stability. • Evenly spaced pillars distribute pressure equally ($P=W/A$), reducing localized stress and deformation. • Diagonal bracing increases resistance to lateral forces, improving stability.
Walls & Ventilation	• The connection between the pole and the arateng is secured using a peg-and-hole system for support. • The materials used in making the walls of the Bola rai' are bamboo, wooden planks, and zinc. • Space is left when installing walls to allow air circulation.	Field observation; Interviews with community members; Sari et al. (2023)	Density & Mass; Specific Heat Capacity; Thermal Conductivity; Aerodynamics; Pascal's Law	**Verified:** • Lightweight materials reduce load; ventilation maintains airflow and stability. Observations confirm wall variability (bamboo dominant). • Density of Bamboo and wood (ρ=0.3–0.9 g/cm³) are lighter than zinc (ρ≈7.14 g/cm³), reducing the overall load of the house. • Specific heat of Wood is higher (≈1700 J/kg°C) compared to zinc (≈390

Component	Local Knowledge (from the informants)	Validation Source (Observation / Documentation / Interview)	Physics Principle	Verification Outcome
Roof	• The roof structure of the bola rai' is designed using materials that are lightweight yet durable. • The roof is generally made of bamboo or wooden planks and only covers a small portion of the structure. It is designed to serve as a storage area for fishing equipment.	Interviews with housebuilders; Field observation	Weight (W=m·g); Specific Heat; Thermal Conductivity	J/kg°C) provides better thermal comfort. • Ventilation gaps regulate airflow, explained by aerodynamics and Pascal's law • Roof weight contributes to total gravitational load on raft and pillars • Lightweight framing lowers roof load, preventing raft instability. • Wood/bamboo insulate better than zinc, aligning with comfort needs. • Matches builder practice.

The validation and verification process demonstrates that the traditional knowledge embedded in the construction of Bola Rai' is consistent with fundamental physics principles, particularly those related to static fluid mechanics, buoyancy, pressure, material properties, and stability. This correspondence confirms that community practices are not merely cultural traditions but are grounded in empirical understandings developed through generations of adaptation to the aquatic environment. At the same time, the verification highlights areas where further empirical measurement and scientific analysis could strengthen the explanation, providing a bridge between indigenous knowledge and formal science education.

Discussion

Table 3 shows the relationship between the local knowledge of the Salo Mate community and the principles of physics applied in the design of Bola Rai.

Table 3. The Relationship Between the Local Knowledge of the Salo Mate Community and the Physics Principles in the Design of the Bola Rai

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
1	Raft	• Making a raft from bamboo and rope	The selection of the main material for constructing the raft requires a material that has a lower density than water, is lightweight, and resistant to water waves. Bamboo that has undergone a specific drying or preservation process can last longer in water. This is consistent with the study conducted by (Mayasari et al., 2015), which found that drying bamboo for a certain period of time

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
			increases its durability. Bamboo has a density ranging from 0,5 to 0,9 g/cm³, which is lower than the density of water at 1 g/cm³. For example, Sumatra-origin bamboo specimens exhibit densities within this range (Hartono et al., 2022). This ability of bamboo to float on water can be explained by the Archimedes' principle. **Archimedes' Principle** states that an object is immersed in a fluid experience an upward buoyant force equal to the weight of the fluid it displaces (Biran & López-Pulido, 2014). Since the density of bamboo (ρ_b) is smaller than the density of water (ρ_{cair}), the upward buoyant force (F_A) acting on the bamboo is greater than its weight (W). Mathematically, this can be expressed as follows: $W < F_A$ $\rho_b . V_b . g < \rho_{cair} . V_2 . g$ $\rho_b . V_b < \rho_{cair} . V_2$
		• The raft is assembled using 3 layers, each with a specific function.	Based on the analysis, the three layers of bamboo each have distinct functions: the first layer serves as the buoy or base of the raft to provide flotation; the second layer supports the polish and acts as a barrier to prevent the first layer from direct contact with water; and the third layer functions as a mobility area for the occupants of the Bola Rai'. Each of these layers applies specific principles of physics, including: **Layer III:** This layer functions as a float, thus applying the principle of buoyant devices that use air or hollow materials to create buoyancy on water where the main concept that applies is the Archimedes principle. The buoyancy force (F_A) is generated from the volume of bamboo submerged in water ($V_{terendam}$), thus providing an upward force that is able to support the load above it. It can be expressed mathematically as follows: $F_A = \rho_a \times V_{terendam} \times g$ Where g is the acceleration of gravity. The buoyancy force of the raft is maintained by the lightweight and hollow bamboo material, which reduces the overall weight of the raft and enhances its stability on the water. In the context of Layer III, the concept of hydrostatic pressure is also applied to explain how water exerts pressure on the lower layer of bamboo. In addition, bamboo culms possess hollow internodes, contributing to their low average density and enhancing buoyancy a detail confirmed by anatomical studies of bamboo fiber structure (Kadivar et al., 2020; Rusch et al., 2019). Thus, both bulk density measurements and microstructural characteristics robustly

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
			validate the traditional choice of bamboo for floating raft construction. **Hydrostatic Pressure**: The pressure caused by the force exerted by a liquid on a surface area at a certain depth. The deeper the bamboo is submerged, the greater the hydrostatic pressure it experiences. Mathematically, it can be written as follows: $$P_h = \rho_{air}.g.h$$ Where, P_h is the hydrostatic pressure; and h is the depth of the object from the water surface. **Layer II**: In this layer, the dominant physics principle is the distribution of load, **pressure** and **weight**. The second layer in the structure of the bola rai' raft functions as a support for the main pillars of the house, which means that this layer plays an important role in distributing the gravity of the entire structure of the house so that the load is not too concentrated at one point. **Weight (W):** Weight (W) is the result of the mass of the house (m) multiplied by the acceleration due to gravity (g). Mathematically written as follows: $$W = m \times g$$ The weight (W) referred to here is the weight generated by the Bola rai', where each component has mass, allowing the total mass of the Bola rai' to be calculated as follows: $$m_{total} = m_{tiang} + m_{lantai} + m_{dinding} + m_{atap} + m_{penghuni}$$ So the weight (W) obtained is: $$W_{br} = m_{total} \times g$$ In the second layer, this gravity is distributed from the structure of the house poles to the entire surface of the first layer (float) through the bamboo ties and arrangements. So that the pressure is not too high at one point, this distribution must be even. **Pressure (P):** force (*F*) acting on a unit area of solid compressive surface (*A*). The wider the compressive surface, the smaller the pressure exerted. Mathematically, it can be written as follows: $$P = \frac{F}{A}$$ The pressure experienced by the second layer is influenced by the weight transferred from the house structure and the surface area resisting this force. Therefore, the pressure exerted on the second layer is directly proportional to the weight of the house and inversely proportional to the surface area. Mathematically, it can be expressed as:

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
			$$P = \frac{W_{br}}{A_{br}}$$ Where is the weight of the bola rai', and is the area of the bola rai'. In the bamboo raft structure, this pressure is transferred to the first layer of bamboo, which functions as the float. If the pressure is distributed properly, the floating house will remain stable without any part bearing excessive load, thereby preventing deformation or damage to the first layer. **Layer I:** The top layer functions as the mobility area for residents and supports activities around the house. In this case, the principle of friction also applies, where the bamboo layer provides sufficient surface for walking and movement without adding significant additional load to the floating layer. The bamboo in the first layer is arranged in rows, forming a wavy pattern that increases friction when stepped on, allowing the occupants of the Bola Rai' to move safely and comfortably. This first layer also helps distribute pressure across its surface area. This principle mirrors what is foundational in structural engineering for raft foundations, where the load from columns or concentrated points must be distributed evenly across the base to prevent localized failure or deformation(Tabsh & El-Emam, 2014)
		• Replace the bamboo raft every 2–3 years, depending on the number of Bola Rai residents.	The bamboo in the Bola rai' raft is replaced every 2–3 years, depending on the intensity of use, which affects its mechanical properties and water absorption. Bamboo contains a hollow fiber network that absorbs water through capillarity, resulting in increased mass and moisture content. The capillarity phenomenon in bamboo fibers can be described by the following equation: $$h = \frac{2.\gamma.\cos\theta}{\rho.g.r}$$ Where *h* is the height of the water rise in the cavity, *γ* is the surface tension of the water, *θ* is the contact angle between the water and the bamboo surface, ρ is the density of the water, and *r* is the radius of the cavity within the bamboo Over time, excessive water absorption causes the bamboo's mass to increase. This leads to a decrease in the bamboo's structural resistance and mechanical strength, reducing its ability to optimally support the load of the bola rai'. When the bamboo reaches its water saturation point, it becomes brittle and loses buoyancy, making it necessary to replace the raft to maintain the stability of the floating house.

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
			This empirical knowledge of the Limpomajang community aligns with scientific studies. (Godbole & Lakkad, 1986) showed that water absorption significantly reduces the tensile strength of bamboo. Jiang et al. (2012) found that moisture uptake in bamboo alters its density and mechanical properties, leading to decreased stability. Similarly, (Sharma et al., 2015) emphasized that untreated bamboo exposed to humid or aquatic environments deteriorates faster, requiring periodic replacement. These findings support the local practice of renewing raft bamboo every few years to sustain buoyancy and structural performance.
		• The raft is constructed wider than the house to provide space for fishing activities and to facilitate the mobility of the house's occupants.	The raft on the ball rai is intentionally made larger than the house in addition to accommodating the mobility of the occupants, the expansion of the raft can also relieve the pressure given to the third layer raft. In accordance with the concept of pressure. $$P = \frac{W_{br}}{A_{br}}$$
2.	Pole/Pillars	• The pattern of the house poles is designed according to the area of the bola rai', with equal spacing between each pole.	The pattern applied to each pillar allows for even distribution of the house's load. If the pressure experienced by one of the pillars is: $$P = \frac{W_{br}}{A_{br}}$$ If the load from the floating house (Bola rai') is evenly distributed and the poles are spaced equally, then theoretically each pole will experience the same pressure (P), so that, $$P_1 = P_2 = P_3 = \cdots = P_n$$ Where, P_1 represents the pressure on the first pole and P_n represents the pressure on the nth pole. It is assumed that: $$\frac{W_{br}}{A_{br}} = \frac{W_{br}}{A_{br}} = \frac{W_{br}}{A_{br}} = \cdots = \frac{W_{br}}{A_{br}}$$ However, in practice, the pressure on each pile may vary slightly due to factors such as uneven mass distribution within the house, imbalances in the placement of items inside, or variations in water conditions beneath the raft, which may not be uniform. Nevertheless, with a symmetrical design and evenly spaced piles, these differences are minimized, causing the pressure on each pile to approach a similar value. This helps maintain the overall stability of the floating house, reduces the risk of structural deformation, and maximizes the lifespan of the piles.
		• The maximum height of the wood used as a	The maximum height of the wooden poles, set at 0,5 meters on the Bola Rai' floating house, is a crucial consideration for ensuring both stability and flexibility of the structure on water. Since the

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
		pole is 0,5 meters.	poles are generally made of wood, which has low elasticity, they are prone to fractures when subjected to frictional forces from the wind and the impact of sea waves. Applying Newton's First and Third Laws, shorter poles are better able to maintain stability by reducing the forces acting on them. **Newton's First Law** states that an object will remain at rest if the net force (F) acting on it is zero, or an object moving in a straight line will continue to move at a constant velocity unless acted upon by an external force. $$\sum F = 0$$ Newton's First Law, or the law of inertia, applies to the bola rai' pillars, but in a context slightly different from objects in a fixed and stationary state. This law states that an object will remain at rest or move at a constant velocity unless acted upon by an external force. In this case, the bola rai' pillars are influenced by the weight of the building structure above them as well as external forces such as wind and water currents. **Newton's Third Law** states that for every action, there is an equal and opposite reaction. This means that if one object exerts a force on another, the second object will exert a force back on the first with the same magnitude but in the opposite direction. $$F_{aksi} = F_{reksi}$$ Every action has an equal and opposite reaction. When a pole experiences a force from the weight of the house above it, the pole exerts an equal but opposite reaction force back on the house, helping to keep it balanced on the water. These findings are consistent with the local practice of limiting pole height, but they can also be compared with engineering studies on cylindrical piles in offshore structures. Morison's equation (Morison et al., 1950) describes the hydrodynamic forces acting on piles, consisting of drag and inertial components caused by water currents and waves. According to this model, taller piles experience greater exposure to dynamic lateral loads, which may compromise stability. In this sense, the shorter wooden poles of the Bola Rai' not only reduce static loads but also mitigate the dynamic forces from wind and water movements, aligning with principles described in offshore engineering (E et al., 1948). This comparative perspective reinforces the local knowledge that keeping the pole height relatively low enhances the resilience of floating houses against environmental stresses. Since the base of the pole is not fixed and moves with the raft, the pole naturally "follows" movements caused by environmental forces such as wind and water pressure. This aligns with the principle of inertia, where the pole continues to respond to these changing external forces until a significant force like a strong wind

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
		• The connection between the pole and the arateng is secured using a peg-and-hole system for support.	or excessive load causes a more drastic change in the pole's state. This system allows the structure of the house to move flexibly in response to wind direction during shocks or vibrations. This also reflects the application of Newton's First Law.
3.	Walls & Ventilation	• The materials used in making the walls of the Bola rai' are bamboo, wooden planks, and zinc.	The selection of materials for constructing the walls of the Bola Rai' also affects the overall weight of the house. Therefore, lightweight yet durable materials are required. The mass (*m*) of an object can be determined by multiplying its density (*ρ*) by its volume (*V*): $$m = \rho . V$$ **The density** of wood ranges from 0,3 to 1,2 g/cm³, bamboo from 0,5 to 0,9 g/cm³, and zinc has a density of approximately 7,14 g/cm³. Bamboo and wood have lower densities compared to zinc, making them lighter and more flexible. Their lower densities allow the walls to maintain good load-bearing capacity without adding excessive weight to the floating structure of the Bola rai'. In contrast, zinc, with its higher density and rigidity, can serve effectively as a protective barrier against external elements but must be used carefully to avoid increasing the overall load, which could compromise the building's stability. Meanwhile, the thermal properties of a material can be observed through its **specific heat capacity** (c) and thermal **conductivity** (k). Specific heat: the ability of a material to absorb and release heat, or more precisely, the amount of heat required to raise the temperature of 1 kilogram of a substance by 1°C. Mathematically, it is expressed as follows: $$c = \frac{m . \Delta T}{Q}$$ Where, c is the specific heat, m is the mass of the material, ΔT is the change in temperature, and Q is the heat energy (in calories or joules). Based on theory, the specific heat of wood is 1700 J/kg°C, while zinc has a specific heat of 390 J/kg°C. This means that wood requires more heat energy than zinc to raise its temperature by the same amount. **Thermal Conductivity**: the intrinsic ability of a material to transfer or conduct heat. It can be expressed by the following equation: $$k = \frac{Q . d}{A . \Delta T}$$ Where k is the thermal conductivity, d is the distance between two isothermal planes, and A is the surface area.

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
			In theory, wood and bamboo are insulating materials, meaning they are poor conductors of heat, while zinc is a conductive material that easily transfers heat.
		• Space is left when installing walls to allow air circulation.	The purpose of providing space when installing the walls of the bola rai' is to regulate the flow of air entering and leaving the house, thereby providing natural ventilation for the occupants. From a physics perspective, the principles of **aerodynamics** and **Pascal's law** influence how air flows through this space, as well as how wind friction affects the stability and thermal comfort of the house. **Aerodynamics:** a branch of dynamics that studies the movement of air, especially when it interacts with solid objects. The gaps between the walls allow wind to flow more smoothly inside and outside the room. In aerodynamics, smooth airflow reduces the frictional force between the wind and the surface of the house walls. The equation used to describe the wind friction force is, $$F_g = \frac{1}{2} \times C_d \times \rho \times v^2 \times A$$ Where F_g is the wind friction force, C_d is the air friction coefficient, v is the wind speed, and A is the surface area. The presence of gaps allows the wind friction force acting on the wall to be better controlled, enabling wind to enter without exerting excessive pressure on the wall. **Pascal's Law** states that the pressure exerted by a fluid in a closed space is transmitted equally in all directions with the same magnitude. The equation for Pascal's law is similar to the equation for pressure in solids, which is: $$P = \frac{F}{A}$$ Based on Pascal's Law, the pressure exerted by a fluid (air) is evenly distributed in all directions within a closed or connected space. The gaps in the walls allow airflow to act as a pressure balancer inside the room, reducing the potential disturbances caused by strong winds and helping to maintain a more stable temperature indoors.
4.	Roof	• The roof structure of the bola rai' is designed using materials that are lightweight yet durable.	The roof structure of the bola rai', which uses materials that are lightweight yet durable, can be explained through physics concepts, especially those related to gravity, specific heat, and thermal conductivity. Considering that the roof is one of the components of the bola rai', its weight will also be supported by the poles and raft, so the material used for the roof must be carefully selected.

No.	Bola Rai' Components	Local Community Knowledge	Analysis of Physics Principles in The Design of The Bola Rai'
			$$W = m \times g$$ The gravity referred to here is the gravitational force generated by the roof. Specific heat and thermal conductivity have also been discussed in the wall section. Therefore, the materials used must be carefully selected to maintain the stability of the bola rai' while ensuring comfort as a place of residence.
		• The roof is generally made of bamboo or wooden planks and only covers a small portion of the structure. It is designed to serve as a storage area for fishing equipment.	The use of a ceiling on the roof of the bola rai' is made from bamboo arranged sparsely to minimize the weight generated by the roof components. Mathematically, this can be expressed as follows: $$W_{atap} = (m_{atap} + m_{plafon}).g$$ When W_{atap} increases, the gravitational force acting on the bola rai' also increases, resulting in a greater load being borne by the raft.

CONCLUSION

Based on the research results that have been obtained and analyzed, it can be concluded that several physics principles are applied in the design of the bola rai', using the local community's knowledge. The design of the bola rai', which maintains the traditional Bugis house style while adapting to the environmental conditions of Lake Tempe, incorporates various physics concepts. The raft section applies the Archimedes' principle, hydrostatic pressure, gravity, and pressure. The pillar section involves principles such as gravity, Newton's laws, and pressure. The wall section applies concepts of aerodynamics, heat, thermal conductivity, and Pascal's law. Meanwhile, the roof section incorporates the principles of pressure, gravity, heat, and thermal conductivity.

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