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Original Research

Lopi Sandeq Construction Ethnomathematics: Analysis of Geometry and Numeracy System of the Mandar Culture

Ida Farida[1], Widya Ningsih[2*)], Aulia Mutmainnah[3], Lalu Muh. Yunus[4], Nurhidaya[5], Aprisal[6], & Yusfa Lestari[7]
[1, 2, 3, 4, 5, 6, 7]West Sulawesi University, Majene, Indonesia

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Abstract: Standard mathematics education often overlooks the rich mathematical concepts embedded in local cultures, leading to a gap between formal learning and indigenous knowledge. This study explores the ethnomathematical elements in the construction of the traditional Mandar boat, the *Lopi Sandeq*, which relies on intuitive mathematical principles. Using an ethnographic approach, data were collected through observation, documentation, and in-depth interviews with *Punggawa* in Karama Village, Polewali Mandar. Data analysis employed mathematical abstraction to transform local knowledge into formal concepts. The findings reveal that geometric integration occurs within its main components: the triangular principle on the sail (Sobal), a parabolic curve on the hull for hydrodynamic efficiency, and bilateral symmetry in the equilibrium system of the *baratang* and *palatto'*. Additionally, the traditional numeracy system based on depa units (dappa) consistently applies specific dimension ratios tailored to the boat's function (fishing vs. competition). This study concludes that the *Lopi Sandeq* serves as a living mathematics laboratory with great potential for integration into the Independent Curriculum (*Kurikulum Merdeka*) as a concrete, Culture-based learning medium.

Correspondence Address: *Jalan Prof. Dr. Baharuddin Lopa, S.H., Kelurahan Talumung, Kecamatan Banggae Timur, Kabupaten Majene, Sulawesi Barat, Indonesia, Post Code 91412; e-mail: wn4608869@gmail.com

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INTRODUCTION

Mathematics plays a crucial role in daily life, both in solving practical problems and developing logical mindsets. However, it is often perceived as an abstract subject disconnected from social reality (Wahyuni et al., 2023). In West Sulawesi, mathematical values have actually been internalized for generations through local wisdom and cultural practices, particularly within the Mandar ethnic community. A prominent representation of this indigenous mathematical intelligence is found in the construction of the *Lopi Sandeq*, a traditional Mandar sailboat renowned for its exceptional speed and stability at sea. The design of the *Lopi Sandeq* is not merely a work of maritime art, it manifests the application of precise geometric concepts, despite being crafted through deep symbolic and intuitive practices by its local builders (Sonni et al., 2021; Wulandah, 2025).

Functionally, the *Lopi Sandeq* serves as a vital instrument for the Mandar people in sustaining their maritime economy, primarily supporting traditional fishermen (Wulandah, 2025). The boat's ability to navigate high-speed waves demonstrates a profound, non-formal understanding of hydrodynamics and structural balance (Syamsuddin et al., 2023). The unique characteristics of the slender hull shape and the use of triangular sails known as tanja sails are not just cultural aesthetic elements, but the result of mature mathematical calculations to ensure the efficiency of boat movement (Sonni et al., 2021). The practice of boat construction is a tangible form of ethnomathematics, where the activity of designing, measuring, and determining proportions is carried out systematically by craftsmen (Fajriyah, 2018). This knowledge is passed down from generation to generation through practical experience, which proves that maritime activities on the coast are closely related to the application of naturally tested geometric concepts (Akbar et al., 2023; Pitaloka et al., 2025).

The richness of ethnomathematics in Mandar culture is not only limited to maritime technology, but has also been explored in various other aspects of local wisdom. Previous research shows a close relationship between school mathematics concepts and the process of making and patterning Lipa' Sa'be (Mandar Silk Sarong), which includes the concept of measurement, circle tangents, and the concept of sets (Aprisal et al., 2023). If the mathematical concept of the weaving cloth is found in geometric patterns, then in *Lopi Sandeq* the concept is manifested in a more complex physical structure. The consistency of using mathematical principles in various cultural products strengthens the argument that the Mandar people have a structured knowledge system. In the construction of *Lopi Sandeq*, this regularity is clearly seen in the use of local units of depa (*dappa*), an anthropometric measurement system based on human hand span. Although traditional, the application of Depa units (*dappa*) in determining the proportions of boat components shows a high level of accuracy to ensure structural balance when sailing (Sonni et al., 2021; Syamsuddin et al., 2023).

More specifically, the construction of *Lopi Sandeq* consists of various main components, each of which has a distinctive local term and geometric function. These parts include the sail mast (*pallayarang*) which determines the fulcrum point, the sail (*sobal*) which is generally in the shape of a triangle of tanja, as well as the wing of the boat (*baratang*) and the buoy (*palatto'*) which function as a mechanical counterweight for the boat (Sonni et al., 2021). The determination of the dimensions and position of each component is carried out by a *Punggawa* by considering the ratio and balance through the use of Depa units (*dappa*). The use of these local terms is not just a linguistic identity, but a representation of the maritime knowledge system of the Mandar community that harmoniously integrates the concept of spatial geometry and the physical structure of the boat.

Much research has been done on ethnomathematics in various cultures in Indonesia, such as exploration of the components of phinisi ships, traditional dance movement patterns, and the concept of circles in cultural artifacts (Akbar et al., 2023; Aminah et al., 2025; Habibah et al., 2022). Especially in the Mandar culture, previous studies have touched on ethnomathematical aspects of the silk sarong motif (*Lipa' Sa'be*) (Aprisal et al., 2023), as well as the use of traditional units of measurement such as Depa (*dappa*). The use of Depa units (*dappa*) in boat construction shows that the Mandar community has consistent measurement standards. In addition, efforts to introduce the concept of numeracy through *Lopi Sandeq* teaching aids have also begun to be developed to make it easier for students to understand (Syamsuddin et al., 2023). Through this exploration of the *Lopi Sandeq*, this study aims to expand the scope of Mandar ethnomathematics into complex maritime construction, uncovering the deep relationship between geometry and traditional numeracy philosophy. Specifically, this research addresses two central questions: (1) what formal geometric concepts and traditional numeracy systems are embedded in the construction process of the *Lopi Sandeq*? and (2) how can these indigenous mathematical elements be structurally integrated into formal mathematics education?

By addressing these questions, this study serves a dual significance. Theoretically, it contributes to the preservation of indigenous knowledge by documenting the mathematical intelligence of Mandar boat builders within a formal academic framework. Practically, the insights gained provide a concrete, culturally responsive roadmap for educators to design contextual learning media aligned with the *Merdeka* Curriculum. This approach not only helps students grasp abstract mathematical concepts through their own cultural heritage but also fosters a deeper appreciation for local wisdom (Syamsuddin et al., 2023; Wahyuni et al., 2023)

METHOD

This study uses a qualitative approach with ethnographic methods to explore ethnomathematical elements in the construction of *Lopi Sandeq*. The ethnographic method was chosen because it is relevant to describe and analyze the cultural practices and local knowledge of the Mandar people related to mathematical activities (Aprisal et al., 2023). The research is focused on collecting data on the principles of geometry and numeracy systems used in the boat-building process, especially on the hull and sails.

The data in this study were collected through participatory observation techniques, in-depth interviews, and documentation. Observations were carried out on the process of measuring and assembling boat components, while interviews were conducted with key resource persons, namely *Punggawa* (boat builder experts) and fishermen who understand the operations of *Lopi Sandeq*. The main instrument in this study is the researcher himself (Human Instrument) assisted by interview guidelines and recording equipment. This research was conducted over a two-month period, from February to April 2026, to allow for an extended ethnographic immersion within the Mandar maritime community. The preliminary fieldwork, community engagement, and continuous observations of boat-building activities culminated in structured, in-depth documentation and interviews with the *Punggawa* on April 6, 2026, at a traditional boat yard located in Karama Village, Tinambung district, Polewali Mandar Regency, West Sulawesi. The data analysis techniques used follow the model of Miles and Huberman (2014). This includes data reduction, data presentation, and drawing conclusions to uncover the relationship between maritime cultural practices and formal mathematical concepts. In addition to using Miles and Huberman, the data analysis in this study was carried out through a mathematical abstraction process consisting of 3 main stages. First, the identification stage of the *Lopi Sandeq* elements through participatory observation. Second, deconstructing local terms and traditional units of measurement used by *Punggawa* (boat-building experts), such as depa units (dappa). Third, formalizing concepts, namely transforming the local knowledge into formal mathematical language (such as curve geometry and ratio comparison). For example, traditional dappa measurements are analyzed using the linear function $f, M. =, M - k.$ to find the standardization of the metrics, so that intuitive local wisdom can be explained scientifically through geometric and numeracy frameworks.

RESULTS

Exploration of geometric concepts in the construction of Lopi Sandeq

Based on the results of observations on the physical structure of *Lopi Sandeq* at the Polewali Mandar Regency Boat Yard, various manifestations of geometric concepts that are functionally integrated are found, represented in Figure 1.

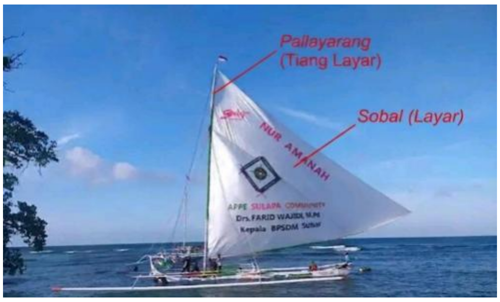

Figure 1. *Lopi Sandeq* with Expanded Triangle Screen

Based on the results of observations, the *Lopi Sandeq* sail precisely forms an arbitrary triangle. This can be seen from the position of the pole (pallayarang) as the vertical axis (a) and the lower support bamboo (foot) as the horizontal side (b) which forms a dynamic angle (γ) in accordance with the need to capture the wind optimally. The relationship between the length of the sides - sides of the sail and the angle formed can be formalized using the cosine rule to determine the length of the oblique side of the sail (c), calculated by the Formula (1).

$$c^2 = a^2 + b^2 - 2ab \cdot cos\ (\gamma) \tag{1}$$

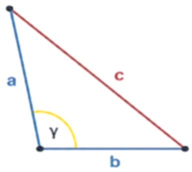

Figure 2. Illustration of an Arbitrary Triangle on a *Lopi Sandeq*

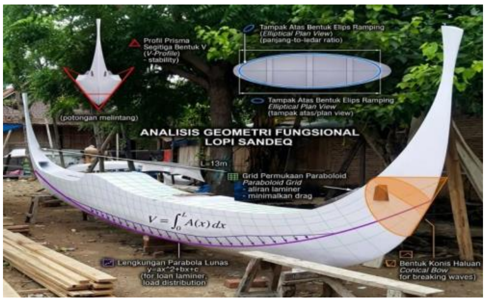

Figure 3. Analysis of *Lopi Sandeq's* Hull

Exploration of the geometry of the hull of the *Lopi Sandeq* shows the application of a high-level curve that is very functional. On the keel of the *Lopi Sandeq*, a parabolic shape is found that follows the bottom of the boat. Systematically, this curve functions to distribute the load evenly along the main structure and minimize water resistance (drag). This is what allows the *Lopi Sandeq* to glide above the water surface at high speed. If the parabolic arc is projected in three dimensions following the wall of the boat, a paraboloid surface will be formed. This structure is clearly visible through the fine grids on the hull that ensure that the flow of water moves smoothly along the sides of the boat without creating large turbulence that can hinder the speed of movement.

Furthermore, when viewed through a transverse cut from the front or aft, the Sandeq hull adopts a triangular prism profile with a very slender V shape. Functionally, this sharp V profile is like a knife that splits the waves, providing excellent directional stability (rate) so that the boat is not easily swayed by the side wind when the sail is deployed. This geometric advantage is also supported by the slim elliptical shape if the boat is viewed from the top (plane view). The length ratio that is much larger than the width geometrically reduces wave resistance. As a complement to the bow, a conical (tapered) shape is applied that helps to break up high waves, so that water does not easily enter the boat deck area when sailing on the open sea.

Structurally, the body of the *Lopi Sandeq* is a complex combination of a spatial structure and an aerodynamic curve (observe the Figure 3.). If sliced transversely, the cross-section of the boat body resembles an elongated trapezoid or semicircle, which in spatial geometry can be analyzed as a modified rectangular prism shape. To calculate the estimated hull volume (V) to determine the buoyancy capacity of the boat, the craftsman intuitively applies the principle of integratingcross-sectional areas along Lopi's hull, represented in Equation (2).

$$\mathrm{V} = \int_0^L A(x)dx \qquad (2)$$

Where L is the length of the hull $(13\ meters)$ and $A(x)$ is the cross-sectional area at a given point. In addition, when viewed from the side view, the bottom to the end of the arc forms a parabolic curve. The existence of this curve is highly functional hydrodynamically for breaking down water resistance, which can be represented through the Equation of a General Quadratic Function (3).

$$y = ax^2 + bx + c \qquad (3)$$

The tapered shape at both ends of the *Lopi* (the concept of a limit to one point) ensures that the water flow remains laminar, so that the *Lopi* can travel with high stability despite having a very slim body width.

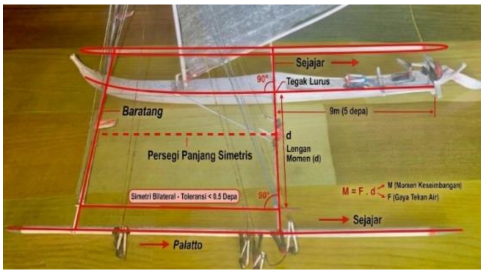

Figure 4. ***Baratang & Palatto'***

Based on Figure 4., the balancing system on the *Lopi Sandeq* is a manifestation of the concept of parallel and perpendicular lines in plane geometry. The *baratang* (transverse support bamboo) is installed horizontally and perpendicular to the longitudinal axis of Lopi's hull, forming a precise 90° angle. At the end of the *baratang*, *a palatto'* (buoy) is installed, which is positioned parallel to the boat. Mechanically and mathematically, this structure is designed to create a large moment arm (d) to produce a moment of balance (M), written in Equation (4).

$$M = F \cdot d \qquad (4)$$

Where F is the compressive force of the water on the buoy, and d is the distance from the center of the *Lopi* to the buoy. The distance of 9 $meters$ (5 depa) is a carefully calculated number to ensure that the very lean Lopi still has static and dynamic stability. In addition, if analyzed from the top view, the skeleton formed by the front *baratang*, the rear *baratang*, and the two *palattos* represents a symmetrical rectangular flat shape. The application of bilateral symmetry in this part is very crucial, if there is a difference in length of only 0.5 Depa between the left and right sides, then the resulting force will be unbalanced, which will systematically cause the Lopi to tend to turn or become unstable when hit by waves.

Numeracy and measurement system in the construction of Lopi Sandeq

This section discusses the number system and measurement activities used by retainers (boatbuilders). The numeracy system in the construction of the *Lopi Sandeq* represents a very interesting cognitive transition between traditional ethnomathematical knowledge and modern metric measurement standards. The main measurement activity used by retainers (boatbuilders) has historically been rooted in the depa unit (*dappa*), which is the length of an adult's arm span that is empirically equivalent to 1.8 meters. Although metric instruments have now been used to achieve high precision according to competitive standards, the design logic is still based on traditional units. The relationship between the metric value (M) and the depa unit (D) can be formalized into a simple linear function as follows Equation (5).

$$f(M) = \frac{M}{k}, with\ k\ =\ 1{,}8 \quad (5)$$

Based on these functions, the results of field observations of the main dimensions of the boat show a significant numerical linkage:

1. Hull length (13 $meters$): Has a conversion value of f (3) ≈7.2 depa.
2. Height of poles and buoys (15 $meters$): Has a conversion value of f (15) ≈ 8.3 depa.
3. Length (9 $meters$): Produces a conversion value of exactly 5 depa.

The finding of the exact number 5 depa in the *baratang* component is clear evidence of the existence of mental mathematics (Mental Calculation) that has been inherited from generation to generation. The use of integers in traditional units shows that the *baratang* as an axis of equilibrium, is the initial reference point in boat construction. This proves that even though measuring tools have been modernized, the basis of thinking of craftsmen still uses a culture-based number system that prioritizes the harmony of integers in order to facilitate the standardization of structures without the use of written records.

Furthermore, these numerical dimensions reveal the consistent application of the principle of proportionality and geometric ratios. The similarity of measurements between the height of the mast (*pallayarang*) and the length of the buoy (*palatto'*) which both reach 15 $meters$, indicates the calculation of a 1: 1 ratio of the counterweight. Mechanically, this similarity of length aims to balance the aerodynamic thrust of the sail with the buoyancy of the buoy.

Finally, there is a transformation of physical parameters driven by functional evolution. Past *Lopi Sandeqs* were designed with a larger volume of space for fishermen's load capacity. However, in today's racing *Sandeqs*, there is numerical optimization in the form of a reduction in hull width and material weight. Systematically, this transformation is committed to increasing the ratio of speed to mass, where the reduction of the area of the hull wet cross-section is directly proportional to the reduction of water resistance, so that the boat reaches maximum speed above the surface of the water.

The application of the numeracy system in the construction of the *Lopi Sandeq* shows the variance in dimensions based on the functional evolution of the boat. There is a difference in the ratio between the Sandeq fisherman (for economic activity) and the *Sandeq* race (for speed). In the *Sandeq* fisherman, the main focus of the numeracy lies in the wider hull volume to accommodate the catch, while in the *Sandeq* race, the length-to-width ratio is mathematically narrowed to reduce water resistance (*drag*) and improve the aerodynamics of the sail.

Table 1. Comparison of Metric Dimensions and Fugional Variance of *Lopi Sandeq* Construction Based on Local and Metric Units

Boat Component	Metric Size	Depa Conversion ($D - M/1{,}8$)	Mathematical Significance
Hull Lenght	13 m	≈ 7,2 Depa	Focus on volume and buoyancy
Pallayarang Height	15 m	≈ 8,3 Depa	Focus on screen aerodynamics
Long *Palatto'*	15 m	≈ 8,3 Depa	1: 1 ratio to mast height
Long *Baratang*	9 m	5 Depa	Equilibrium constant

Based on Table 1., comprehensively, *Lopi Sandeq's* design is not just the result of manual skills, but a manifestation of the mathematical intelligence of the Mandar people that has been inherited from generation to generation. The integration of functional geometric forms (such as arbitrary triangles, parabolic curves, and prisms) with culture-based numeracy systems (depa units) creates an engineering harmony. The use of the integer 5 depa as a constant in the *baratang* part is key evidence that there is a consistent logical structure in the ethnomathematical thinking of the Mandar people, where precision is not only measured with modern metric tools, but also through mature sensitivity to ratios and proportions.

DISCUSSION

The finding that *Lopi Sandeq's* sail forms an arbitrary triangle shows a high level of adaptation of local technology. In contrast to the concept of school geometry, which often dissects triangles in an ideal (static) form, the retainers intuitively use the principles of non-Euclidean geometry to respond to natural dynamics. The use of triangular shapes on this screen is in line with research by Akbar et al. (2023), which states that coastal communities tend to use geometric shapes that minimize air resistance to improve motion efficiency. This is supported by the findings of Ali et al. (2016) that precision in determining the angle of inclination of the sail mast is the result of traditional calculations that are accurate to the direction of the wind.

The construction of *Lopi Sandeq* has great potential to be transformed from just a cultural object to a learning medium. In line with research by Juhardi et al. (2024) which showed that the context of *Lopi Sandeq* significantly improved the mathematical connections of junior high school students in Polewali Mandar, the results of this exploration also show that the functional dimensions of boats can be integrated into flat building materials and spaces. This reinforces the findings of Putri et al. (2024) through their meta-analysis study that culture-based learning has a positive impact on students' cognitive achievement.

Furthermore, the trigonometric analysis on this screen is not only limited to the tan value θ, but also involves cosine rules to determine the length of the slope that is most stable to the wind load. This reinforces the theory by Pitaloka et al. (2025) that maritime ethnomathematics often involves complex calculations wrapped in practical skills. The integration between vertical mast positions and horizontal footpegs creates a local coordinate system that allows boats to keep going fast despite the very slim width of the boat's hull. These findings also support the argument by Sonni et al. (2021) that each indentation in the *Lopi Sandeq* component has a symbolic meaning as well as a mature mathematical function.

In addition to aerodynamic aspects, the performance of the *Lopi Sandeq* is highly dependent on the hydrodynamics of the hull. The use of paraboloid curves on the keel aims to create a laminar flow of water, which is technically very crucial in maintaining directional stability and minimizing ship resistance when splitting waves (Paroka, 2018). The reliability of these boats in high-seas navigation is also supported by the use of additional buoyancy components such as palatto that maintain dynamic balance, a practice that is in line with modern traditional ship safety standards (Wahyuni et al., 2023).

From an educational perspective, the ethnomathematical complexity of this boat offers great potential to be transformed into a project-based learning model in schools (Kesumawati et al., 2025). Through assignment designs that are relevant to the local context, students can be invited to explore the concepts of ratio and proportion that have proven to be effective in honing computational thinking skills (Jayanti et al., 2025). The use of digital teaching aids that integrate local wisdom like this can also increase numeracy literacy while strengthening pride in cultural identity (Aminah et al., 2025; Pitaloka et al., 2025).

The institutionalization of school geometry concepts through a maritime context allows students to see mathematics not as a dead formula, but as a living instrument to solve real problems (Nurafifah et al., 2024). This provides space for the exploration of geometric patterns that are also found in various other traditional cultural movements and symbols in Indonesia (Habibah et al., 2022; Istikomah et al., 2024). This approach consistently supports the role of ethnomathematics in strengthening students' mathematical literacy in a meaningful way (Fajriyah, 2018).

Comprehensively, this exploration proves that the construction of *Lopi Sandeq* is a manifestation of the mathematical intelligence of the mandar community which includes aspects of numeracy, geometry, and mature engineering logic as found in various other components of traditional Indonesian ships (Akbar et al., 2023; Syamsuddin et al., 2023). These findings support the idea that every curve and size on the boat has a functional value that can be scientifically reasoned (Sonni et al., 2021; Wulandah, 2025). By integrating these findings into the curriculum, we not only preserve culture, but also enrich mathematics education methodologies through the exploration of the local wisdom of the nautical community (Wahyuni et al., 2023).

In addition to the technical aspect, the institutionalization of ethnomathematical concepts through the maritime context allows students to see mathematics as a living instrument to solve real problems (Nurafifah et al., 2024). This is in line with the development of local culture-based learning tools that are able to increase students' positive attitudes towards mathematics (Ariantini, 2017; Ode et al., 2020). The integration of technology through digital teaching aids is also an important bridge in respecting cultural heritage while improving numeracy and literacy in the modern era (Agustino et al., 2025; Aminah et al., 2025). Technically, in-depth analysis of traditional ship structures through modeling and Computational Fluid Dynamics (CFD) proves that local wisdom has a very strong scientific basis in the aspect of hydrodynamics (Liu et al., 2019; Subbaiah et al., 2015). Thus, strengthening the national ethnomathematics-based curriculum is a strategic step to enrich the methodology of mathematics education in Indonesia (Arifin, 2020; Habsyi et al., 2025; Siregar et al., 2024).

CONCLUSION

Based on the results of the analysis and discussion, it can be concluded that the construction of *Lopi Sandeq* is a tangible manifestation of the application of precise geometric concepts, including the use of Pythagorean theorems and cosine rules on sails, as well as the application of the quadratic function on the hull curve for hydrodynamic efficiency. The Mandar community has had a consistent measurement system through depa units (dappa) for generations, where the use of integers such as the 5 depa constant in the *baratang* component is evidence of the existence of a mental mathematical logic that prioritizes harmony and structural equilibrium without the use of written records. These findings confirm that *Lopi Sandeq* is not just a cultural identity but a living mathematics laboratory that offers great potential to be transformed into a project-based learning model that is relevant to the understanding of geometry in the context of the modern curriculum and the development of numeracy literacy.

The ethnomathematical findings of this study offer direct practical implications for curriculum development, particularly within the framework of contextual learning in school mathematics. The mathematical components identified in *Lopi Sandeq* can be transformed into concrete learning activities across several instructional domains: (1) Geometry and trigonometry: The structural layout of the boat's sail provides a real-world model for studying right-angled triangles. Educators can utilize this to teach the Pythagorean theorem $a^2 + b^2 + c^2$ and basic trigonometric ratios, such as calculating the tilt angle using $tan\ \theta$; (2) Quadratic functions: The unique curvature of the boat's keel can be modeled as a parabolic graph. This offers a tangible visualization for students learning quadratic functions represented by the formal equation $y = ax^2 + bx + c$, showing how mathematical variables directly affect hydrodynamic efficiency in the real world; (3) Coordinate and Vector Systems: Analyzing the equilibrium and physics of the boat specifically the balance of wind forces acting on the sail versus the water resistance on the buoy can be integrated into advanced lessons on coordinate geometry and vector analysis; (4) Geometric Transformations: The bilateral symmetry enggineered between the left and right sides of the boat along its longitudinal axis serves as an excellent, culturally relevant example to demonstrate the principles of reflection and symmetry.

By contextualizing abstract mathematical concepts through the local wisdom of *Lopi Sandeq*, teachers can create highly engaging, project-based learning models. This approach not only strengthens students' conceptual understanding and mathematical literacy but also reinforces cultural identity and appreciation for indigenous technology.

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