

The Ethnomathematics of Symmetric War-boat of Biak Tribe

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Abstract

Traditional indigenous technologies are often undervalued in academic discourse, resulting in limited understanding of the mathematical principles underlying culturally specific engineering practices. Addressing this gap, this study examines the Wairon, a distinctive War-boat of the Biak tribe, to illuminate how local boatbuilding traditions embody sophisticated spatial reasoning rarely documented in current ethnomathematical literature. The present research is novel in its focus on the symmetrical construction of the Wairon, contributing to the discourse by revealing how Biak artisans systematically implement geometric and anthropometric concepts within their craft. The main objective is to document and analyze the design elements of Wairon symmetry, elucidating the operationalization of mathematical logic through artisanal knowledge. Employing an exploratory qualitative methodology, data were collected via twelve in-depth interviews with cultural experts and elder boatbuilders, direct observation of three traditional construction sessions, and a comprehensive literature review. Rigorous triangulation across these sources ensured thematic validity and analytic saturation. Thematic coding was conducted in several cycles, guided by peer review, with particular attention to recurrent patterns of symmetry, measurement practices, and structural reasoning. Symmetry in this context is defined as bilateral congruence along the central longitudinal axis, as demonstrated in the paired positioning of structural elements, including najun (crossbeams), outriggers, pegs, and carvings. Empirical evidence was established through analyses of spatial repetition, alignment, and the use of anthropometric units such as arm span and fathom. Findings reveal that the Wairon's symmetrical architecture is functionally integral beyond its symbolic and aesthetic roles, it enhances maneuverability and tactical efficacy in wartime navigation. Theoretically, this research enriches the field of ethnomathematics by highlighting how cultural logics of symmetry are inseparable from indigenous solutions to navigational challenges. Practically, these insights inform STEM education and support digital heritage preservation, offering a model for the virtual reconstruction and meaningful integration of indigenous technological wisdom.

Keywords: Biak Tribe, Cultural Geometry, Ethnomathematics, Symmetry, Wairon Boat



Introduction

Mathematics extends beyond abstract computation and formal proof; it is fundamentally interwoven with cultural practices that shape how communities understand and interact with space, form, and measurement (Fouze & Amit, 2023). This expansive view underpins the field of ethnomathematics, which systematically explores the diversity of mathematical reasoning present across cultures (Lidinillah et al., 2022; Mania & Alam, 2021). Ethnomathematics is delineated as the body of mathematical knowledge developed within diverse societal contexts, formed by the distinctive ways cultures conceptualize and enact mathematical processes such as grouping, quantification, measurement, design, and artistic expression (d'Ambrósio, 1985; Kabuye, 2024). Crucially, ethnomathematics investigates these constructs within their cultural and historical milieus (Abdulrahim & Orosco, 2020; Ahmad et al., 2024; Hendriyanto et al., 2023; Lidinillah et al., 2022), analyzing both practical discoveries and the aesthetic manifestations of mathematical thinking. Where direct engagement with the original creators is precluded by temporal or physical constraints, contemporary researchers reconstruct the underlying mathematical reasoning through immersion in analogous processes of creation and experimentation (Aditya, 2018; Ascher, 2002; Mania & Alam, 2021).

One salient manifestation of ethnomathematics is evident in traditional boatbuilding, where indigenous geometric logics and measurement systems are inherent to the craft. For instance, wood selection for boat construction is governed by stringent criteria, requiring that materials be robust, break-resistant, straight-grained, lightweight, minimally knotted, and resilient against environmental degradation particularly from marine organisms (Kurniawan et al., 2023; Lanoeroe et al., 2005; Suherman, 2018). Ethnomathematical principles such as these are profoundly embedded in daily life across Indonesia, permeating various aspects of social practice (Ahmad et al., 2024; Deda & Disnawati, 2024; Faiziyah et al., 2021; Umbara et al., 2021). Empirical studies affirm that cultural mathematical principles are readily observable in routine activities, reinforcing the integral role of ethnomathematics within Indonesian lived reality (Aditya, 2018; Ahmad et al., 2024; Deda & Disnawati, 2024; Hidayati & Prahmana, 2022; Suherman, 2018). Given Indonesia's maritime geography dominated by oceans and rivers boats are indispensable for transportation (Malalina et al., 2022; Muna et al., 2023; Nurafifah et al., 2024; Ratuanik & Filindity, 2021; Rumbekwan, 2014). Notably, the Biak people residing in Biak Numfor Regency construct three primary types of boats, distinguished by form and function: Waimansusu (passenger boat), Waipapa (fishing boat), and Wairon (war boat) (Rumbekwan, 2014).

Historically, the Biak engaged in extensive maritime trade with neighboring islands including Ternate, Tidore, Halmahera, Flores, Gebe, Celebes, and Buton as well as with Chinese and European sailors. The Manibobi partnership, which facilitated mobility among traders, was driven by factors such as competitiveness (korfandi), geography, economics, tribal alliances, and cultural protocols. Navigational leadership was provided by figures such as Manseren Mnu, Suprimanggun, and Mambri, who piloted the Wairon war boat using celestial navigation based on the Orion (Sawakoi) and Scorpio (Romanggwandi) constellations. Designed for warfare, the Wairon is distinct from other boat types due to its comprehensive

bilateral symmetry a characteristic evident in its bows, hull, najun (rectangular crossbeams), outriggers, pegs, decorative components, and figureheads. This symmetrical architecture permits bidirectional movement without the necessity of turning, a tactical advantage in battle scenarios; the crew can instantly change course by reorienting within the vessel. Symmetry is meticulously maintained through the mirrored arrangement of structural features, ensuring operational consistency regardless of navigational direction. The construction of a Wairon encompasses multiple sites, dictated by the varied availability of suitable timber, yet the foundational design principle precise and consistent symmetry remains universally applied across all builds, as illustrated in [Figure 1](#).



Figure 1. The *Wairon* boat of Biak Tribes

The craft of traditional boatbuilding is a specialized expertise possessed exclusively by the Biak people, transmitted across generations through oral tradition and never formally codified in written records. Nonetheless, the accelerating pace of technological development poses a significant threat, as shifts in cultural orientation and diminishing interest among younger members risk eroding this artisanal legacy. It is therefore imperative to intervene through systematic academic inquiry, prioritizing the documentation, reinterpretation, and safeguarding of indigenous boatmaking knowledge for future generations. Such efforts not only reinforce the theoretical foundation of ethnomathematics but also serve as practical instruments for recording and perpetuating indigenous knowledge within the broader scientific discourse. Accordingly, this research was undertaken with the explicit objective of identifying and analyzing the symmetrical design principles embedded in the Wairon war boat, as well as interpreting their ethnomathematical relevance and significance.

Methods

This research employed a descriptive qualitative approach within an exploratory survey design to investigate the ethnomathematical features of the Wairon war boat. Data collection was rigorously triangulated between the following sources:

1. In-depth interviews were conducted with twelve participants, including elders, tribal chiefs (Manawir), skilled boat artisans, and cultural experts primarily individuals born in the 1950 selected for their extensive hands-on experience and deep-rooted knowledge of traditional boat construction.

2. Direct field observations encompassed three separate Wairon building sessions, systematically documenting the construction phases and ensuring precise recording of component alignment and techniques.
3. Literature and document analyses focused on Biak maritime traditions, timber selection criteria, symbolic carvings, and indigenous boat-making methodologies.

Multiple verification strategies were introduced to guarantee data validity and credibility:

1. Member checking ensured that interview transcripts were reviewed and validated by the respective participants.
2. Peer debriefing facilitated thematic interpretation through collaborative consultation with academic peers.
3. Data triangulation was instituted by corroborating codes and themes across interviews, observations, and documentary evidence.
4. Thick description was applied to thoroughly account for the intricate cultural and technical aspects observed.

Data analysis was executed through a series of thematic coding cycles. Initial manual coding identified emergent categories such as symmetrical layout, measurement practices, and material selection criteria. Subsequent focused coding distilled these categories into central themes: bilateral geometric arrangements, proportional relationships based on anthropometric data, and strategies of spatial orientation. Cross-comparative analysis of codes enabled contextual interpretation concerning both cultural meaning and mathematical significance. Analytical memos were systematically developed to chronicle the progression of interpretation and to strengthen the transparency and auditability of the research process. A research flowchart as shown in [Figure 2](#) delineates the procedural steps, including instrument validation, comprehensive data triangulation, and progressive interpretation.

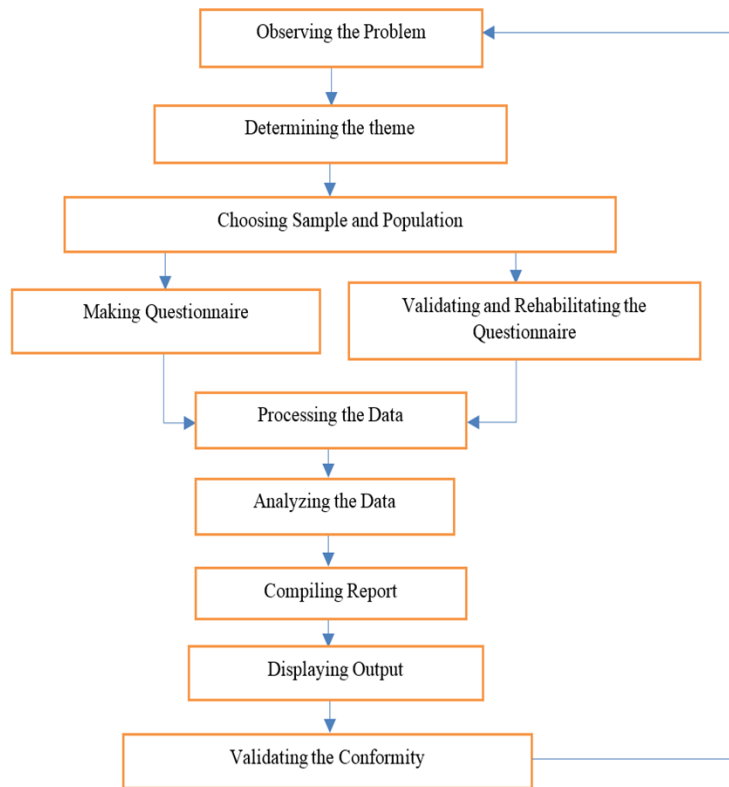


Figure 2. Research flowchart

Results and Discussion

The findings from this study reveal that the Wairon warboat is distinguished by both its structural and manufacturing attributes. Construction occurs in three distinct stages, necessitated by the geographic separation of suitable timber sources. Timber selection for each component is governed by rigorous functional criteria. For the hull, ideal wood must offer strength, buoyancy, lightness, and fracture resistance. The outrigger and stem require timber that is light and durable, while pegs and poles are crafted from denser, moderately heavy woods to ensure stable submersion and fastening. These choices are critical for optimizing the Wairon’s structural integrity and maritime performance as shown in [Figure 3](#).

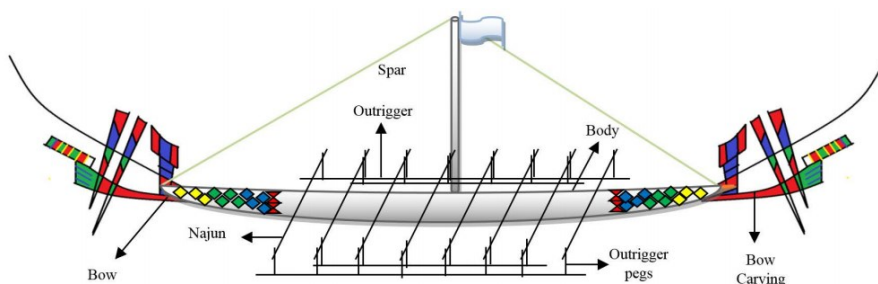


Figure 3. The Sketch of *Wairon* Boat

Systematic documentation identified that the Wairon body is typically constructed from Aimamur, Morem, Moref, Adoi, Ainus, Mansamaoi, and Maruwai. Stems and outriggers utilize Marempiam, Barnesem, and Manjau, and poles and pegs are made from Are, Kabuy, and Sner. The construction timeline is established by the availability of these materials and adherence to traditional protocols. A central principle evident throughout is the use of symmetry, which is foundational to the Wairon's stability, functional balance, and operational efficiency a practice corroborated by broader ethnomathematical studies of traditional boatbuilding (Lanoeroe et al., 2005; Ratuanik & Filindity, 2021; Saidi et al., 2024; Suherman, 2018).

The Symmetrical Shape of Bow Carving

Bow and body carvings are produced within the same construction phase to ensure overall balance. Once the body is formed, symmetrical motifs with distinct cultural significance are applied to both eastern and western flanks. Separate carved panels are integrated into the bow, achieving harmony in both structural and decorative features (see Figure 4).

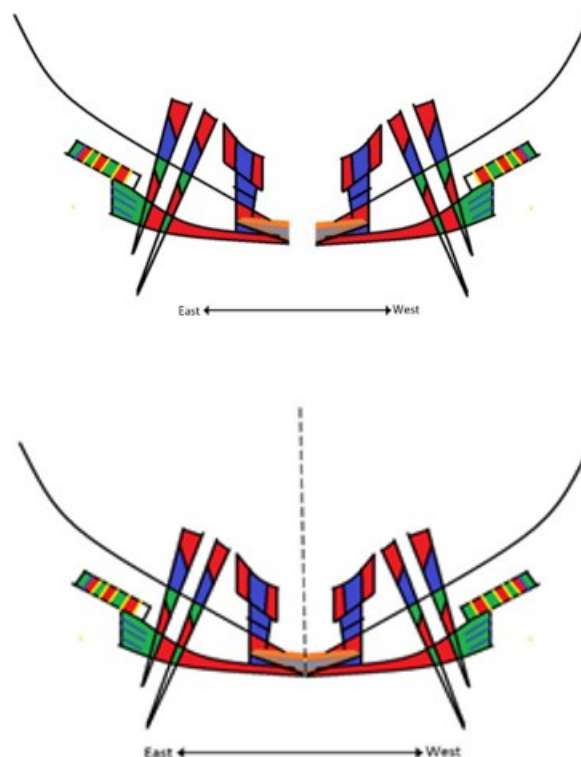


Figure 4. The sketch of Wairon bow carvings, (top) Wairon's separate carvings; (bottom), the joint bow carvings

The Symmetrical Length of the Boat

The length of the Wairon warboat is traditionally established through an anthropometric technique in which the measurement is taken from fingertip to fingertip with both arms fully extended. Adjustments to the boat's final length are made in accordance with its intended

military function, particularly the number of warriors it must accommodate during combat operations. This practice of measurement ensures that each boat is proportionally constructed, meeting both the practical and tactical demands of warfare illustrated in Figure 5.

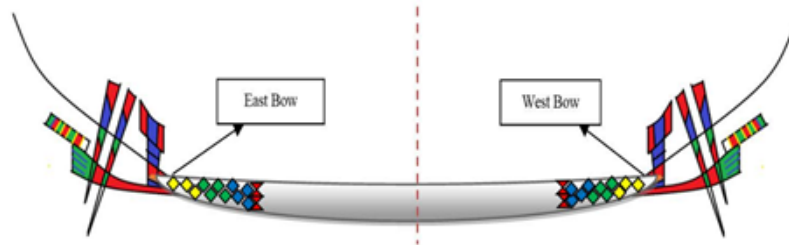


Figure 5. The Symmetrical body of the boat

The design of the *Wairon* also integrates a variety of accessories that function as critical supports for the outrigger system as shown in Figure 6. The specific characteristics of these accessories are determined by the expert preferences of individual boatbuilders, allowing for tailored functional adaptations while upholding the vessel's symmetrical architecture.

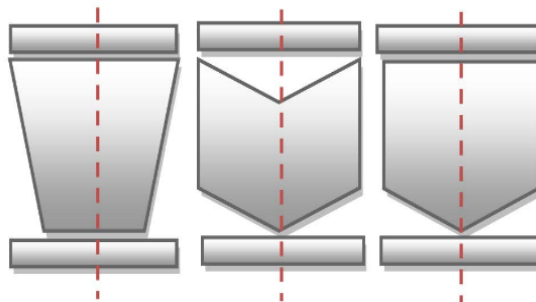


Figure 6. The accessories of the boat

The proportions of these accessories both in length and width are derived relative to the corresponding dimensions of the *Wairon*'s main body. Constructed primarily from thick wooden boards, these components serve as structural buffers, internal dividers, and secure anchor points for marine ropes. The attached rope is meticulously fixed to these points, ensuring robust stability and resisting displacement from wave action and sea winds. In addition, the symmetrical configuration of the accessories is essential, as it enables balanced tension distribution when fastening the boat's protective covers.

The Symmetrical Shape of the Bows

The findings demonstrate that the bow of the *Wairon* warboat is seamlessly integrated with the main hull, a construction approach that ensures both structural cohesion and stability. Each bow is configured as a triangular section, with ABC oriented towards the east and EFG towards the

west. The length of each bow component is traditionally measured in fathoms, reflecting indigenous anthropometric practices. As depicted in Figure 7, both the eastern and western ends of the boat are constructed as isosceles triangles edges AC and BC on the east, and EG and FG on the west are of equal length, with each triangle featuring two congruent angles and a distinct axis of symmetry (CD for the east, HG for the west). This meticulous, symmetrical design not only provides balanced support and continuous alignment but also enhances the hydrodynamic efficiency and overall functionality of the vessel in accordance with traditional maritime knowledge.

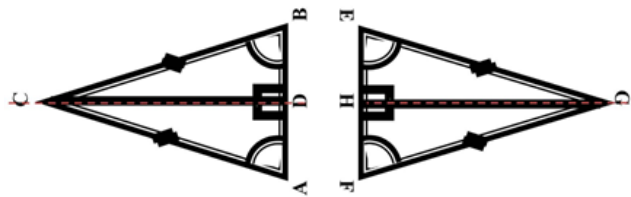


Figure 7. The Bows of the Boat

The Symmetrical Shape of the Outrigger Boom

As with the main hull, the najun which comprises both long and short crossbeam components is traditionally measured using fathoms. The precise dimensions of these elements are established through mutual consensus among experienced boatbuilders, acknowledging their vital role in preserving the balance and stability of the Wairon warboat during both routine navigation and combat maneuvers. This methodical and culturally rooted approach to measurement is instrumental in ensuring that the vessel attains optimal performance under diverse maritime conditions.

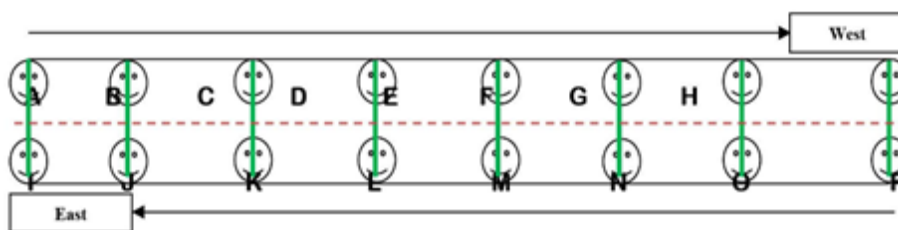


Figure 8. The outriggers (coloured in green) of Wairon boat

The distances of $AB = IJ = BC = JK = \dots = GH = OP$ then $AB = GH$ and $IJ = OP$. Also, $AI = BJ = CK = \dots = GO = HP$, then $AI = HP$. Other positions $ABJI = BCKJ = \dots = GHPO$, then $ABJI = GHPO$.

As illustrated in Figure 8, the seating arrangement for the war party aboard the Wairon is deliberately configured to maximize efficiency and agility during combat operations.

1. In offensive maneuvers, crew members designated as A, B, C, and so on through H, as well as I, J, K, etc., are positioned facing westward.
2. During defensive maneuvers, the rowers shift orientation to face east, with each individual (e.g., Person A) moving to the corresponding seat previously occupied by Person I, Person B to Person J, and so forth.
3. This systematic rotation enables rowers to maintain coordinated paddling technique, ensuring synchronized movement, steady propulsion, and adaptive flexibility regardless of tactical direction.

The Symmetrical Shape of the Outriggers

The Wairon warboat is equipped with four outriggers, consisting of one short and one long outrigger positioned on each side of the hull. The lengths of these outriggers are proportionally adjusted to align with the east and west bow carvings, a design choice that maintains the vessel's overall balance and stability during navigation. As illustrated in [Figure 9](#), this configuration of outriggers serves not only to increase buoyancy but also to enhance maneuverability and optimize hydrodynamic performance, allowing the warboat to operate efficiently in challenging maritime environments.

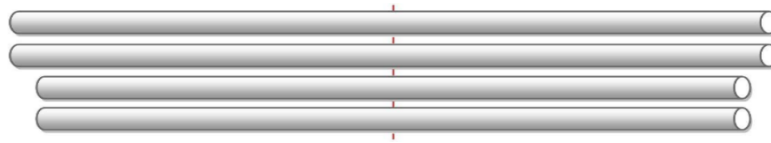


Figure 9. The four outriggers of Wairon boat; two (short and long outriggers) for the left the Wairon boat and the other pair for the right side.

The Symmetrical Shape of the Pegs

The Wairon warboat is constructed with a total of 28 pegs, which function to secure both the outriggers and najun crossbeams with precision. Each side of the bow left and right features 14 pegs, thereby maintaining the vessel's symmetrical architecture. The pegs are crafted to uniform dimensions on both sides, ensuring consistent and balanced support for the outriggers. On the left bow, which accommodates two outriggers, six pegs are installed on the inner side and eight on the outer side; this configuration is exactly mirrored on the right bow, as depicted in [Figure 3](#). [Figure 10](#) further clarifies the precise spatial arrangement of all structural elements, highlighting the deliberate emphasis on symmetry.

Comprehensive analysis confirms that these symmetrical relationships are informed by culturally embedded anthropometric benchmarks, such as arm span and fathoms, rather than arrived at arbitrarily. The replication of bow carvings on both sides is emblematic of Biak philosophical concepts of cosmic order and perpetual preparedness. Thus, the use of symmetry extends beyond decorative appeal, representing a rigorous, culturally situated understanding of

geometric balance within navigation. The presence of equilateral and isosceles triangles in bow construction, combined with proportional measuring practices across lateral components, exemplifies the implicit application of fundamental geometric theorems to real-world boat design.



Figure 10. The pegs used to clamp the outrigger; a) 8 Pegs on the outside left and right bow with a total of 16 pegs; and b) 6 Pegs on the outsidebow left and right, with a total of 12 pegs.

Distinct from the Sayap Bagang of the Gorap tribe which is intentionally designed with functional asymmetry to maximize maneuverability (Saidi et al., 2024) the Wairon war boat embodies a commitment to bilateral balance. This feature is consistent with d’Ambrosio’s theoretical framework, which posits that mathematical knowledge is fundamentally shaped by practical cultural imperatives; in the case of the Wairon, symmetry supports swift directional shifts during warfare (d’Ambrósio, 2006). Comparable conclusions have been drawn by Ratuanik and Filindity (2021) regarding the symmetrical motifs found on Tanimbar stone boats, but this study contributes further by integrating anthropometric measurement techniques and material logic into the analysis of boat symmetry.

Additional ethnomathematical investigations, such as those conducted among the fishing communities of Rembang (Muna et al., 2023), have demonstrated that estimation, measurement, and spatial reasoning are deeply rooted in local traditions. These practices, along with discoveries related to other traditional wooden boats, have had enduring impacts on community life across Indonesia (Lanoeroe et al., 2005; Nurafifah et al., 2024).

The design philosophy of the Wairon represents a distinctly localized epistemology: mathematical concepts like geometry are mastered through hands-on, embodied practice rather than abstract instruction. Theoretically, this study advances the field of ethnomathematics by illustrating how symmetry operates as a cultural narrative, spatial logic, and strategic asset in naval engineering. It reveals the presence of rigorous mathematical reasoning within indigenous systems, even in the absence of formal symbolic language. Practically, these findings have significant implications for STEM education, enabling cultural heritage such as boat construction to serve as a powerful context for teaching principles of symmetry, congruence, and proportion. Furthermore, digital 3D modeling of the Wairon’s symmetrical architecture holds great promise for both the preservation of traditional knowledge and as an interactive medium for learning.

Conclusion

The symmetrical architecture of the Wairon warboat is grounded in the application of precise mathematical principles and culturally embedded geometric logic. Structural components including the bow, hull, najun, and pegs are designed and arranged in accordance with anthropometric and geometric standards, such as isosceles triangles and rectangular spacing, which serve to ensure both functional balance and navigational efficacy. The reproducibility of Wairon warboats across geographically dispersed construction sites provides further evidence of standardized mathematical procedures sustained through oral tradition. However, it must be acknowledged that the scope of this research was limited by its reliance on elder informants, without systematic comparison to the practices or adaptations of younger artisans or the influence of modern technological trends.

Furthermore, the documentation and analysis presented herein constitute a valuable contribution to the preservation and advancement of indigenous mathematical knowledge systems. The study lays a foundation for the integration of traditional maritime engineering into emerging domains such as digital ethnomathematics particularly through 3D modeling and augmented reality educational materials. For future investigations, it is recommended that computational geometry be synergistically combined with localized anthropometric approaches to facilitate virtual reconstruction of the Wairon and other traditional vessels. Moreover, the empirical insights gained from this research advocate for the incorporation of indigenous boat construction into STEM education, employing tangible models to teach mathematical concepts including symmetry, congruence, measurement, and engineering thereby bridging cultural heritage with modern pedagogical practice and widening the impact of ethnomathematical research.

Conflicts of Interest

The authors declare that there is no conflict of interest regarding the publication of this manuscript. In addition, the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies have been covered completely by the authors.

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