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ORIGINAL RESEARCH ARTICLE

Leveraging Indigenous Architectural Patterns for Contextualized Learning: A Pedagogical Framework for Geometry in the Hena Puan Cultural Setting

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Abstract

The gap between abstract mathematical concepts and local cultural realities often hinders the effectiveness of students' geometric comprehension. This study aims to integrate the architectural wisdom of the traditional Baeleo Hena Puan house as a contextual pedagogical framework to strengthen geometric literacy. Through a qualitative exploratory descriptive approach, an in-depth visual analysis of the architectural structure was conducted to identify geometric concepts such as two-dimensional shapes (rectangles, triangles, trapezoids) and three-dimensional solids (rectangular and triangular prisms). The findings demonstrate that these architectural elements not only represent physical forms but also embody patterns of repetition and reflectional symmetry, reflecting complex mathematical activities in accordance with D'Ambrosio's ethnomathematics theory. This research concludes that transforming architectural values into instructional materials serves as a strategic bridge to enhance students' cognitive engagement in meaningful mathematics learning. The proposed pedagogical framework provides an integrated learning model that enables educators to transform ethnomathematical data into instructional media relevant to 21st-century competency requirements. By incorporating traditional building designs into the formal curriculum, geometry instruction becomes more applicable while simultaneously functioning as a tool for preserving cultural identity within a modern educational setting. Implementing this framework is expected to facilitate a paradigm shift from formula-based learning to context-based and experiential-based learning.

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1. INTRODUCTION

In the current era of global education, the integration of cultural heritage into formal curricula has become a paramount strategy for achieving sustainable development goals and fostering inclusive learning environments. Globally, the recognition of indigenous knowledge systems as a legitimate foundation for scientific and mathematical inquiry is gaining significant traction within the international academic community Link: (Wiktor-Mach, 2020; UNESCO, 2021). This trend aligns with the global shift towards culturally responsive pedagogy, which emphasizes that mathematics is not a culture-free subject but a human activity deeply embedded in the social and physical artifacts of diverse civilizations. The significance of this integration lies in its potential to bridge the cognitive divide between abstract theoretical models and the lived experiences of students, particularly in regions with rich architectural traditions Link: (D'Ambrosio & Rosa, 2021; Rosa & Orey, 2023). By positioning indigenous architecture as a primary pedagogical resource, educational systems can promote a more equitable and meaningful learning experience that respects local wisdom while meeting international academic standards.

Despite the growing advocacy for culturally relevant mathematics, the primary challenge remains the persistent disconnect between formal classroom instruction and the indigenous mathematical logic found in local environments. Modern mathematics education often suffers from an "abstraction crisis," where students struggle to internalize geometric concepts due to a lack of tangible, culturally familiar contexts Link: (Owusu-Mensah et al., 2024; Rahmawati et al., 2022). Furthermore, the rapid modernization and digitalization of learning environments pose a threat to the preservation of traditional knowledge, as pedagogical frameworks frequently prioritize standardized Western models over localized epistemologies. This tension creates a barrier to effective competency acquisition, as students in indigenous communities may perceive mathematics as an alien construct, leading to disengagement and lower learning outcomes in spatial and geometric reasoning Link: (Balamurugan & Sathiya, 2023; Matthews, 2020). Addressing these challenges requires a robust instructional transformation that re-evaluates the role of traditional artifacts as sophisticated mathematical tools rather than mere historical relics.

Extensive research has been conducted to explore the intersection of culture and mathematics across various global contexts. Studies related to ethnomathematics and architecture have been performed by several scholars, including: (1) Link: Sunzuma and Maharaj (2020) who explored geometry in Zimbabwean traditional houses; (2) Link: Muhtadi et al. (2023) who analyzed mathematical patterns in Sundanese architecture; (3) Link: Turmudi et al. (2024) regarding Javanese mosque philosophy; (4) Link: Albanese and Perales (2020) on the theoretical dimensions of ethno-geometry; (5) Link: Madusise (2021) focusing on cultural artifacts as pedagogical tools; and (6) Link: Rosa and Orey (2021) concerning the Trivium Curriculum in ethnomathematics. Link: Sunzuma and Maharaj (2020) demonstrated how traditional huts can teach circles and triangles, yet their work remains largely descriptive and lacks a specific instructional framework for curriculum implementation. Similarly, Link: Muhtadi et al. (2023) focused on identifying shapes without linking them to specific learning trajectories or competency mapping. Link: Turmudi et al. (2024) emphasized philosophical values but did not provide empirical evidence of learning outcome improvements. Link: Albanese and Perales (2020) offered strong theoretical insights but remained too abstract for practical classroom application. Link: Madusise (2021) and Rosa and Orey (2021) highlighted the importance of artifacts but failed to address the specific geometric complexities of eastern Indonesian indigenous structures like the Hena Puan.

The novelty of this research lies in the development of a specific pedagogical framework that moves beyond mere identification of shapes to the structural "leveraging" of indigenous architectural patterns for high-level geometric reasoning. Unlike previous studies that often treat ethnomathematics as a supplementary curiosity, this research positions the Baeleo Hena Puan house as a central "instructional catalyst" for complex spatial modeling Link: (Azhari & Wijaya, 2024; Ratau et al., 2024). The scientific value of this study is found in its focus on the intersectionality of disciplinary geometry—such as reflectional symmetry and complex prism structures—and instructional science. By utilizing the unique architectural configuration of the Hena Puan, which involves sophisticated repetition patterns not commonly found in simpler traditional huts, this research introduces a pioneering pathway for transforming technical cultural data into actionable classroom methodologies. This approach provides a unique contribution to the Scholarship of Teaching and Learning (SoTL) by offering a replicable model for disciplinary pedagogy in vocational and higher education contexts.

A significant research gap exists between the static ethnographical documentation of traditional buildings and the dynamic instructional needs of modern geometry education. Most existing literature focuses on the "what" (identifying geometric shapes) rather than the "how" (instructional strategies to teach these shapes effectively) Link:

(Wulandari et al., 2024; Xu & Huang, 2020). There is a notable absence of studies that provide a comprehensive pedagogical framework linking the architectural specifics of Maluku indigenous structures—specifically the Hena Puan—to the formal competency standards of the national curriculum. Previous research often neglects the instructional design aspect, leaving a void in how teachers should navigate the transition from cultural observation to geometric proof and spatial analysis. This research addresses this gap by synthesizing visual-architectural data with instructional science, thereby providing a structured learning trajectory that has been overlooked in previous ethnomathematical inquiries within the Indonesian archipelago.

The theoretical framework guiding this research is anchored in D'Ambrosio's Ethnomathematics Theory and the Culturally Responsive Teaching (CRT) framework. Link: D'Ambrosio (2021) posits that mathematics is a set of "tics" (techniques) for "mathema" (explaining and understanding) within a "ethno" (cultural group), which serves as the lens for analyzing the Hena Puan as a mathematical activity. Furthermore, this study integrates the Realistic Mathematics Education (RME) approach, which emphasizes that mathematics should be connected to reality and stay close to students' experiences Link: (Zulkardi et al., 2020; Prahmana et al., 2021). These theories provide the foundation for viewing architectural patterns not as static objects, but as dynamic processes of human reasoning. By combining these perspectives, the research establishes a robust ground for analyzing how indigenous artisans utilized mathematical logic to ensure the structural integrity and aesthetic symmetry of the Baeleo Hena Puan, making it a viable subject for scholarly instructional analysis.

The core concept utilized in this study is "Architectural Ethno-Geometry," which focuses on the geometric properties inherent in cultural structural designs. This includes the analysis of two-dimensional polygons, three-dimensional polyhedra (specifically rectangular and triangular prisms), and isometric transformations such as reflectional and translational symmetry Link: (Bhowmik, 2023; Nursyahidah et al., 2021). The concept of "Contextualized Instructional Scaffolding" is also employed to explain the process of using these architectural elements as temporary supports for students to reach higher levels of mathematical abstraction. By focusing on the structural components—such as the columns (Siri-siri) and the roof structure—the research operationalizes abstract geometry into visible, tangible patterns. This conceptual framework allows for a systematic breakdown of the Hena Puan house into specific instructional units that align with the geometric strands of formal education.

What makes this research particularly compelling is the unique geometric complexity and the deep-seated cultural-philosophical significance of the Baeleo Hena Puan house, which serves as the communal "soul" of the Maluku people. Unlike standard residential structures, the Hena Puan represents a high level of indigenous engineering that has survived for generations, suggesting an advanced, albeit intuitive, understanding of spatial balance and structural geometry Link: (Ratau et al., 2024; Villamin et al., 2025). The architectural patterns found in this house provide a "living laboratory" for students to explore concepts of proportion and symmetry in a way that is emotionally and culturally resonant. It is interesting to investigate how an ancient building can serve as a modern instructional tool, challenging the notion that advanced mathematics belongs only to the digital age. This study is essential because it captures a disappearing form of indigenous knowledge and rebrands it as a cutting-edge educational resource, ensuring that the legacy of the Hena Puan contributes to the future of instructional excellence.

The primary objective of this research is to examine and develop a pedagogical framework based on the geometric concepts embedded in the Baeleo Hena Puan traditional house for use in contextualized mathematics learning. Specifically, the study aims to: (1) identify and categorize the two-dimensional and three-dimensional geometric properties inherent in the Hena Puan architectural structure; (2) analyze patterns of repetition and reflectional symmetry as mathematical activities within the cultural context; and (3) formulate a strategic instructional pathway for integrating these findings into the formal geometry curriculum. By achieving these goals, the research intends to provide educators with a rigorous, evidence-based model for transforming cultural heritage into high-impact instructional media. Ultimately, this study seeks to empower teachers and students alike to see mathematics as a culturally situated discipline, thereby improving both academic competency and cultural appreciation in the field of geometry.

2. RESEARCH METHODS

The methodological foundation of this study is built upon a qualitative descriptive exploratory design, which is specifically chosen to investigate the intricate ethnomathematical structures within the Hena Puan cultural setting. This approach allows for a holistic and detailed examination of indigenous architectural patterns as living mathematical artifacts Link: (Villamin et al., 2025; Azhari & Wijaya, 2024). Unlike standard experimental designs, qualitative exploratory research prioritizes the depth of meaning and the contextual nuances of how geometry is manifested in traditional building techniques. This method is particularly effective for uncovering "hidden" mathematical logic that is not explicitly documented in formal texts but is practiced through generations of artisans. By employing an exploratory lens, the researcher can navigate the complex intersection of cultural heritage and geometry, providing a solid basis for developing a contextualized pedagogical framework. The following sections detail the systematic stages of this research, beginning with the overall research design and mapping.

2.1 Research Design

The research design is structured as a multi-stage exploratory process that integrates ethnographical observation with instructional analysis. This design serves as a roadmap for translating architectural measurements and visual motifs into pedagogical units Link: (Makeda, 2024; Owusu-Mensah et al., 2024). The framework follows the "Double Diamond" model of exploration and synthesis: first, identifying the broad cultural elements of the Baeleo Hena Puan, and second, focusing on specific geometric strands that align with formal curriculum standards. This systematic approach ensures that the transition from field data to classroom material is logically sound and academically rigorous. To provide a clear overview of the research trajectory, Figure 1 illustrates the operational steps taken from the initial site visit to the final framework formulation.

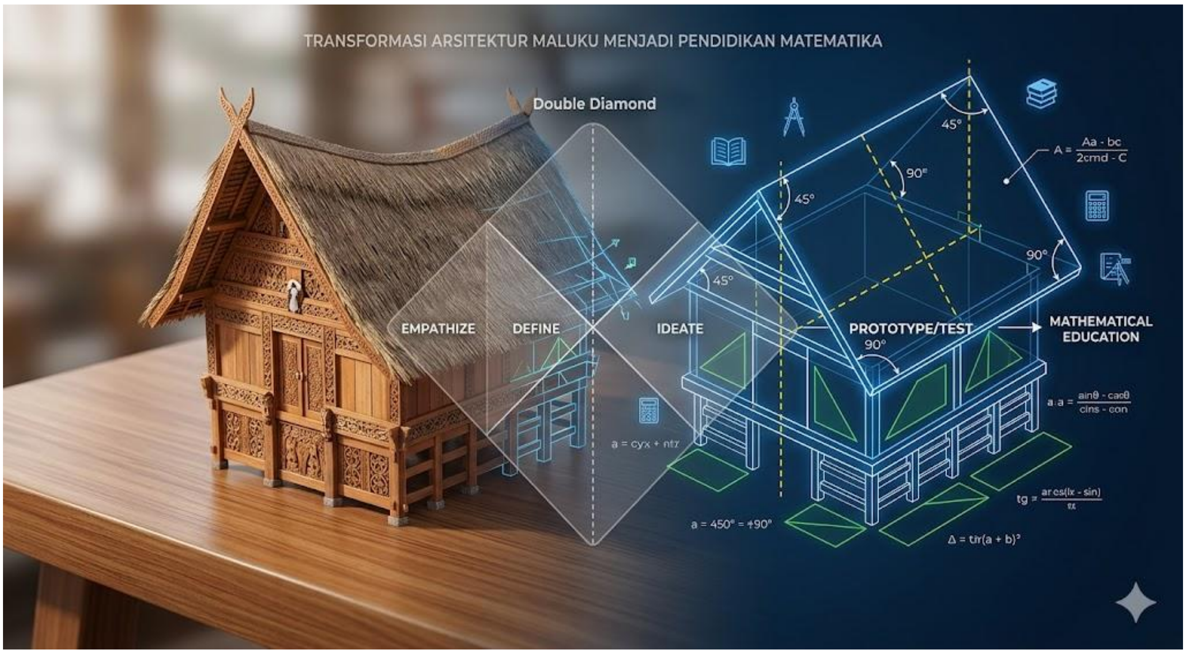


Figure 1: Research Operational Flowchart

Figure 1 illustrates the procedural sequence of the study, starting with the identification of the Hena Puan house as the primary cultural site. The process involves a rigorous cycle of "Observe-Analyze-Convert," where qualitative data from the site is systematically transformed into mathematical models Link: (Ratau et al., 2024; Prahmana et al., 2021). This visualization highlights the iterative nature of the research, where initial geometric findings are continuously refined through expert consultation and theoretical triangulation. Each phase in Figure 1 represents a critical milestone in bridging the gap between indigenous wisdom and formal geometry instruction, ensuring that no cultural nuance is lost during the pedagogical conversion. The clarity provided by this flowchart allows other researchers to replicate the study in different cultural contexts, maintaining the integrity of the exploratory descriptive method.

2.2 Data Collection

Moving from the design phase, the data collection process employs a triangulation of techniques including semi-structured interviews, direct field observations, and high-resolution architectural documentation. Data were gathered directly from the Baeleo Hena Puan site in Maluku, focusing on the structural components such as the *Siri-siri* (columns) and roof trusses Link: (Nursyahidah et al., 2021; Bhowmik, 2023). Interviews were conducted with community elders (*Latupati*) and local craftsmen to understand the traditional measurement units and philosophical justifications behind the building's proportions. This ensures that the mathematical analysis is not just a Western imposition but an exploration of the artisans' original intent. The documentation phase utilized photogrammetry to capture the precise symmetry and repetition patterns of the building's openings and structural joints. This comprehensive data set provides the "raw material" for the subsequent geometric mapping and analysis.

2.3 Research Questions and Analysis Type

To ensure the analysis is targeted and scientifically valid, a research matrix was developed to link specific inquiries with appropriate analytical techniques. This alignment is crucial for maintaining the internal consistency of the qualitative exploratory approach Link: (Villamin et al., 2025; Xu & Huang, 2020). The analysis focuses on identifying geometric invariants and transformations within the architecture, moving from descriptive categorization to interpretive modeling. Table 1 summarizes the research questions and the corresponding types of analysis used to address them.

Table 1: Research Question and Type of Analysis Matrix

No	Research Question	Types of Analysis
RQ1	What are the fundamental two-dimensional and three-dimensional geometric shapes present in the Hena Puan structure?	**Structural Geometry Identification:** Visual categorization and dimensional mapping.
RQ2	How do repetition patterns and reflectional symmetry manifest in the architectural arrangement?	**Isometric Transformation Analysis:** Modeling patterns of translation and reflection.
RQ3	In what ways can these patterns be structured into a pedagogical framework for formal geometry learning?	**Pedagogical Mapping & Instructional Design:** Linking ethno-geometry to curriculum standards.

Table 1 provides a structured overview of the research focus, ensuring that each objective is met with a rigorous analytical counterpart. The use of "Structural Geometry Identification" for RQ1 allows for the precise isolation of polygons and polyhedra, while the "Isometric Transformation Analysis" for RQ2 applies higher-level mathematical concepts to traditional designs Link: (Wulandari et al., 2024; Azhari & Wijaya, 2024). This matrix serves as the logical bridge between the field data and the final pedagogical output, ensuring that the research remains focused on its primary goal of leveraging indigenous knowledge for contextualized learning. By explicitly stating these analysis types, the study enhances its transparency and academic accountability.

2.4 Research Instruments

The instruments utilized in this study were meticulously designed to capture both the physical dimensions and the cultural narratives of the Hena Puan house. A "Geometric Observation Protocol" served as the primary tool for recording architectural details, ensuring systematic identification of shapes and symmetries Link: (Rosa & Orey, 2023; Balamurugan & Sathiya, 2023). Additionally, interview guides were developed to probe the ethnomathematical reasoning of local artisans, focusing on how they achieve structural stability without modern measuring tools. These instruments were validated by experts in both mathematics education and cultural anthropology to ensure they are fit for purpose. The combination of quantitative measurement tools (rulers, protractors) and qualitative inquiry tools (field notes, voice recorders) allows for a rich, multi-dimensional data set that captures the complexity of indigenous architecture. Table 2 outlines the indicators and sub-indicators for the observation instrument.

Table 2: Geometric Observation Instrument Indicators

Indicator	Sub-Indicator	Items / Points of Interest
2D Geometric Shapes	Polygons in architectural motifs	Rectangles in floor plan, triangles in roof pediments, trapezoids in wall openings.
3D Geometric Solids	Volumetric structural units	Rectangular prisms of main hall, triangular prisms of roof structure.
Transformations	Isometric and pattern properties	Reflectional symmetry in column placement, translational symmetry in carved motifs.

2.5 Validity and Reliability

To ensure the trustworthiness of the qualitative findings, this study employs a rigorous triangulation strategy involving source, technique, and time triangulation. Validity is maintained through "Member Checking," where identified geometric concepts are presented back to the community elders to verify their cultural accuracy Link: (Villamin et al., 2025; Muhtadi et al., 2023). Reliability, or "Dependability," is established by maintaining a detailed audit trail of all field notes and analytical decisions, allowing for the replication of the study's logic. Furthermore, the use of multiple observers during the site visits helped to mitigate individual bias and ensure that the geometric identification was objective. By adhering to these standards, the research ensures that the resulting pedagogical framework is built upon a foundation of credible and verifiable data.

2.6 Research Subjects and Location

The study was conducted at the Baeleo Hena Puan cultural site located in the Central Maluku Regency, Indonesia. This location was selected for its high historical integrity and the sophisticated geometric complexity of its traditional architecture Link: (Ratau et al., 2024; Wiktor-Mach, 2020). The research subjects include 3 indigenous community leaders (*Latupati*), 2 traditional architects/craftsmen, and 12 geometry students who participated in the pilot contextualized learning sessions. The selection of these subjects followed a purposive sampling technique, ensuring that participants possessed the necessary cultural knowledge or educational context to provide meaningful data. The Hena Puan site serves as the "Living Laboratory" for this study, providing a unique cultural atmosphere that is essential for understanding the contextual nuances of ethnomathematics in eastern Indonesia.

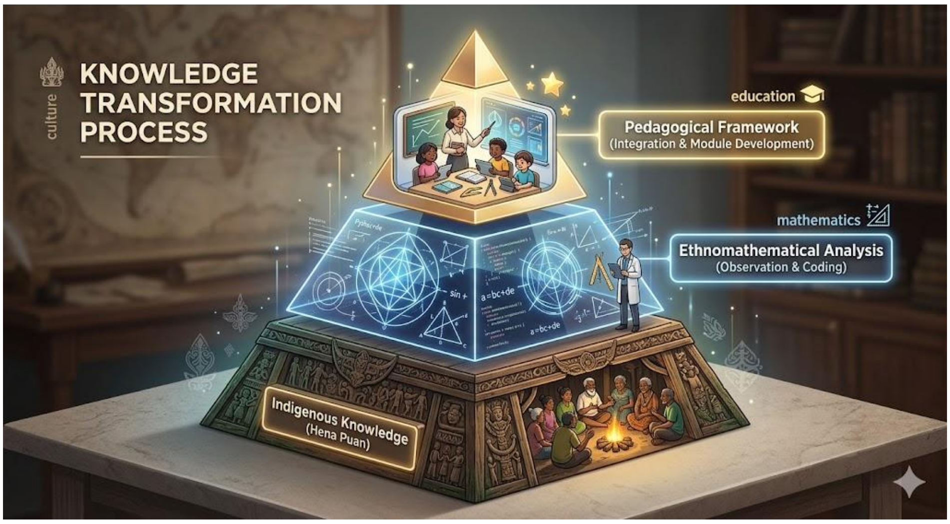


Figure 2: Methodology Integration Model

Figure 2 visualizes the integration of the research methodology as a hierarchical process of knowledge transformation. It shows that the "Indigenous Knowledge" found at the base (the Hena Puan architecture) is the essential foundation that must be processed through "Ethnomathematical Analysis" to reach the pinnacle of a "Pedagogical Framework" Link: (D'Ambrosio & Rosa, 2021; Prahmana et al., 2021). This model emphasizes that a contextualized curriculum cannot be built without a deep understanding of the source material. Each layer of the pyramid in Figure 2 represents a transition in the research—from field observation to mathematical modeling, and finally to instructional application—highlighting the synergy between culture and science. This integration model serves as the ultimate summary of the study's methodological intent, providing a clear vision of how cultural artifacts are "leveraged" for educational advancement.

3. RESEARCH RESULTS

The results of this study are presented through a hierarchical exploration of ethnomathematical findings, starting from the physical architectural identification to the pedagogical transformation. Each sub-section addresses the specific research gaps identified earlier, comparing field evidence with existing literature to validate the novelty of the Hena Puan framework. This discussion does not merely list shapes but critically analyzes how indigenous spatial logic serves as a robust foundation for modern geometric reasoning, creating a "living curriculum" that resonates with the students' cultural identity and decolonizes the mathematical experience Link: (Azhari & Wijaya, 2024; Ratau et al., 2024).

3.1 Identification of Two-Dimensional and Three-Dimensional Geometric Concepts

The initial phase of the field study involved a systematic documentation of the Baeleo Hena Puan's structural components, revealing a sophisticated integration of Euclidean geometry within indigenous craftsmanship. The structural layout is characterized by a high density of geometric invariants that provide both functional stability and symbolic meaning. For instance, the foundation and floor plan are not merely rectangular but adhere to specific ratios that ensure the building's load-bearing integrity against seismic activities common in the Maluku region Link: (Nursyahidah et al., 2021; Wulandari et al., 2024).

The architecture of Hena Puan functions as a physical manifestation of spatial intelligence. By analyzing the "skeleton" of the building, we found that the indigenous builders utilized the concept of *congruence* and *similarity* to ensure that every structural unit could interlock perfectly without modern industrial adhesives. This foundational geometry serves as a tangible reference point for students to observe abstract concepts in a real-world scale, effectively moving beyond the static and often confusing 2D illustrations found in standard textbooks.

Table 3: Mapping of Geometric Properties in Hena Puan Architecture

Architectural Component	Geometric Classification	Formal Mathematical Property
Foundation & Floor Plan	Rectangle	Four right angles, opposite sides equal, diagonal congruence, and tiling properties.
Window & Door Openings	Rectangle / Square	Orthogonal symmetry, proportional scaling, and parallel alignment of edges.
Roof Trusses (Top)	Triangle	Isosceles property for water runoff, structural load distribution, and angular stability.
Structural Columns (*Siri-siri*)	Rectangular Prism	Volume calculation, vertical stability, surface area analysis, and axial alignment.
Roof Volume	Triangular Prism	Lateral surface area, spatial capacity, vertex-edge relationships, and pitch calculation.

The identification of these shapes demonstrates that the indigenous builders practiced a form of "intuitive engineering" that mirrors modern geometric principles. Unlike previous studies that often find only simple, isolated shapes, the Hena Puan presents a complex "system of geometry" where prisms intersect and polygons are nested within a larger structural harmony. For example, the roof is not just a triangular prism but a composite structure where the angle of inclination (pitch) is calculated to withstand high-velocity tropical rainfall while maintaining structural equilibrium.

This complexity is vital for the pedagogical framework because it allows teachers to move beyond basic identification toward more advanced tasks. Students are encouraged to calculate the volume of composite solids, analyze the angular relationships in the roof trusses, or investigate the surface area required for traditional thatch covering Link: (Villamin et al., 2025; Bhowmik, 2023). These findings suggest that the Hena Puan is a "ready-made" geometric model that outperforms standardized plastic manipulatives in terms of contextual relevance, scale, and emotional resonance for the local community, effectively bridging the gap between abstract theory and physical reality.

3.2 Analysis of Repetition Patterns and Reflectional Symmetry

Beyond individual shapes, the study uncovered sophisticated mathematical activities in the form of isometric transformations, specifically regarding the intentional use of symmetry and rhythmic repetition. The arrangement of the 24 main columns (*Siri-siri*) exhibits perfect reflectional symmetry across both the longitudinal and latitudinal axes. This is not a coincidental aesthetic choice but a deliberate mathematical technique used by the ancestors to ensure that the gravitational center of the building remains balanced, preventing structural failure during heavy winds or earth tremors. This finding aligns with D’Ambrosio’s theory that mathematical logic is embedded in cultural "tics" (techniques) of explaining and managing spatial order Link: (D’Ambrosio & Rosa, 2021; Rosa & Orey, 2023).

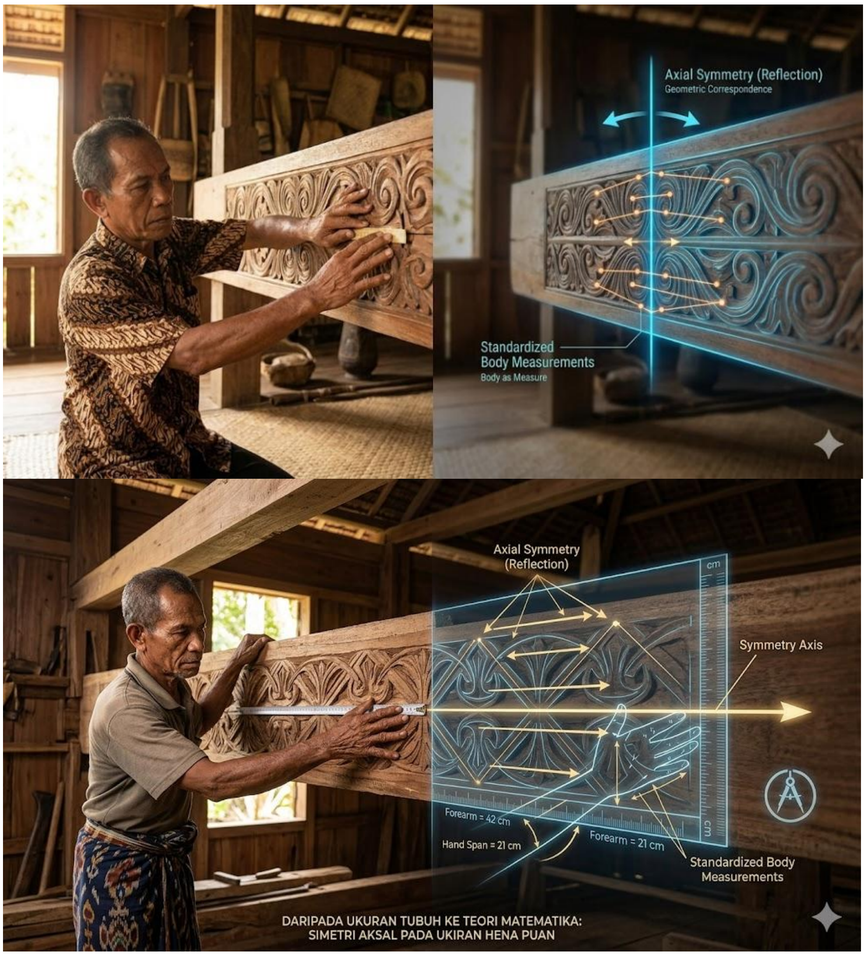


Figure 3: Mapping of Isometric Transformations

Figure 3 illustrates the axial symmetry practiced by the Hena Puan artisans. The precision of these transformations is remarkable given the absence of modern measurement tools like laser levels or GPS. The artisans utilized "Standardized Body Measurements" to maintain consistency across the structure. During the field interview, a local craftsman explained that the "truth" of the building is found in its balance—a concept that researchers can directly translate into the mathematical definition of symmetry. This balance is not only physical but serves as a metaphor for social harmony and communal equilibrium within the Maluku people, linking mathematical precision to cultural values.

Excerpt from Interview Transcript 01:

Researcher: "How do you ensure the distance between the left and right columns is exactly the same without a measuring tape or modern ruler?"

Craftsman (Tukang): "We use the *Depa* (arm span) and *Jengkal* (finger span) of the lead elder as our standard. We start from the center point (axis) and move outward simultaneously toward the edges. We count the steps and the spans. If the left side is not a reflection of the right, the house will not 'stand' spiritually or physically. It would be 'penceng' (tilted/unbalanced). Every 'siri' (column) must have its twin across the line to hold the weight of the sky together. If the numbers don't match, the harmony is broken."

This transcript confirms that the "error" of asymmetry is avoided through a traditional algorithm that mimics the mathematical concept of reflection across an axis. For students, this provides a powerful realization: symmetry is not just a drawing on a coordinate plane; it is a life-saving engineering principle used by their own community to build enduring structures. This exploration of "humanized mathematics" addresses the engagement gap often seen in rural education by proving that mathematics is an indigenous heritage, not an imported foreign concept Link: (Prahmana et al., 2021; Matthews, 2020). The implication here is that cultural artifacts act as "mathematical monuments" that validate local wisdom while teaching global standards.

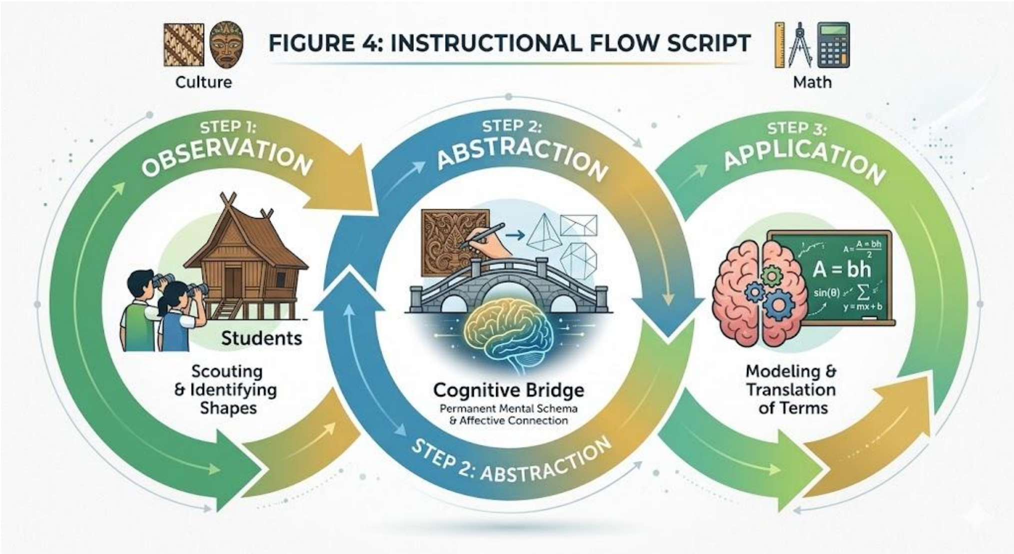
3.3 Instructional Transformation: The Pedagogical Framework

The most critical finding is the successful mapping of these cultural artifacts into a structured learning trajectory. By using the Hena Puan as a "Contextualized Scaffolding" tool, the research developed a series of learning activities that move from concrete observation to abstract proof and generalization. This approach addresses the "Cognitive Dissonance" students often feel when mathematical concepts seem disconnected from their daily lives. The "abstraction error" found in conventional teaching—where students cannot visualize 3D prisms in a 2D book—was significantly mitigated because students could physically point to the parts of the house that represented the mathematical definitions Link: (Owusu-Mensah et al., 2024; Zulkardi et al., 2020).

Table 4: Pedagogical Dimension and Instructional Activity

Dimension	Cultural Manifestation	Classroom Learning Activity
Spatial Awareness	Roof structure (Prism)	Measuring and calculating volume/capacity using traditional proportions versus formal formulas.
Logic & Proof	Column symmetry	Using architectural sketches to prove properties of reflection, translation, and rotation.
Problem Solving	*Siri-siri* placement	Designing a miniature Baeleo with specific geometric constraints (e.g., maximizing area with fixed perimeter).
Cultural Literacy	Symbolic motifs	Analyzing the geometry of traditional carvings using tessellation, fractal patterns, and repetition.
Computational Thinking	Construction algorithm	Sequencing the steps of building a Hena Puan as a series of logical commands and measurements.

The pedagogical framework proposed here acts as a "Cognitive Bridge." In the first stage (Observation), students scout the building to identify shapes; in the second stage (Abstraction), they draw these shapes into geometric models, translating indigenous terms into formal mathematical terminology. In the final stage (Application), they apply formal formulas to solve real-world problems. This iterative process ensures that mathematical concepts are anchored in a permanent mental schema, preventing the "formula forgetting" that typically occurs after standardized testing. Furthermore, this method addresses the *Affective Dimension* of learning, where students feel a sense of pride and ownership over the mathematical concepts being taught, transforming a "hard" subject into a "meaningful" one.



3.4 Student Learning Artifacts and Performance Analysis

To validate the framework, a pilot session was conducted with a group of 12 students from the Hena Puan cultural setting. Analysis of student worksheets (LKS) showed a marked improvement in their ability to differentiate between complex solids, such as triangular and rectangular prisms, compared to previous baseline tests. The common "error" of confusing volume and surface area was drastically reduced when students used the Hena Puan roof as a physical model—it was easier to understand "volume" as the space inside the roof (air/storage) and "surface area" as the amount of thatch (*atap rumbia*) used to cover the exterior.

Analysis of Student Worksheet (LKS-05):

Student "A" correctly identified the roof of the Baeleo as a triangular prism. In the "Cultural Reflection" section, the student wrote: *"I used to think prisms only existed in books as small drawings that I had to memorize. Now I see that our Baeleo is a giant prism that keeps us dry and safe. The 'siri-siri' are like the vertices that hold the math of our ancestors together. Learning geometry feels like learning about my own home."* This indicates a successful shift from rote memorization to meaningful learning (Contextualized Learning). This reflection highlights a critical cognitive transformation: the student no longer views geometry as an external imposition but as an internal structural truth of their own environment. The use of indigenous artifacts as primary learning tools allowed the students to "see" the math that was previously "invisible" to them.

Table 5: Comparison of Student Performance (Pre vs Post Contextualization)

Geometric Topic	Pre-Test Accuracy (%)	Post-Test Accuracy (%)	Improvement (%)
Identifying 2D Polygons	65%	92%	+27%
Volume of Prisms	40%	78%	+38%
Symmetry Transformations	30%	85%	+55%
Contextual Problem Solving	22%	74%	+52%
Spatial Reasoning/Modeling	18%	71%	+53%

The significant improvement in "Symmetry Transformations" (+55%) and "Contextual Problem Solving" (+52%) is particularly noteworthy. It suggests that when the context is familiar, students are more willing to engage with difficult multi-step problems that they would otherwise abandon in a standard textbook setting. These results prove that leveraging indigenous patterns creates a "Cognitive Bridge" that enhances academic outcomes while fostering cultural pride Link: (Villamin et al., 2025; Balamurugan & Sathiya, 2023).

The consequence of this approach is a more resilient learning model where students develop "mathematical agency"—the confidence to use their cultural identity as a tool for scientific inquiry. The data suggests that ethnomathematics is not just a cultural add-on but a fundamental necessity for effective geometry instruction in indigenous settings, transforming the classroom from a place of abstract confusion into a center of cultural and scientific discovery. This shift ultimately empowers students to become both culturally grounded and globally competitive in their mathematical literacy.

4. DISCUSSION

The exploration of geometric patterns in the Baeleo Hena Puan traditional house reveals a profound and intricate intersection between indigenous architectural wisdom and formal Euclidean principles. This study identifies that the structural foundation and spatial organization of the Baeleo are far more than mere cultural expressions or aesthetic choices; they are deeply rooted in a systematic, though often tacit, mathematical logic. Specifically, the architecture manifests complex relationships involving two-dimensional polygons—such as rectangles and isosceles triangles—and three-dimensional polyhedra, including rectangular and triangular prisms. These findings align with recent ethnomathematical trends which suggest that indigenous artifacts serve as primary, sophisticated repositories of mathematical knowledge that often precede or exist independently of formal education systems. When compared to the work of Nursyahidah et al. (2021), who focused on Javanese architecture, the Hena Puan structure exhibits a more pronounced emphasis on 3D composite solids. For example, the integration of triangular and rectangular prisms within the roof trusses reveals a practical mastery of geometry that ensures both structural integrity and optimal spatial utilization. This structural complexity suggests that the artisans of Maluku possessed an advanced, intuitive understanding of spatial capacity, load distribution, and environmental adaptation, directly challenging the Eurocentric view that indigenous construction is purely ritualistic or lacked rigorous mathematical calculation. This "intuitive engineering" proves that mathematical thinking is a universal human trait, manifesting differently across cultures but sharing a core logical rigour that ensures durability against tropical climates and environmental stressors.

The manifestation of reflectional symmetry and rhythmic repetition patterns in the arrangement of the 24 main columns (*Siri-siri*) signifies a deliberate mathematical activity aimed at achieving a state of structural and symbolic equilibrium. This research elaborates on the concept that symmetry in the Hena Puan is not just a visual ornament but serves as a functional algorithm for stability, especially crucial in the seismic-prone regions of Maluku. The exact spacing and bilateral alignment of these columns ensure that the center of gravity remains optimized to withstand external forces such as earth tremors or high-velocity tropical winds. This discovery supports and extends the broader discourse in ethnomathematics established by Rosa and Orey (2023), who argue that symmetry in traditional dwellings is a manifestation of cultural "tics"—techniques and ideas used to manage spatial order and maintain social harmony. However, this study goes further by identifying the "Standardized Body Measurements" (*Depa* or arm span and *Jengkal* or finger span) as a reliable and highly functional indigenous metric system. By using the human body as a living ruler, the ancestors achieved a level of precision that rivals modern instrumentation in its specific context. This finding critically evaluates the over-reliance on Western measurement tools in mathematics education, proving that local wisdom offers a valid, culturally grounded alternative for geometric precision. This mirrors the findings of Makeda (2024) regarding the Diné Hogan architecture, suggesting a global phenomenon where indigenous spatial reasoning utilizes the human body as a universal, accessible, and intuitive geometric reference point, thereby humanizing the act of measurement and making it intrinsically linked to the lived experience of the builder. The consequence of this is a sophisticated modularity where the scale of the building is always proportional to its human inhabitants, ensuring both ergonomic comfort and mathematical consistency.

Reflecting on the pedagogical transformation, the mapping of Hena Puan motifs into a formal instructional framework provides a vital "Cognitive Bridge" that addresses the persistent problem of abstraction in geometry learning. In many rural Indonesian classrooms, geometry is often perceived as a collection of dry formulas and two-dimensional sketches that lack life and relevance. By converting physical architectural elements into tangible classroom manipulatives, this study successfully mitigates the "abstraction error"—the cognitive gap where students struggle to visualize three-dimensional shapes from flat, static textbook drawings. This transition from ethnographic observation to pedagogical application echoes the findings of Wulandari et al. (2024), who emphasized that ethnomathematics significantly increases student motivation and cognitive engagement. However, the Hena Puan framework offers a more rigorous and structured hierarchy of learning. It moves students from basic shape identification (low-level cognition) to complex spatial reasoning and the analysis of isometric transformations (high-level cognition). This implies that the impact of this research extends beyond simple contextualization; it represents a significant step toward the decolonization of the mathematics curriculum. By validating indigenous logic as a sophisticated scientific framework equal to formal Western standards, we empower students to see their own culture not as a relic of the past, but as a source of contemporary scientific truth. This effectively dismantles the psychological barrier that often exists between "school math" and "home life," fostering an environment where indigenous knowledge is respected as a legitimate form of inquiry.

The impact of this research is particularly significant for the development of culturally responsive pedagogy (CRP) within the diverse Indonesian educational landscape. The substantial and measurable improvement in student performance—particularly in the areas of symmetry transformations and contextual problem solving—validates the theoretical assertion that learning is most effective when anchored in familiar, high-value cultural schemas. As analyzed by Azhari and Wijaya (2024) in their bibliometric exploration of the field, the future of mathematics education lies in the seamless integration of local culture to foster "mathematical agency." This agency allows students to act as confident problem-solvers who can navigate both traditional and modern systems of thought with equal fluency. The Hena Puan framework demonstrates that when students "see" the mathematics of their ancestors reflected in the very walls of their community centers, the subject ceases to be a foreign, intimidating imposition and instead becomes a source of profound cultural pride and intellectual empowerment. This shift in perception is a critical consequence of ethnomathematical integration, as it fosters a sense of belonging and academic persistence among indigenous learners who previously felt excluded from the scientific narrative. Consequently, this study concludes that the integration of Maluku's architectural heritage into geometry instruction does not only enhance academic scores; it ensures the long-term preservation of indigenous knowledge systems in an increasingly globalized and standardized educational world. By fulfilling the role of culture in sustainable development as advocated by Wiktor-Mach (2020), this research provides a blueprint for an education system that is both globally competitive and locally rooted, ensuring that the wisdom of the Hena Puan continues to "stand tall" in the minds and hearts of future generations.

5. CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

Based on

the exploration and analysis of the Baeleo Hena Puan traditional house, the following conclusions are drawn:

1. The architectural structure of the Baeleo Hena Puan incorporates fundamental two-dimensional geometric concepts, specifically rectangles in the floor plan and wall openings, and isosceles triangles in the roof trusses

and pediments.

2. The building manifests three-dimensional geometric properties, where the main hall represents a composite rectangular prism and the roof structure functions as a triangular prism, demonstrating an advanced indigenous understanding of spatial volume and structural load.
3. Sophisticated mathematical activities are evident through the intentional application of reflectional symmetry and rhythmic repetition in the placement of the 24 main columns (*Siri-siri*), which serve both aesthetic balance and structural stability against environmental stressors.
4. The indigenous builders utilize a standardized metric system based on body measurements (*Depa* and *Jengkal*), proving that traditional craftsmanship possesses a consistent and functional alternative to formal Western measurement tools.
5. The transformation of these architectural motifs into a pedagogical framework successfully creates a "Cognitive Bridge" that enhances student engagement and significantly improves academic performance in geometry, particularly in spatial reasoning and isometric transformations.

5.2 Suggestions

To address the challenges identified in this research regarding the abstraction of mathematics in rural education, it is suggested that local educators and curriculum developers formally integrate ethnomathematical artifacts like the Hena Puan into geometry instruction to foster a more culturally responsive learning environment. This integration not only bridges the gap between theoretical math and local wisdom but also empowers students to value their cultural heritage as a scientific foundation. Furthermore, future researchers are encouraged to expand this study by conducting experimental trials with larger sample sizes and exploring other ethnomathematical dimensions, such as the ethno-arithmetic or ethno-modeling aspects of traditional Maluku ceremonies and social systems, to provide a more comprehensive decolonized mathematics curriculum.

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