

Integration of Ethnomathematics and Deep Learning in Mathematics Education: Cultural and Structural Valuation of Earthquake-Resilient Javanese Traditional Houses

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Abstract This study aims to integrate ethnomathematical values embedded in Javanese traditional architecture with a Deep Learning model to enhance mathematical literacy and disaster awareness. The focus is on Limasan and Limas houses, representing local wisdom and structural resilience against earthquakes. A mixed-method approach with a sequential explanatory design combined field observation, geometric measurement, documentation, and interviews with cultural figures and educational practitioners. Cultural valuation was analyzed using Rosa & Orey's (2011) framework, covering functional, aesthetic, ecological, spiritual, and educational aspects. The findings reveal that architectural elements such as pyramid-shaped roofs, the ratio of pillar height to building width, mortise–tenon joints without nails, spatial orientation, and the flexibility of local materials embody mathematical concepts of ratio, similarity, transformation, and proportion. These values were integrated into ethnomathematics-based student worksheets and combined with a Deep Learning approach. The implementation resulted in a 30,32 % improvement in students' mathematical literacy while strengthening cultural connection and disaster preparedness. This study highlights the potential of integrating Ethnomathematics and Deep Learning to enrich culturally grounded mathematics learning innovations that are contextual and meaningful.

Keywords: • Ethnomathematics • Javanese traditional houses • deep learning • mathematical literacy • disaster resilience

1 Introduction

Modern mathematics education emphasizes the importance of connecting abstract concepts with real-life contexts, particularly to develop mathematical literacy, which has become one of the key indicators of global education quality (Ndlovu & Mhlolo, 2023; OECD, 2019). In Indonesia, students' mathematical literacy remains relatively low compared to international standards, as PISA results consistently place Indonesia below the OECD average (OECD, 2019; Stacey, 2011). This condition underscores the need for more contextual and meaningful learning innovations.

One emerging approach is Ethnomathematics, which integrates local culture as a learning resource (D'Ambrosio, 1985). In the local context, traditional houses such as the Limas and Joglo symbolize Javanese culture and represent structural knowledge that has proven resilient against natural disasters, particularly earthquakes (Widodo et al., 2022). The ethnomathematical values embedded in these houses include principles of geometry, proportion, and transformation interwoven with social functions and local wisdom (D'Ambrosio, 1985; Rosa & Orey, 2011). Previous ethnomathematics studies have largely emphasized aesthetic, cultural, and symbolic aspects (Ndlovu & Mhlolo, 2023), while research exploring the mathematical values in traditional architecture and their relevance to disaster mitigation remains limited. However, education rooted in local wisdom has been shown to play a significant role in fostering disaster awareness and preparedness from an early age (Zulkardi & Putri, 2009; Widada, Herawaty, & Nugroho, 2019). It indicates a research gap that needs to be addressed to develop mathematics learning that is not only contextual but also relevant to issues of cultural resilience and disaster risk reduction.

Existing studies often stop at the stage of identifying mathematical concepts without conducting systematic cultural valuation or integrating them into modern learning frameworks (Rosa & Orey, 2016; Nugraha et al., 2021). Meanwhile, the Deep Learning model emphasizes deep understanding, concepts' interconnectedness, and knowledge transfer to new situations (Fullan & Langworthy, 2014). These characteristics are highly relevant for integrating ethnomathematical values into mathematics learning, enabling students not only to master concepts procedurally but also to connect them with local culture and disaster-related issues. Furthermore, few studies have explored integrating structural values from traditional houses with innovative learning models such as Deep Learning, which emphasizes reflective understanding, conceptual interconnections, and transferability to new contexts (Fullan & Langworthy, 2014; Stern & Ahlgren, 2020).

Therefore, the integration of Ethnomathematics and Deep Learning has the potential to enhance mathematical literacy while simultaneously fostering cultural awareness and 21st-century skills. Based on this background, the present study focuses on the cultural and structural valuation of Limas and Joglo traditional houses as contextual media for mathematics learning within a Deep Learning

framework. Unlike previous studies that mainly focused on identifying ethnomathematical values in cultural artifacts, this study advances further by integrating these values into practical learning tools and empirically testing their effectiveness through a Deep Learning model. The main contributions of this study lie in two aspects: (1) theoretically, extending the scope of Ethnomathematics from aesthetic dimensions toward structural and functional dimensions; and (2) practically, producing learning tools in the form of ethnomathematics-based student worksheets (LKPD) that can improve mathematical literacy while instilling disaster mitigation awareness and cultural identity.

2 Research method

This study employed a mixed-methods approach with an expanded sequential explanatory design, aligning with the urgency to integrate ethnomathematical values of traditional Javanese houses into mathematics learning for literacy, cultural awareness, and disaster mitigation.

The qualitative stage adopted descriptive ethnography (Spradley, 1980) to investigate the ethnomathematical aspects of Limasan and Joglo houses. Data were collected through visual documentation, participatory observation, and interviews with traditional builders, cultural experts, and local communities, supported by secondary sources such as manuscripts and scientific literature. Thematic analysis (Miles, Huberman, & Saldaña, 2014) was applied to identify mathematical elements—geometry, proportion, symmetry, load distribution, and earthquake-resistant techniques—and to classify them into Bishop's (1988) six mathematical activities: counting, locating, measuring, designing, playing, and explaining. These findings were then transformed into instructional content using the Design-Based Research (DBR) framework (Anderson & Shattuck, 2012; McKenney & Reeves, 2019), allowing iterative design, implementation, and refinement of ethnomathematics-based student worksheets (LKPD). Integrating a Deep Learning framework emphasized conceptual understanding, reflective thinking, and knowledge transfer.

With the goal of ensuring equal access to high-quality education and promoting societal acceptance, including autistic children in mainstream education has emerged as a global policy priority. However, there are many obstacles to overcome in order to properly integrate autistic kids into a diversified learning environment. In order to address these issues, this research explores the complex interactions that facilitate and moderate successful inclusion through the use of legal systems, law models, and government innovation efforts.

The quantitative stage tested the developed LKPD with 100 students which were composed from 50 junior high school students and 50 elementary school students in East Java. Instruments included a PISA-based mathematics literacy test, pretest–posttest, student response questionnaire, and observation sheets. Data were analyzed using descriptive statistics, paired-sample t-tests, and gain-score analysis to measure learning improvements. Complementary qualitative data from classroom observations and student interviews were thematically analyzed to capture cultural and philosophical dimensions emerging in practice.

Validity and reliability were ensured through triangulation of data sources, expert validation involving mathematics educators and cultural practitioners, and member checking with local informants. The LKPD's readability testing was conducted in two stages—limited and extended trials—to ensure pedagogical quality and contextual relevance.

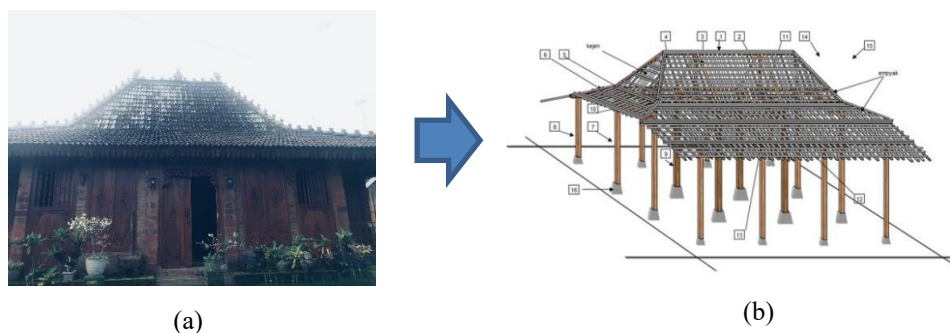
This methodological integration enabled the study to document ethnomathematical structures in disaster-resistant traditional houses and design, test, and refine pedagogical tools that bridge mathematics literacy with cultural and resilience education.

3 Results and Discussion

3.1 Identification of the Geometry of Traditional Houses

The primary data collected in this study were visual documentation, interviews with traditional Limasan house informants, and participant observations of Limasan houses in East Java. The data obtained are as follows.

Figure 1: (a) Limasan Traditional House, (b) Sketch of Limasan Traditional House



The sketch of a traditional Limasan house has several parts. Here are the names of the parts in the sketch of a traditional Limas house.

Table 1: Names of the Parts of the Limasan Traditional House Sketch

No	Name	Amount
1	Sesirah/Molo	1 piece
2	Ander	2 pieces
3	Demak	4 Pieces
4	Usek	Lots
5	Sledge	4 Pieces
6	Blandar	4 Pieces
7	Main Pillar	4 Pieces
8	Soko Rowo	4 Pieces
9	Soko Guru	4 Pieces
10	Drawstring	2 pieces
11	Gonjo	4 Pieces
12	Sunduk	2 pieces
13	Kili	2 pieces
14	Songgo Gelung	2 pieces
15	Reog	Lots
16	Umpak	16 pieces
17	Ploughshare	2 pieces

Table 2: Description of Primary Data

No	Bishop Math Activities	Documented aspects	Brief description of the research	There is (√)	None (×)	Conclusion of visual documentation, interviews, and participant observation
1	Designing and Measuring	Geometric shapes	The roof slope is approximately 35–45 degrees to the horizontal plane, forming an isosceles triangle.	√		- The roof's two sides are the same length and slope angle, forming an isosceles triangle when viewed from the side or front. - The roof peak angle (between the two sloping sides) ranges from 90° to 110 °, depending on the building's width and the height of the central pillar. - This structure can be analyzed using trigonometry rules and the Pythagorean theorem, especially to calculate the height of the roof from the base to the peak, the length of the sloping side of the roof based on the width of the house, and the angle of inclination.

Continue Table 2: Description of Primary Data

No	Bishop Math Activities	Documented aspects	Brief description of the research	There is (√)	None (×)	Conclusion of visual documentation, interviews, and participant observation
2	Designing and Locating	Symmetry System	The main pillars (saka guru) are four in number and form the central square of the structure's strength .	√		- The axis of symmetry divides the house from front to back vertically through the main pillar (saka guru). - The angles and lengths of both sides of the roof are identical, reflecting reflection symmetry about the central axis of the building.
3	Counting	Proportion/Scale	Determining the height of the pole if the width of the roof is known (and vice versa)	√		The ratio of pillar height to roof width on Limasan houses ranges from 1:2 to 1:2.5
4	Explaining	Earthquake-Resistant Connections	Dowel joint, wood joint without nails	√		A traditional construction technique that uses a system of wooden dowels or holes and protrusions (mortise and tenon) as fasteners between wooden structural components, without using metal such as nails or screws.
5	Explaining	Use of Local Materials	Teak wood, local stone, red brick	√		Materials are chosen for durability, flexibility, and a tropical climate (functional). - All materials come from the surrounding environment, are easily renewable, and produce minimal waste (ecological). - Natural colors, textures, and shapes create a traditional (aesthetic) visual harmony. - The sizes of wood, stone, and roof tiles are processed with proportional sizes in a local (mathematical) system. - Teak wood and river stones are believed to have protective and balancing (spiritual) energy.

Continue Table 2: Description of Primary Data

No	Bishop Math Activities	Documented aspects	Brief description of the research	There is (✓)	None (×)	Conclusion of visual documentation, interviews, and participant observation
6	Playing	Mathematical Ornaments	Batik motifs or carvings with fractal/symmetrical patterns	✓		Wood carvings on Limasan houses, especially on doors, frames, beams, and fascias, often display repeating patterns (tessellations) and basic geometric shapes.
7	Explaining	Disaster Resilience Aspects	(Earthquake/wind-resistant structure)	✓		- River stone foundation (each main wooden pillar stands on a stone base. The base is trapezoidal or a trapezoid cut off at the top. The base's top is usually concave (curved) so that the pillar does not shift easily). - The foundation system is not rigid (it does not use permanent connections) and can respond flexibly to ground movements or earthquakes because the poles are not planted in the ground. They are only placed on the base (not embedded), relying on gravity and the weight of the poles. Freestanding wooden structure system. Relationship to the foundation: The wooden pillars stand freely, not attached to the stone foundation. It allows the house to be dismantled and not easily damaged when the ground shifts.)
8	Playing	Aesthetic and Philosophical Values	(For example: the shape of the roof reflects Javanese cosmology)			- The aesthetics of the Limasan house are reflected in its simplicity, symmetry, and profound proportionality in form and arrangement. - Limasan houses are full of symbolism and deep Javanese cultural values, namely cosmological philosophy, simplicity and humility, symbols of wholeness and harmony, and environmental adaptation.

3.2 Ethnomathematical Valuation of the Limasan Traditional House

The traditional Limasan house, as part of the traditional Javanese architectural heritage, contains ethnomathematical values that can be analyzed culturally. According to Bishop (1988), mathematical ideas are classified into six categories: counting, locating, measuring, designing, playing, and explaining.

Table 3: Ethnomathematical Valuation of the Limasan Traditional House

Bishop Category (1988)	Examples of Ethnomathematic Practices in Limasan Houses	Cultural Valuation	Mathematical Valuation
Counting	Counting the number of main pillars and sub-pillars as a symbol of social status	Symbol of social structure, sacredness of numbers (numbers 4 and 9)	The concept of whole numbers, sets, and multiplication
Locating	Placement of the room based on the direction of the wind (qibla <i>papat lima pancer</i>)	Spiritual, cosmological (harmony between humans and nature)	Cartesian coordinates, direction, orientation
Measuring	Measuring the length of the beam, the height of the pillar, and the angle of the roof slope	Functional: earthquake and rain-resistant structure	Length, angle, ratio, and proportion
Designing	Limasan roof design and symmetrical carved ornaments	Aesthetic, cultural, ecological	Plane geometry, transformations (reflection, rotation), symmetry
Playing	Symbolic patterns in carvings and the play of shapes in home ornaments	Visual entertainment, cultural expression	Patterns, combinations of shapes, logical sequences
Explaining	Oral explanation of building philosophy by a craftsman or elder	Educational, transgenerational (knowledge inheritance)	Logical narrative, spatial argument, estimation, and reasoning

With this classification, the local cultural values contained in the construction of Limasan houses can be transformed into teaching materials that not only contain mathematics but also enrich students' awareness of local wisdom values.

3.3 Integration of Ethnomathematics Values into Mathematics Learning

The transformation of the ethnomathematical values of Limasan houses into mathematics learning is carried out through a contextual approach. This integration facilitates meaningful learning and increases cultural literacy and disaster preparedness. The context of school mathematics materials is plane and space geometry: Analysis of roof shapes and house plans; Geometric transformation: Analysis of fascia ornaments and floor patterns; ratio and proportion: The relationship between the height of the main pillar and the width of the house; and Data and statistics: The relationship between house structures and earthquake disaster data.

The ethnomathematical concept of the Limasan house is contextualized into the mathematics curriculum at the elementary and junior high school levels, referring to Capa-Aydin and Yildirim (2021), who suggested that cultural connectedness can enhance learning engagement and understanding of abstract concepts. The following are some conceptual integrations.

Table 4: Ethnomathematical Valuation of the Limasan Traditional House

Ethnomathematic Elements	Curriculum Material	Basic Competencies (KD)	Concept Transformation
Roof slope 35–45° (isosceles triangle)	Plane geometry	KD 3.8 (Grade 5 Elementary School)	Drawing and calculating the area of a triangle
Symmetry of carved fascia	Geometric transformation	KD 3.4 (Grade 7 Middle School)	Reflection, rotation, translation
Ratio of pillar height: house width	Comparison and scale	KD 3.6 (Grade 7 Middle School)	Scale comparison
Layout based on cardinal directions	Coordinates and location	KD 3.7 (Grade 6 Elementary School)	Simple Cartesian coordinate system
Earthquake-resistant structure	Simple statistics	KD 3.9 (Grade 8 Middle School)	Disaster data and mitigation

The Limasan roof is shaped like a rectangular pyramid with a slope of about 35–45 degrees. It provides an opportunity to introduce the concepts of the Isosceles triangle (roof slope), Trapezoid (fascia on the side of the roof), and Regular rectangular pyramid (overall roof structure).

Figure 2: (a) Limasan Traditional House, (b) Sketch of Limasan Traditional House, (c) Rectangular Ornament, (d) Rectangular Shape

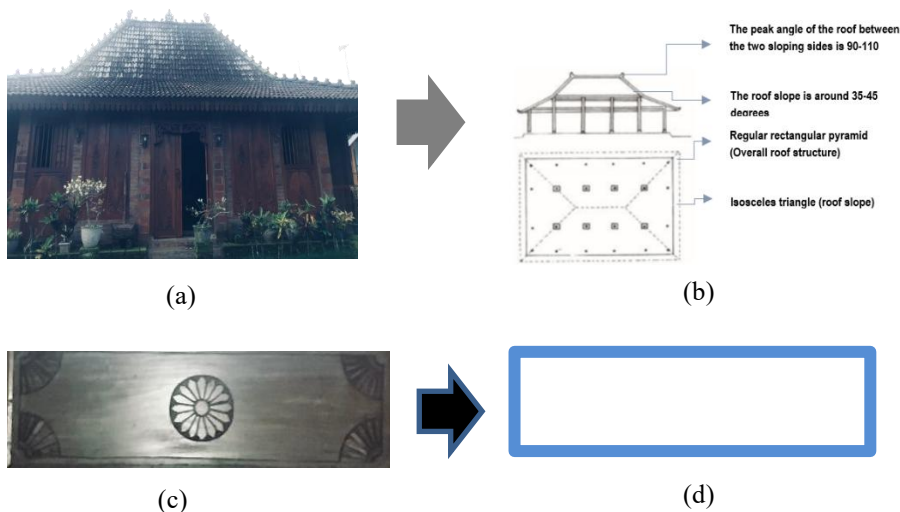
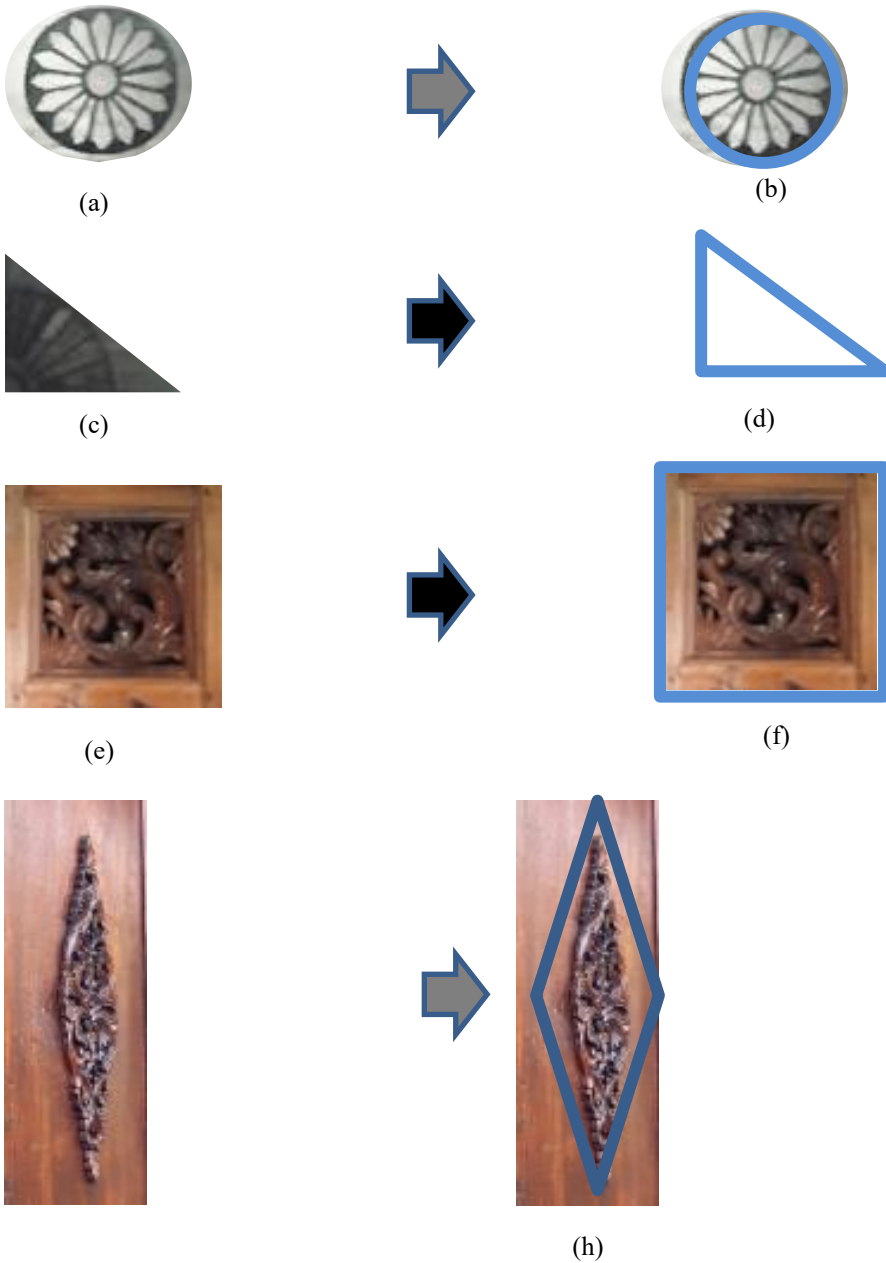


Figure 3: (a) Circle Ornament, (b) Building a Circle, (c) Triangular Ornament, (d) Triangle Construction, (e) Square Ornament, (f) Square shape, (g) Rhombus ornament, (h) Rhombus shape



The floor plan of a Limasan house can be analyzed as a combination of plane shapes such as rectangles, squares, and triangles. Students can measure the building's spaces' area, perimeter, and volume in real time. Learning activities include redrawing the Limasan house floor plan, measuring and calculating the roof volume, and comparing the structure of traditional houses with modern ones.

3.4 Implementation in Learning

One hundred junior high school students implemented ethnomathematics-based student worksheets (LKPD) derived from the Limasan and Joglo traditional houses. The learning scenarios employed contextual problems such as calculating the Limasan roof's surface area, comparing the main pillars' ratios, and constructing simple 3D models based on the geometry of traditional architecture.

Descriptive results showed that the mean score of students' mathematical literacy increased from 60.98 in the pretest ($SD = 6.45$; $Min = 47.5$; $Max = 77.5$) to 79.46 in the posttest ($SD = 6.10$; $Min = 57.5$; $Max = 87.5$). Almost all students (99 out of 100) demonstrated score improvement, while only one experienced a decrease.

Since the data were not fully normally distributed (Shapiro–Wilk $p < 0.05$), the Wilcoxon Signed Rank Test was applied. The results indicated $Z = -8.683$; $p = 0.000 < 0.05$, confirming a statistically significant difference between pretest and posttest scores. These findings suggest that the ethnomathematics-based LKPD effectively improved students' mathematical literacy.

3.5 Discussion

The findings of this study reaffirm that the Limasan traditional house functions not only as a cultural symbol of Javanese identity but also as a repository of mathematical knowledge. Architectural features such as the roof slope forming isosceles triangles, the proportionality between pillar height and house width, and the reflectional symmetry in ornaments exemplify how mathematics is embedded in cultural artifacts. It directly supports Bishop's (1988) notion that mathematical ideas arise from six universal activities—counting, measuring, locating, designing, playing, and explaining—all clearly manifested in the Limasan house.

The quantitative patterns found in this research—specifically the pillar height to roof width ratio (1:2–1:2.5) and the roof slope (35–45°)—illustrate how cultural designs can be analyzed through trigonometry and proportional reasoning. Gerdes (1996) similarly noted that traditional architectures encode geometric knowledge that can serve as a foundation for teaching formal mathematics. Thus, Ethnomathematics acts as a bridge between cultural heritage and academic mathematics.

The use of local materials and earthquake-resistant construction techniques reflects a form of ecological mathematics. Features such as mortise-and-tenon joints and trapezoidal stone bases represent practical engineering wisdom and provide relevant contexts for introducing geometry, mechanics, and probability concepts. Kusuma and Rosyidi (2020) argue that embedding such traditional disaster-resistant knowledge into mathematics education promotes both mathematical literacy and disaster resilience awareness, a finding that resonates strongly with our study.

At the same time, the philosophical and symbolic dimensions—such as the cosmological orientation (qibla papat lima pancer) and the use of sacred numbers (4 and 9)—reveal how mathematics in cultural contexts carries both functional and spiritual meanings. It aligns with D'Ambrosio's (2001) definition of Ethnomathematics as an epistemological bridge between tradition and modernity, ensuring that learners see mathematics as part of their cultural heritage.

Implementing ethnomathematics-based LKPD significantly increased students' mathematical literacy ($Z = -8.683$; $p < 0.05$), with mean scores rising from 60.98 to 79.46. These results corroborate Rosa and Orey (2011), who found that contextualizing mathematics within cultural practices enhances engagement and conceptual understanding. Although their study lacks a DOI, it remains a widely cited reference in ethnomathematics literature.

Furthermore, the contextual integration practices in this research—such as using roof geometry for plane geometry lessons and ornament symmetry for transformation geometry—echo the findings of Capa-Aydin and Yildirim (2021), who emphasize that cultural connectedness improves learning motivation and retention. More recently, Zainovi et al. (2025) confirmed that ethnomathematics-based geometry instruction boosts primary students' numeracy skills, paralleling the improvement in mathematical literacy observed in this study.

Taken together, these findings underscore that ethnomathematics-based learning strengthens not only cognitive skills but also cultural literacy and resilience awareness. In the context of the Limasan house, mathematics education becomes a medium for transmitting Javanese values of harmony, balance, and adaptability, affirming the transformative potential of Ethnomathematics as a pedagogy that unites scientific reasoning with cultural sustainability.

3.6 Implications, Limitations, and Future Research Directions

The findings of this study carry several important implications. First, they demonstrate that integrating ethnomathematical elements of traditional architecture into mathematics instruction can enhance student engagement and comprehension of abstract concepts. This implication supports calls for contextual and culturally responsive pedagogy in STEM education (Capa-Aydin & Yildirim, 2021; Zainovi et al., 2025). In practice, the Limasan house provided tangible contexts for teaching geometry, proportion, and symmetry while fostering cultural literacy and disaster awareness. This dual cognitive–cultural outcome highlights the potential of Ethnomathematics as a sustainable educational approach, particularly in regions where traditional knowledge systems remain strong.

Second, the results suggest that mathematics education can reduce disaster risk. By embedding earthquake-resistant architectural principles in classroom learning, students acquire mathematical literacy and resilience-oriented knowledge, as Kusuma and Rosyidi (2020) emphasized. It demonstrates that mathematics curricula can serve both academic and socio-environmental purposes.

Despite these contributions, the study has several limitations. The implementation was limited to 60 junior high school students in East Java, which restricts the generalizability of the results to other cultural contexts or educational levels. Additionally, the analysis of cultural symbolism (e.g., sacred numbers, cosmological orientations) relied on interviews with a few cultural informants, which may not fully capture the diversity of interpretations within Javanese society. Finally, while the pretest–posttest design demonstrated significant improvement, the study did not employ a control group, limiting the strength of causal claims.

Future research should address these limitations in several ways. Larger-scale and multi-site studies are needed to test the replicability of ethnomathematics-based interventions across different regions and cultural traditions. Comparative studies with control groups could provide stronger evidence of causal effects. Moreover, longitudinal designs allow researchers to assess the sustainability of mathematical literacy and cultural awareness improvements. Finally, cross-disciplinary collaborations involving education, anthropology, and disaster studies may yield richer insights into how traditional knowledge can be systematically integrated into modern curricula.

4 Conclusion

This study demonstrates that Javanese traditional houses—particularly Limasan, Limas, and Joglo—are rich in ethnomathematical values that can be effectively integrated into mathematics education. Their architectural elements, such as proportional roof slopes, pillar-to-width ratios, mortise–tenon joints, and spatial orientation, embody mathematical concepts of ratio, proportion, similarity, and transformation while reflecting ecological wisdom and earthquake resilience. Using Rosa and Orey's (2011) framework, these houses also express functional, aesthetic, ecological, educational, and spiritual values, providing meaningful contexts for learning, fostering critical and reflective thinking, and cultivating disaster awareness.

Integrating these ethnomathematical values into a Deep Learning model significantly improved students' mathematical literacy by 30,32 %, strengthening cultural identity and preparedness for natural hazards. This approach underscores Ethnomathematics's dual academic and cultural relevance and positions it as an innovative and sustainable strategy for 21st-century mathematics education, uniting scientific reasoning with cultural preservation and resilience building.

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