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Exploring Buginese ethnomathematics in *Saoraja La Tenri Bali* to foster cultural intelligence

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ABSTRACT

Mathematics is often taught without sufficient cultural context, resulting in limited relevance and student disengagement. To address this issue, integrating ethnomathematics into mathematics instruction is essential for enhancing both mathematical understanding and cultural intelligence. This study explores the mathematical concepts embedded in the architectural design of the Saoraja La Tenri Bali, a traditional Buginese house, and examines its potential as a culturally grounded learning resource. Using a qualitative descriptive design with an ethnographic approach, data were collected through observations, documentation, and in-depth interviews, and analysed using Spradley's ethnographic model. The findings identify various mathematical concepts, including linear equations (parallel, intersecting, and perpendicular lines) and geometric transformations (reflection, translation, rotation, and dilation), reflected in the house's architectural structure. These mathematical elements are closely intertwined with Buginese philosophical values such as *sipakalebbi*, *sipakaraja*, *sipakatau*, and *sipakainge*, which emphasise mutual respect and social harmony. The study highlights that integrating traditional architecture into mathematics education can strengthen mathematical reasoning while fostering students' cultural intelligence. Therefore, culturally responsive learning models that incorporate local wisdom are recommended to support both academic achievement and intercultural competence.

INTRODUCTION

In today's era of globalisation, students are expected not only to master academic content but also to develop the cultural sensitivity and adaptability required to navigate increasingly diverse and dynamic environments. This aligns with the concept of cultural intelligence, defined as an individual's capacity to function effectively in various cultural settings (Andrade Da Silva & Klein, 2020; Ang et al., 2020). Sadiku et al. (2020) identify four core dimensions of cultural intelligence: metacognitive, cognitive, motivational, and behavioural. These dimensions collectively shape a person's ability to understand cultural cues, sustain motivation in intercultural contexts, and respond with appropriate behaviour. In a multicultural nation like Indonesia, with its vast ethnic and cultural diversity, cultivating cultural intelligence through education is both urgent and strategic (Koreň, 2024; Nosratabadi et al., 2020). One of the most promising domains for fostering this capacity is mathematics education, which, despite its abstract nature, holds significant potential as a medium for cultural engagement, especially when approached through contextualised and interdisciplinary lenses (Maryati & Prahmana, 2019; Risnanosanti et al., 2024).

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The dominant paradigm in mathematics education has long regarded the discipline as universal, culturally neutral, and detached from everyday life (Bishop, 1994; Prahmana & D'Ambrosio, 2020a; Umbara et al., 2023). This view has contributed to students' sense of alienation and the widespread perception of mathematics as rigid, difficult, and irrelevant (Abdullah, 2017; Rosa & Orey, 2011). The ethnomathematics movement, introduced by D'Ambrósio (2007), counters this narrative by asserting that mathematical thinking is deeply rooted in the practices, artefacts, and worldviews of cultural communities. Existing research on ethnomathematics generally falls into three categories: (1) the identification of mathematical concepts in cultural artifacts such as traditional crafts and tools; (2) the integration of local culture into mathematics instruction to increase student engagement; and (3) philosophical inquiries into the epistemology of mathematics from a cultural perspective. However, a critical research gap persists: few studies have holistically examined the intersection between mathematical structures and cultural-philosophical symbolism within traditional architecture, particularly in the Buginese context. While previous research has explored weaving systems Busrah et al. (2023), traditional agricultural practices Pathuddin et al. (2023), and cultural values (Khasanah et al., 2025), no study to date has explicitly investigated how the architecture of the *Saoraja La Tenri Bali* traditional house can be interpreted as a source of mathematical knowledge and cultural meaning to foster students' cultural intelligence. This study addresses that specific gap.

This research aims to identify the mathematical concepts embedded in the architectural design of the *Saoraja La Tenri Bali* traditional house and to examine their potential as a culturally rich learning resource for fostering students' cultural intelligence. The study focuses on uncovering geometric elements such as parallel, intersecting, and perpendicular lines and transformation geometry, including reflection, translation, rotation, and dilation, as manifested in the structure of the house. Furthermore, the research explores how these mathematical forms are intertwined with the philosophical values of the Buginese people, which are symbolically expressed in the house's design. More broadly, the study seeks to develop a culturally responsive framework for mathematics education by leveraging architectural heritage to contextualise abstract concepts and promote intercultural awareness. This approach is intended to deepen mathematical reasoning while simultaneously strengthening students' cultural identity and appreciation for diversity.

This study operates on the assumption that mathematical knowledge is not culturally neutral but is socially constructed and contextually embedded by the theoretical foundation of ethnomathematics (Bishop, 1994; D'Ambrosio, 2016; Rosa et al., 2016). In this view, mathematics is a human activity that reflects the practices, beliefs, and spatial reasoning of a given society. The study also draws on the theory of cultural intelligence proposed by Ang et al. (2020), which views cultural competence as a multidimensional construct that can be nurtured through intentional learning experiences. Based on these theoretical perspectives, this study assumes that integrating culturally embedded mathematical artefacts such as the *Saoraja La Tenri Bali* house into mathematics education will foster both cognitive and cultural development (Hartoyo et al., 2025; Nur et al., 2021; Sari et al., 2022). Students will not only gain mathematical skills but also learn to interpret, respect, and internalise the cultural and philosophical meanings conveyed through these architectural forms. Thus, the learning process becomes a site for intellectual engagement and cultural reflection (Payadnya et al., 2024; Sugiman et al., 2025).

Theoretically, this study contributes to expanding the scope of ethnomathematics by incorporating architectural-philosophical analysis into mathematical inquiry, an area still underrepresented in current literature (Turmuzi et al., 2024; Zuliana et al., 2023). It also reinforces the connection between mathematics education and the development of cultural intelligence, positioning mathematics not merely as a tool for logical reasoning but also as a medium of cultural communication (Cesaria et al., 2025; Dhema et al., 2025). Practically, the study offers a model for educators and curriculum developers to design culturally grounded, inclusive, and meaningful learning experiences. By utilising cultural artefacts in mathematics instruction, teachers can forge stronger connections between students and subject matter, thereby enhancing engagement and motivation (Pratama & Yelken, 2024a). In the long term, this approach holds promise for cultivating

Table 1
Ethnomathematical research design

General Questions	Initial Answers	Starting Point	Specific Activity
Where is it?	*Saoraja La Tenri Bali* traditional house architecture In Kabupaten Wajo	Culture	Reviewing references containing *Saoraja La Tenri Bali* traditional house architecture and conducting an interview with the informant with his nowledge.
How does it look?	Investigate aspects of the *Saoraja La Tenri Bali* traditional house architecture related to mathematical concepts.	Alternative thinking	Investigate aspects of the *Saoraja La Tenri Bali* traditional house architecture related to mathematical concepts.
What is it?	Evidence	Philosophical mathematics	Identify the characteristics of the *Saoraja La Tenri Bali* traditional house architecture related to mathematical concepts. It is shown that *Saoraja La Tenri Bali* traditional house architecture have mathematical concepts that can be seen from the elements of knowledge used in daily life.
What does it mean?	The significant value of culture and mathematics.	Anthropology	Describe the relationship between science and culture. Describe the mathematical concepts found in the *Saoraja La Tenri Bali* traditional house architecture.

students who are not only mathematically literate but also culturally competent, ready to contribute to a pluralistic society and a globally interconnected world (Vygotsky, 1980).

METHODS

The method used in this study is a qualitative method using an ethnographic approach. Ethnography is a research approach to describe a culture (Spradley, 2007). The main purpose of ethnography is to understand a way of life from the perspective of members of a culture. This is in line with the purpose of this study, namely, to reveal the mathematical concepts in the architecture of the *Saoraja La Tenri Bali* traditional house in fostering students' cultural intelligence. This research was conducted at the *Saoraja La Tenri Bali* traditional house, Tempe District, Wajo Regency. This research design was developed using four general questions, which are the core of ethnographic principles, namely "Where is it?", "How does it look?", "What is it?", and "What does it mean?" (Pathuddin et al., 2021; Prahmana & D'Ambrosio, 2020b). It is presented in Table 1.

Data were collected through observation, interviews, and documentation. Data were collected through observation, interviews, and documentation. The interviews were conducted using a semi-structured format, guided by an interview protocol containing questions related to the history, symbolic meaning, and implementation process of the tradition. The observations were conducted using structured observation sheets, supplemented by field notes, photographic records, and basic architectural sketches to capture spatial arrangements and ritual sequences. Documentation included photographs, audio recordings of the ritual and interviews, and archival materials relevant to the tradition, such as community records and written descriptions preserved by local cultural institutions.

The informants interviewed were Petta Bau Manussa, a descendant of Arung Matoa Wajo as a key informant, and Sudirman Sabang, a Wajo cultural figure, as a supporting informant. During the interview, everything expressed by the informant was recorded to obtain more accurate information.

Figure 1. *Saoraja La Tenri Bali* Traditional House

In addition, all information relevant to the research objectives was clearly documented. After obtaining the data, analysis was carried out through data reduction, where the collected information was sorted and summarised to retain only the relevant and meaningful aspects. Following data reduction, domain analysis was conducted to identify key categories needed to answer the research questions, followed by taxonomic analysis, which described these categories in greater detail based on the mathematical concepts found in the architecture of the Saoraja La Tenri Bali traditional house and their relevance to fostering students' cultural intelligence.

To ensure data validity, this study employed triangulation, comparing findings from observations, interviews, and document analysis to verify the consistency of emerging themes. Member checking was also conducted by confirming essential interpretations with selected participants. To ensure reliability, the interview process followed a consistent semi-structured guide, and the interpretation of mathematical elements in the architectural structure was reviewed collaboratively by the research team to minimise subjective bias. The final stage was the presentation of the analysed data, illustrating the relationship between mathematical concepts and the architectural characteristics of the Saoraja La Tenri Bali traditional house.

FINDINGS

The *Saoraja La Tenri Bali* traditional house is unique as shown in Figure 1. The shape of the stilt house is a characteristic of traditional Sulawesi houses. But what makes it different is its enormous size, having 101 pillars. The *Saoraja La Tenri Bali* traditional house has several rooms that have different functions and layout provisions. It has its aesthetic value and uniqueness of symbolic meaning as architecture, materials used, and there is educational value in its architecture. *Saoraja La Tenri Bali* is unique not only because of its shape but also because of its philosophical foundation that describes 3 things, namely *langi* (upper world), *ale kawa* (middle world), and *awa bola* (lower world).

The ideal concept of space in the *Saoraja La Tenri Bali* traditional house applies the philosophical concept of *sulapa eppa na' to ugi'e*. Where the concept of arranging the spaces adheres not only to the symbol of the four-sided philosophy of the origin of human life, comprising earth, water, wind, and fire, as the pattern of the arrangement of the space in the house. However, the ale bola room in the *Saoraja La Tenri Bali* traditional house also horizontally forms the values of the mappakaraja nobility identity in the four dimensions of its spatial composition, as a symbol of respect and appreciation for fellow human beings, namely: *sipakaraja in the lego-lego* space, *sipakatau* in the *tamping* space, *sipakalebb*i in the watampola space, and *sipakainge* in the *jongke* space. These four dimensions of space are in the space where humans carry out their daily life activities as shown in Figure 2.

This is in line with the thoughts of Immanuel Kant, who argued that space is not only an object or tangible, but space is also something subjective or intangible because of human thoughts and feelings. The architectural form of the *Saoraja La Tenri Bali* traditional house contains philosophical values, including *sipakaraja padatta rupa tau*, *sipakatau*, *sipakalebbi*, *sipakainge*, and *mappasona ri Dewata Sewwa'e*. These values can increase the cultural intelligence of students and college students from the cognitive, metacognitive, motivational, and behavioural aspects. Through this approach,

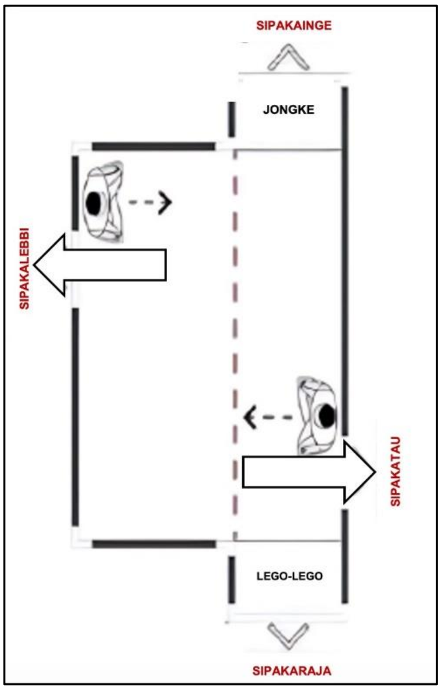

Figure 2. Four Dimensions of Space

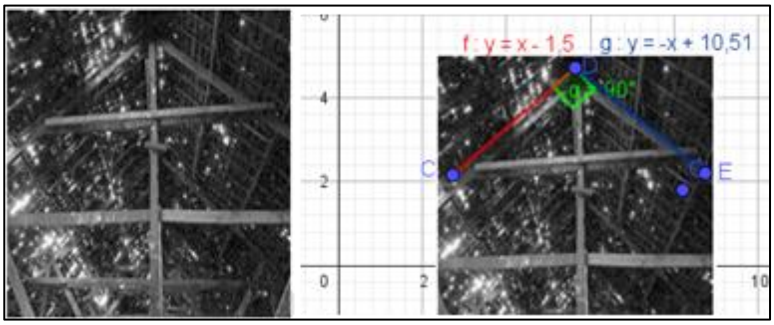

Figure 3. Geometric Representation of The Roof Structure of The *Saoraja La Tenri Bali* Traditional House in Relation to the Vertical Line Equation

architecture not only functions as a place to live but also as an educational medium that enriches cultural experiences and increases social awareness among students and college students. The following are mathematical concepts contained in the architectural design of Saoraja La Tenri Bali.

In the roof structure of the *Saoraja La Tenri Bali* traditional house, there is a relationship with mathematics, namely, the roof support pillars form a line perpendicular to each other as shown in Figure 3. A straight-line equation that is perpendicular to another is two lines that have a special related gradient (slope). If two lines are perpendicular to each other, then the product of the gradients (m) of the two lines must be equal to -1.

Based on the Figure 3, the equation of lines that intersect perpendicularly is

$$f : y = x - 1{,}5$$

$$g : y = -x + 10{,}51$$

The equation f has gradient values (m_1) = 1 and equation g has gradient values (m_2) = -1, so m_1 x m_2 = 1 x -1 = -1

The stairs of the Saoraja La Tenri Bali traditional house form a pattern of parallel straight lines where the two longest sides have the same slope, as well as the steps that are parallel to the other steps as shown in Figure 4. If the two lines are parallel to each other, then the gradient (m) same. For example, if the first line gradient is m_1, and the second line gradient is m_2, then the relationship applies: m_1=m_2.

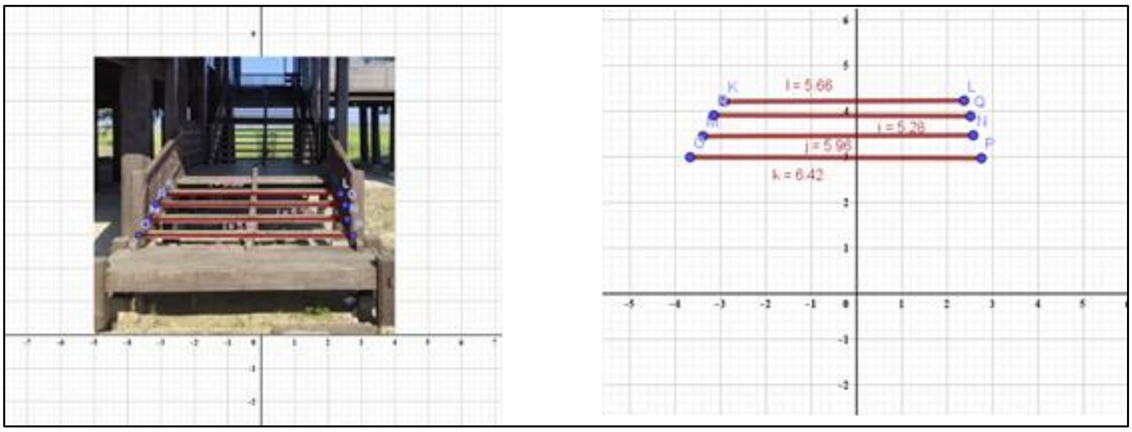

Figure 4. Geometric Representation of the Sapana Stairs of the *Saoraja La Tenri Bali* Traditional House about the Parallel Line Equation

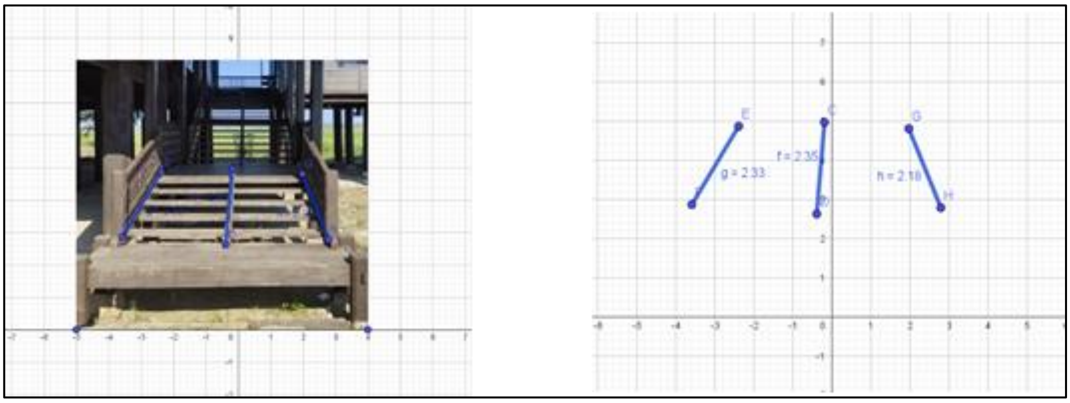

Figure 5. Geometric Representation of the *Sapana* Stairs of the *Saoraja La Tenri Bali* Traditional House about the Equation of Intersecting Straight Lines

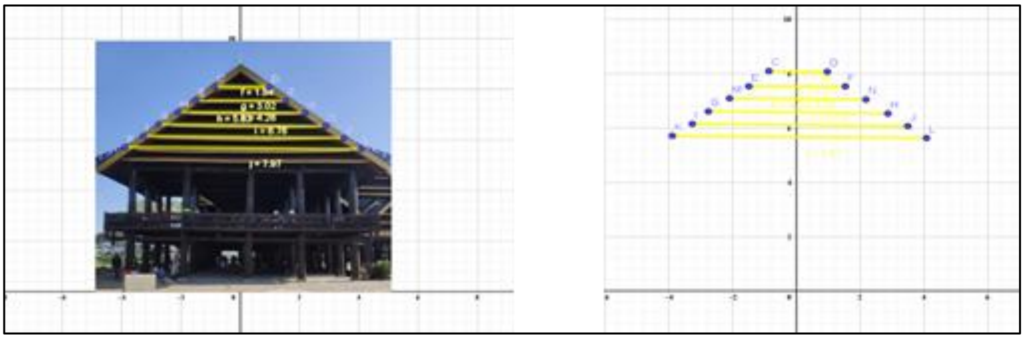

Figure 6. Geometric Representation of *Timpa Laja* of the *Saoraja La Tenri Bali* Traditional House in Relation to the Equation of Parallel Lines

The *Sapan*a Ladder of the *Saoraja La Tenri Bali* Traditional in Relation to the Intersecting Straight-Line Equation as shown in Figure 5. The ladder of the *Saoraja La Tenri Bali* traditional house forms a straight-line pattern. This can be seen from its shape between the longest side of the ladder and the blocks lined up on both sides. The ladder forms a straight-line pattern that intersects each other on both of its longest sides, meeting the steps at one point. The gradient of the intersecting lines has no special relationship.

The overwriting of the traditional house of *Saoraja La Tenri Bali* forms a pattern of straight-line equations as shown in Figure 6. The arrangement of the beams that make up the rate override forms a parallel line equation. If the two lines are parallel to each other, then the gradient (m) is the

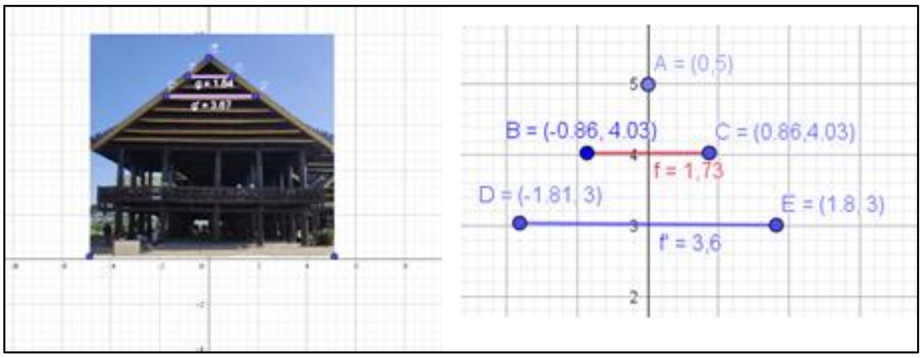

Figure 7. Geometric representation of the *Timpa Laja* traditional house of *Saoraja La Tenri Bali* in relation to dilation

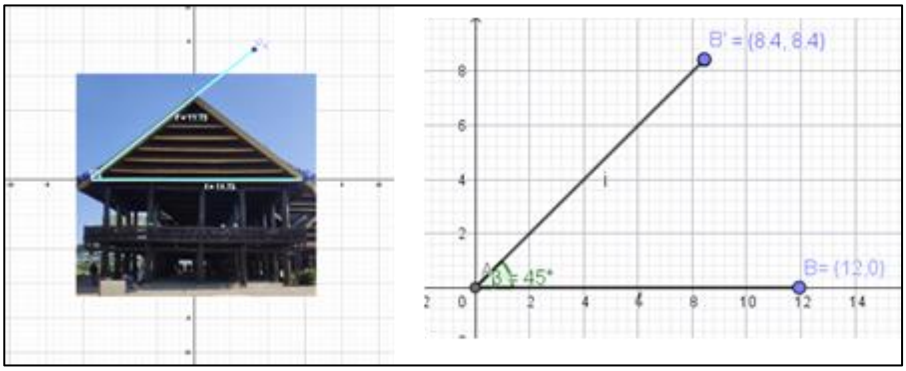

Figure 8. Geometric Representation of the *Timpa Laja* Traditional House of *Saoraja La Tenri Bali* in Relation to Rotation

same. For example, if the first line gradient is m_1, and the second line gradient is m_2, then the relationship applies: $m_1=m_2$.

The form of *Timpa Laja* of the *Saoraja La Tenri Bali* traditional house contains a mathematical concept, namely the concept of dilation as shown in Figure 7. Dilation is a geometric transformation that changes the size of a shape without changing its shape. Dilation is done by enlarging or reducing the shape based on the centre of dilation and the scale factor. Each point on the shape resulting from the dilation has a distance from the centre that is proportional to the scale factor to the distance of the starting point. Based on Figure 7, the superimposition (timpa laja) representation shows that the line segment f = 1.73. After applying a dilation centered at P (0,0) with a scale factor k = 2.1, the resulting line segment is f' = 3.6. This calculation can be derived using the formula.

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = k \begin{pmatrix} x \\ y \end{pmatrix} \; or \; \begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} k & 0 \\ 0 & k \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

$$f' = k(f)$$

$$f' = 2{,}1(1{,}73)$$

$$f' = 3{,}6$$

Rotation is a geometric transformation that rotates a figure or point in a flat plane at a certain angle (θ) around a fixed point, called the center of rotation. Based on Figure 8 the rotation applies on a straight line f to point A and point B (12,0) on the overwrite when the horizontal beam is rotated at point A (0,0) by 45°. This will result in a slanted straight line B' ($6\sqrt{2}$, $6\sqrt{2}$). This forms a triangular-shaped roof structure. This can be explained using the rotation formula.

$$x' = x \cos \theta - y \sin\theta$$

$$y' = x \sin \theta + y \cos \theta$$

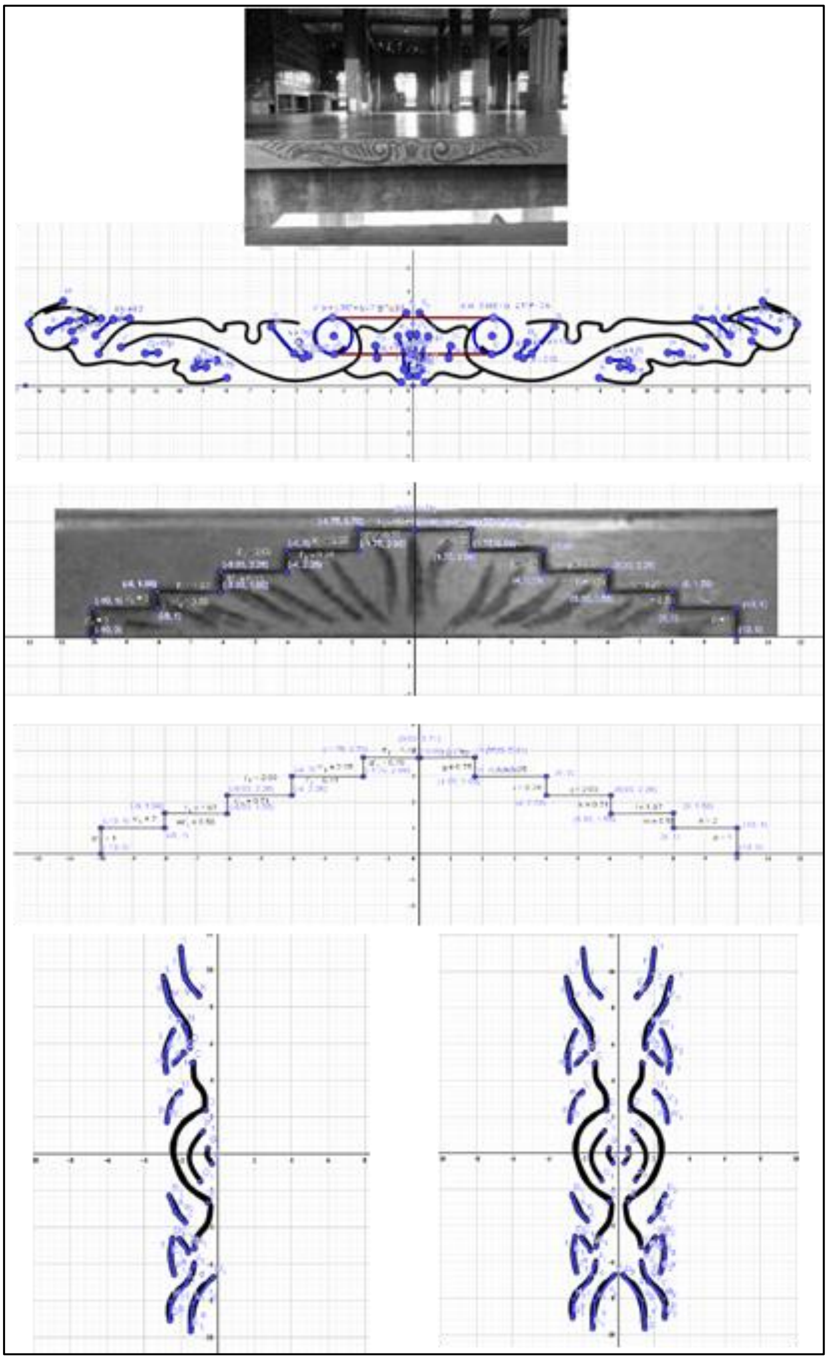

Figure 9. Carved Royal Seat Ornamentation in relation to reflection

in matrix form:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos\theta & -\sin\theta \\ \sin\theta & \cos\theta \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \cos 45^\circ & -\sin 45^\circ \\ \sin 45^\circ & \cos 45 \end{pmatrix} \begin{pmatrix} 12 \\ 0 \end{pmatrix}$$

$$B' = \begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} \frac{1}{2}\sqrt{2} & -\frac{1}{2}\sqrt{2} \\ \frac{1}{2}\sqrt{2} & \frac{1}{2}\sqrt{2} \end{pmatrix} \begin{pmatrix} 12 \\ 0 \end{pmatrix}$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 6\sqrt{2} \\ 6\sqrt{2} \end{pmatrix}$$

Carving of the King's Seat of the *Saoraja La Tenri Bali* traditional house in relation to reflection as shown on Figure 9. The carving of the king's seat can be related to the mathematics of reflection of geometric transformation material. In transformation geometry, reflection is a type of transformation that maps every point in an object to a symmetrical point across the reflection line. The reflection line acts as a "mirror," and every point on the original object is moved to a position as far away as possible from the line, with the line being its midpoint.

As in Figure 9 there is a sympathetic shape of the carving, which causes it to be said that the left carving is a reflection of the right carving with a reflection line on the y-axis. A point A (x,y), which is reflected on the y-axis, then:

$$x' = -x$$

$$y' = y$$

The equation can be written in the form:

$$x' = (-1).x + 0.y$$

$$y' = 0.x + 1.y$$

or in matrix form:

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix}$$

DISCUSSION

The results of this study demonstrate that the architectural design of the Saoraja La Tenri Bali traditional house contains a range of mathematical structures, including linear equations (parallel, intersecting, and perpendicular lines) and geometric transformations such as translation, reflection, rotation, and dilation. These structures can be represented through explicit mathematical modelling, for example, by expressing roof beam orientations through coordinate-based linear equations and describing repetitive carved motifs using translation and rotation matrices. Such modelling confirms D'Ambrosio's (1985) argument that mathematics is deeply embedded in cultural practices, and that local architectural forms can serve as authentic sources of mathematical knowledge with high pedagogical value. Thus, the Saoraja La Tenri Bali traditional house not only functions as a cultural artefact but also as a mathematically rich, contextual learning medium.

The integration of mathematical content with Bugis cultural values further demonstrates that ethnomathematics is not merely a supplementary approach but can serve as a central framework for contextualising mathematics learning (Nur et al., 2020). This finding aligns with Rosa et al. (2016) claim that connecting mathematics to culture enhances conceptual understanding while simultaneously strengthening cultural identity. In this study, specific mathematical concepts correspond directly to Bugis philosophical values. For example, reflection patterns in façade ornaments symbolise *sipakainge*' (mutual reminder), where symmetrical balance represents moral guidance within the community. The parallel orientation of structural beams reflects *sipakalebbi* (mutual respect), symbolising order and harmony. Rotational motifs embody *sipakatau* (mutual humanisation), representing unity and interdependence. Clarifying these relationships reinforces the theoretical position that mathematical structures can encode cultural meanings (Barton, 1985; Umbara et al., 2023)

These connections also contribute to the development of students' cultural intelligence across its four dimensions (Ang et al., 2020). Cognitively, students acquire cultural knowledge as they learn how Bugis architectural forms integrate symbolic values with mathematical structures. This supports Koreň (2024) view that embedding cultural content in mathematics enhances meaningful conceptual learning. Metacognitively, students are encouraged to reflect on how cultural contexts shape their interpretation of mathematical ideas, thereby enhancing cultural awareness and higher-order thinking skills (Andrade Da Silva & Klein, 2020). Motivationally, the aesthetic and intellectual appeal of local architecture stimulates students' curiosity and fosters long-term interest in the interplay between mathematics and culture (Thomas, 2015). Behaviourally, recognising that mathematical concepts are embedded in cultural artefacts encourages students to act respectfully and adaptively within diverse cultural environments, consistent with findings by Dogra & Dixit (2016).

These strengthened connections contribute to the development of ethnomathematics as a cross-cultural paradigm for mathematics education. The findings reinforce Vygotsky's sociocultural theory (Nur et al., 2021; Pratama & Yelken, 2024; Wulandari et al., 2024), which views knowledge as mediated by cultural tools, and extend Piagetian constructivism by emphasising culturally situated mathematical reasoning (DeVries, 2000). This study also contributes to critical mathematics education by positioning cultural artefacts as tools for reflection, dialogue, and identity formation (Prahmana et al., 2023). Locally, the Saoraja La Tenri Bali traditional house becomes a concrete representation of how Bugis values are encoded not only in social practices but also in mathematically meaningful forms, providing a theoretical foundation for developing culturally grounded mathematics learning models.

The findings offer valuable implications for educators, researchers, and policymakers. Ethnomathematics can serve as a strategic approach for developing 21st-century competencies, particularly cultural literacy, global citizenship, and interdisciplinary thinking (Pradana et al., 2022; Tampa et al., 2023). Curriculum developers can incorporate traditional houses and other cultural artefacts as real-world learning resources to explain abstract mathematical concepts (Ratau et al., 2025; Sari et al., 2022; Setyaningrum & Untarti, 2024). This opens pathways for developing instructional modules, worksheets, interactive visual media, and cross-curricular cultural projects. In addition to enriching educational content, this approach strengthens students' cultural identity, nurtures pride in local heritage, and fosters tolerance toward cultural diversity, aligning with both national and regional education goals to cultivate learners who are critical, culturally grounded, and globally engaged.

CONCLUSION

This study demonstrates that the architectural design of the Saoraja La Tenri Bali traditional house contains explicit mathematical structures, including linear equations (parallel, intersecting, and perpendicular lines) and geometric transformations (translation, rotation, reflection, and dilation), which can be modelled through coordinate geometry and transformation matrices. These mathematical forms are closely linked to core Bugis cultural values such as *sipakatau*, *sipakalebbi*, and *sipakainge'*, showing that traditional architecture functions as an authentic medium for integrating mathematics with cultural meaning. The findings also indicate that engaging students with culturally embedded mathematical concepts can support the development of cultural intelligence across cognitive, metacognitive, motivational, and behavioural dimensions, offering valuable implications for contextual and culturally responsive mathematics education. Future research should include empirical effectiveness studies using pre–post assessments, the Cultural Intelligence Scale (CQS), classroom observations, and analysis of student work to rigorously evaluate the impact of ethnomathematics-based instruction on students' mathematical understanding and cultural intelligence.

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AUTHOR'S DECLARATION

Author's Contribution	:	AA: Conceptualisation, data curation, formal analysis, interpretation of mathematical elements, visualisation, and writing original draft. SD: Methodology, philosophical analysis, investigation of cultural and symbolic meanings, supervision, and

		writing review & editing, FZB: Ethnographic investigation, validation of cultural data, integration of social context, resources, and writing review & editing.
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Availability of data and materials	:	All datasets used in this study are accessible from the authors upon request.
Competing interests	:	The authors confirm that there are no conflicts of interest associated with this study. This manuscript is original, has not been previously published, and is not under consideration for publication elsewhere.

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