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Exploring Mathematical Concepts in Buna Woven Fabric Motifs of the Amanuban Community and Their Integration into Mathematics Education

Farida Daniel[1], Turmudi[1], Dadang Juandi[1], Kusnandi[1]

[1]*Department of Mathematics Education, Faculty of Mathematics and Science Education, Universitas Pendidikan Indonesia*

**Corresponding Author: Turmudi*
Email: turmudi@upi.edu

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Abstract

This study explores the mathematical concepts embedded in the woven motifs of Buna, specifically Tais Kaimnutu and Buna Panbuat, from the Amanuban community, and their potential integration into mathematics education. Using a qualitative ethnographic approach, the researchers conducted six months of observations, interviews with indigenous weavers and cultural experts, and documentation of woven patterns. The study reveals that Buna woven motifs embody rich mathematical concepts such as symmetry, geometric transformations, fractals, and group theory, while also reflecting deep cultural values, identity, and spirituality. These motifs serve as intuitive artistic and cosmological expressions, with mathematical interpretations offering a new form of cultural appreciation that respects local contexts. Educationally, these motifs support learning across all levels: introducing symmetry and spatial visualization in elementary school; deepening understanding of transformations and congruence in middle school; exploring fractals and algebraic structures in high school; and fostering culturally responsive teaching in higher education through ethnomathematics integrated with mathematical modeling and topology. Beyond pedagogy, the study emphasizes the importance of integrating indigenous knowledge into formal curricula to strengthen cultural identity, community involvement, and empowerment. It highlights ethnomathematics as a transformative bridge linking academic research, cultural preservation, and community development. Future research should explore participatory curriculum design and community perspectives on the mathematical interpretation of indigenous crafts to enhance educational and cultural sustainability.

Introduction

Mathematics is deeply intertwined with human civilization and cultural development. It is not only a system of abstract knowledge but also a tool that helps humans understand, analyze, and structure their surroundings (D'Ambrosio, 2010). Every cultural community cultivates mathematical knowledge tailored to its environment and daily practices (D'Ambrosio, 2007). Ethnomathematics examines how mathematics is intertwined with cultural practices, exploring how different communities develop and apply mathematical concepts in their daily lives. It encompasses the mathematical ideas found in various cultural groups, from indigenous societies to professional communities and different age groups (D'Ambrosio, 1985), and is understood as the study of mathematical concepts within cultural contexts (Ascher, 2017). Ethnomathematics plays a vital role in contextualizing mathematics education and making it more relevant to students (Rosa & Orey, 2011).

Over time, ethnomathematics has evolved beyond merely tracing Western mathematical structures in cultural practices. It now seeks to understand how local cultures create

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autonomous forms of mathematical reasoning and logic. Barton (1996) criticizes approaches that simply identify Western geometry or arithmetic elements in local traditions as a form of epistemic imperialism, reducing the complexity of indigenous knowledge. He emphasizes that "*The aim should not be to find 'our' mathematics in 'their' culture, but to understand the systems of thought that generate their own mathematical practices*." In this context, D'Ambrosio (2006) advocates a participatory and humanistic approach to ethnomathematics. He states that "Ethnomathematics is not just a way of looking at mathematics in other cultures, but a strategy for empowerment through recognition of different knowledge systems." This approach carries an emancipatory mission, positioning mathematics not as a single universal system, but as a plurality of cognitive expressions shaped by diverse cultures. In line with this, Rosa et al. (2016) emphasize the importance of dialogical and transformative approaches that allow two-way interactions between culture and mathematics. They write: "*Ethnomathematics values cultural ways of knowing, and through pedagogical interaction, both the learner and the educator co-construct mathematical understanding grounded in the learners' sociocultural context*."

Ethnomathematics has been studied across various cultural traditions, from architecture and agriculture to textile production. Weaving, in particular, has long been recognized as a medium where mathematical concepts like symmetry, transformations, and geometric patterns emerge as cultural expressions (Ascher, 2017). Research worldwide has shown that Indigenous communities incorporate mathematical principles into their textile designs, making ethnomathematics a bridge between theoretical mathematics and practical applications.

Mathematical ideas in weaving often manifest through geometric transformations such as translation, reflection, and rotation. These concepts appear in repeating patterns across textiles, revealing tessellations and fractal structures (Eglash, 1999). Badoe & Opoku-Asare (2014) and Ayesu et al. (2021) examined Asante Kente cloth from Ghana from cultural and design perspectives. Badoe & Opoku-Asare focused on its structural aspects, explaining that Kente is woven into long strips using a traditional loom and then stitched together to create distinctive patterns. They also highlighted its potential as an instructional resource in textile design education, enhancing the understanding of patterns and structures in fabric art. Meanwhile, Ayesu et al. emphasized the meaningful geometric patterns in Kente, which reflect the social values and philosophical beliefs of the Asante people. These findings underscore the universal presence of mathematics in textile traditions worldwide.

In Indonesia, ethnomathematical research has explored various traditional textile arts. Mathematical concepts have been identified in weaving activities in Baduy (Turmudi et al., 2016), Yogyakarta's Batik motifs (Prahmana & D'Ambrosio, 2020), weaving activities in Timor island (Dominikus et al., 2023), motifs of woven fabrics of East Nusa Tenggara in general (Sumartono, 2022), Kawung Surakarta batik motif (Abidin et al., 2023), batik Sidomulyo Solo (Uula et al., 2024), Uis Karo weaving (Nasution & Maysarah, 2024), Ulos Ragidup cloth (Basmara & Yahfizham, 2024). Textiles, particularly woven fabrics, are rich in mathematical structures.

Despite these advancements, there is still little research on the ethnomathematics of Buna woven fabric motifs from the Amanuban community in South Central Timor. The Buna weaving tradition, deeply rooted in the Amanuban people's cultural heritage, features unique geometric designs that have yet to be analyzed through an ethnomathematical lens. While ethnomathematics research in Amanuban has explored other cultural elements, such as architecture and traditional practices, weaving remains an underexplored domain. (Amul et al., 2019) examined the Amanuban Royal Palace (Sonaf Son Besi) and identified mathematical

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concepts such as solid figures, plane figures, and congruence, which can be used in mathematics education to introduce architectural patterns and geometric structures. (Dosinaeng et al., 2020) studied Lopo, the traditional house of the Boti tribe, uncovering elements of symmetry, geometry, and area calculation that can be integrated into contextual mathematics learning. Meanwhile, Kikhau & Nenoliu (2020) investigated the livestock-tying techniques of the Dawan community, which involve circular concepts, making them a valuable contextual medium for teaching circle geometry in schools.

This study aims to bridge this gap by exploring the mathematical principles embedded in Buna woven motifs. Specifically, it seeks to understand how these motifs can serve as educational tools in mathematics learning, offering a fresh perspective on how cultural artifacts can support education. Buna woven fabric, a traditional textile of the Amanuban people, showcases intricate motifs passed down through generations. Often inspired by nature and local beliefs, these motifs inherently incorporate mathematical elements such as symmetry, transformations, and geometric patterns. Given the central role of woven textiles in both daily and ceremonial life in Amanuban society, understanding their mathematical properties can provide valuable insights into how Indigenous knowledge can enrich mathematics education.

Furthermore, integrating ethnomathematics into the curriculum has been shown to enhance student engagement by connecting mathematical concepts to real-world cultural artifacts (Barton, 2008; Gerdes, 1999). This study is particularly relevant in light of recent educational policies in South Central Timor, which promote the incorporation of local cultural elements into school curricula. With students required to wear woven-patterned attire at least once a week, ethnomathematics offers a meaningful and context-based approach to mathematics education. By linking mathematics to their cultural heritage, students can develop a deeper appreciation for both subjects while strengthening their cognitive skills (Orey & Rosa, 2010).

Additionally, incorporating ethnomathematics into education can serve as an innovative approach to decolonizing mathematics. By integrating cultural artifacts such as woven fabrics, educators can create a more inclusive and culturally relevant learning environment, helping students connect mathematical concepts to their lived experiences (D’Ambrosio, 2006; Rosa & Orey, 2011). Studies suggest that using culturally embedded mathematical examples helps students grasp abstract concepts more effectively (Nasir et al., 2008).

This study addresses two key research questions: What mathematical concepts are present in the Buna woven fabric motifs of the Amanuban community? And how can these motifs be utilized as learning resources in mathematics education? The novelty of this research lies in its focus on the mathematical structures within Buna motifs, an area that remains largely unexplored. While previous studies have examined ethnomathematics in various Indonesian weaving traditions, the specific characteristics of Amanuban textiles have yet to receive significant scholarly attention. By analyzing the mathematical concepts embedded in Buna motifs, this study contributes to the growing field of ethnomathematics, shedding light on an underrepresented cultural artifact. By identifying and analyzing the mathematical patterns in Buna motifs, this study aims to establish a foundation for integrating traditional weaving into mathematics education. This approach enriches mathematics learning by demonstrating how cultural patterns can be used to teach fundamental mathematical concepts, making abstract ideas more tangible and engaging for students. It aligns with the global movement toward culturally responsive pedagogy, emphasizing the importance of local knowledge in formal education (Banks, 2015; Gay, 2010). Recognizing and validating traditional knowledge systems within formal education can help bridge the gap between abstract mathematics and real-world applications (Knijnik, 2002).

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Ultimately, this research not only addresses a significant gap in Indonesian ethnomathematics but also offers practical implications for curriculum development. By integrating the mathematical elements of Buna woven motifs into educational materials, this study supports culturally responsive teaching practices, helping students connect mathematical concepts with their lived experiences while fostering a sense of identity and pride in their cultural heritage. The findings are expected to enrich both ethnomathematics research and educational practices, laying the groundwork for future studies on the intersection of mathematics and culture in other traditional crafts.

Methods

This study employs a qualitative ethnographic approach to investigate the mathematical concepts embedded in the Buna woven motifs of the Amanuban tribe. This method is suitable because it facilitates a comprehensive understanding of cultural artifacts within their natural and sociocultural contexts (Gay et al., 2011). The study focuses on identifying, analyzing, and interpreting the mathematical structures in these woven motifs and exploring their integration into mathematics education.

This research was conducted in the Amanuban area, South Central Timor district, especially in villages which are famous for traditional Buna weaving. Research participants included local weavers, cultural experts, and mathematics educators. They were selected through purposive sampling aimed at ensuring that they had extensive experience in the field of weaving and cultural heritage. In addition, mathematics educators participated to assess the potential for integrating ethnomathematics into the school curriculum. This diversity of perspectives is important to gain a comprehensive understanding of the mathematical elements in woven motifs.

To ensure a thorough data collection process, the study utilized three primary techniques: observation, interviews, and documentation. Researchers observed the weaving process firsthand to understand the patterns, techniques, and mathematical concepts applied by artisans. These observations were meticulously recorded through field notes, photographs, and videos, capturing both visual and contextual details. Semi-structured interviews were conducted with weavers, cultural experts, and educators to gain insights into the significance of the motifs, their mathematical relevance, and how they could be used in education.

Data collected from observations, interviews, and documentation was analyzed using qualitative content analysis. The process began with data reduction, summarizing key observations and interview transcriptions while focusing on relevant mathematical concepts. Next, the data was organized into categories such as geometry, symmetry, and transformations. Finally, conclusions were drawn by interpreting the findings in relation to ethnomathematical principles and validating them through triangulation, which involved cross-checking data from different sources.

To enhance the credibility of the study, methodological triangulation was used by combining observations, interviews, and documentation. Member checking was also conducted by sharing preliminary findings with the weavers and educators to confirm accuracy and refine interpretations based on their feedback. Furthermore, during the member checking process, the preliminary interpretations were shared with several weavers and cultural elders. Their feedback helped refine the researchers' understanding of how motif regularity is perceived as a reflection of life balance and ancestral rhythm. Such reflections prompted the researchers to reconsider the emphasis on technical symmetry and instead foreground the cultural meanings ascribed to visual balance. In several cases, participants also proposed alternative

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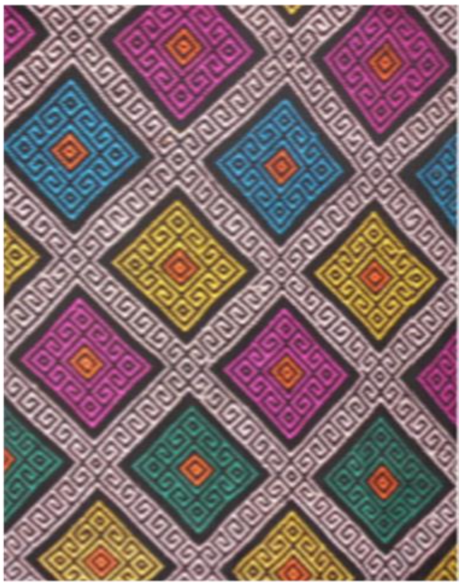
interpretations that emphasized storytelling, symbolic continuity, and spiritual alignment over geometric precision. These insights were incorporated into the final analysis to ensure that the categorizations reflect both mathematical structure and local epistemological meaning.

Results and Discussion

Amanuban is one of the main ethnic groups in the South Central Timor district, East Nusa Tenggara province, which was previously a kingdom or *swapraja* along with two other *swaprajas*, namely *swapraja* Mollo and *swapraja* Amanatun. After Indonesian independence, the traditional government structure in Amanuban underwent significant changes. In 1959, the swapraja regions were combined into the South Central Timor Regency. In 1962-1963, the remnants of the traditional government structure were officially abolished, marking the end of the customary government system in the region (UPTD Museum Daerah Propinsi Nusa Tenggara Timur, 2005). In terms of culture, the Amanuban people have rich and diverse traditions including weaving various cloth motifs including Buna.

Buna is a type of weaving traditionally produced by the Amanuban community, characterized by patterns or motifs made using previously dyed yarn. The process of making buna textiles is very complicated and time-consuming because the motifs are formed through manual weaving techniques while the yarn is stretched on the loom, resulting in symmetry on both sides. The interweaving of the weft and warp threads creates a raised pattern, so this technique has a distinctive name, Buna. Buna weaving is mostly found in the Central, South and West Amanuban regions, where the motifs display more color variations while maintaining geometric shapes, especially the rhombus (UPTD Museum Daerah Propinsi Nusa Tenggara Timur, 2005; Yusa, 2016). The most common motifs woven and used in the Amanuban community are tais kaimnutu and buna panbuat. Therefore, this study focuses on these two motifs as presented in Figure 1.

(a) Tais kaimnutu



(b) Buna Panbuat

Figure 1. Buna Woven Motifs

Historically, within the Amanuban community, particularly among the Sonaf (Niki-Niki, Central Amanuban), the Tais Kaimnutu motif was initially exclusive to the nobility but subsequently disseminated throughout the Amanuban region through intermarriage. This

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motif, traditionally worn during ceremonies, wedding receptions, or as everyday attire, symbolizes the kinship of figures (*amnaubat*) who venerate the king. Similarly, the Buna Panbuat motif, originating from the central, western, eastern, and southern sub-districts of Amanuban, was first reserved for the King and traditional leaders before its adoption and use by individuals across various social strata in the Amanuban region. Worn during traditional ceremonies, official events, receptions, and daily life, the rhombus motif on the Buna Panbuat represents the gathering place for the leaders of each Amanuban kingdom (UPTD Museum Daerah Propinsi Nusa Tenggara Timur, 2005; Yusa, 2016).

These restrictions in the use of specific woven textiles for the Amanuban elite, as highlighted by the initial reservation of Tais Kaimnutu and Buna Panbuat motifs for the nobility and royalty, underscore their integral positioning within the community's social and symbolic structure. Interviews with customary elders and senior weavers in the Amanuban region corroborate this historical stratification, with one elder stating, "*These motifs were only worn by the king and those of noble lineage. Not everyone could use them indiscriminately*," a sentiment that aligns with Therik (2023) findings on the regulation of textile motifs as markers of status and social hierarchy in Timorese society.

The mid-20th-century transition from a self-governing system (swapraja) to a regency government precipitated a notable shift in the social function and cultural significance of these once-exclusive textile motifs. Weavers reported the widespread adoption of these designs by the general populace for diverse occasions, from everyday wear to ceremonial events. One weaver noted, "*now everyone can wear the king's motifs, unlike before. They have become the property of all*," a phenomenon consistent with McWilliam (2007) analysis of the democratization of previously restricted cultural symbols following the erosion of traditional political structures.

Furthermore, this evolution reflects a transformation in the purpose of textile motifs, transitioning from sacred artifacts embodying social distinction to valued cultural commodities within the local economy. Weavers indicated, "*we now create these motifs for sale. Many people from outside also like them because they are beautiful and unique*." Thus, traditional motifs now serve not only as expressions of community identity and heritage—linking to the symbolic representation of kinship and leadership gatherings within the Tais Kaimnutu and Buna Panbuat designs, respectively—but also as integral components of local economic strategies, echoing McWilliam (2007) observation of the recontextualization of ritual artifacts in response to market demands and tourism.

Despite these significant shifts in usage and meaning, the transmission of weaving knowledge within the Amanuban community remains primarily familial and communal, bypassing formal educational channels. Weavers explained their learning process as direct instruction from mothers and grandmothers, "*We learn directly from our mothers and grandmothers, not from school*," underscoring the continued vitality of local knowledge systems through practice and oral tradition, a point also made by Therik (2023) regarding the exclusive inheritance of weaving techniques and meanings within specific matrilineal groups.

The evolving use of motifs like Tais Kaimnutu and Buna Panbuat in the Amanuban region not only demonstrates dynamic aesthetic preferences but also encapsulates broader processes of identity renegotiation, cultural democratization, and economic commodification. These traditional motifs have become vehicles for expressing community pride, fostering local economic growth, and adapting cultural heritage to contemporary life. Nevertheless, these profound transformations, particularly in relation to their inherent mathematical structures, warrant further analytical scrutiny.

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Both the Tais Kaimnutu and Buna Panbuat motifs feature a repeated rhombus pattern arranged symmetrically along the length of the cloth. Weavers from Amanuban emphasize the importance of this repetition for maintaining harmony and balance. One senior weaver described, "*we arrange these patterns so that they reflect harmony—left and right must be the same, like in life, everything must be balanced*." Another weaver added, "*we keep repeating the motif until the length of the cloth is enough. The pattern must be the same, otherwise it is considered damaged*." These explanations reveal that uniformity and symmetry in the motifs are deeply connected to cultural values about perfection and order, where any disruption would symbolize imbalance or imperfection.

Geometrically, each repeated shape in these motifs corresponds to a rhombus—a quadrilateral with four equal sides and opposite angles that are congruent. The rhombus's diagonals intersect perpendicularly, dividing the shape into four congruent right-angled triangles. These consistent geometric properties create symmetrical and balanced forms that visually manifest the cultural values expressed by the weavers. While mathematical analysis helps describe the formal properties of the motifs, it is only one perspective among many for understanding the rich cultural meanings embedded in these traditional textiles. The Tais Kaimnutu and Buna Panbuat motifs both feature a rhombus-based pattern arranged repetitively, as visualized in Figure 2.

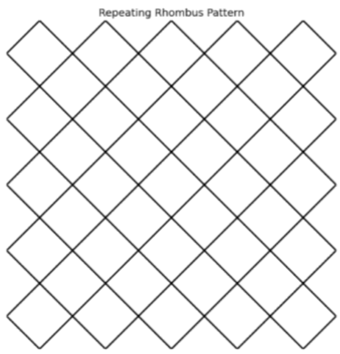
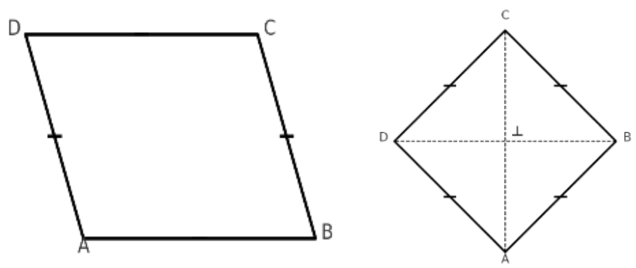


Figure 2. Visualization of the Buna motif

Each rhombus has four sides of equal length and pairs of opposite angles that are congruent. Geometrically, a rhombus can be classified as a special type of parallelogram because it has two pairs of parallel sides, and its diagonals are perpendicular to each other while bisecting one another. In addition to rhombuses, the motif also contains small triangular elements formed by the intersection of the rhombus's diagonals, as shown in Figure 3.



Parallelogram *Rhombus*

Figure 3. A rhombus is a special type of parallelogram

In a rhombus, parallel and intersecting lines play a crucial role in shaping its structure. Parallel lines refer to opposite sides that run alongside each other without ever meeting AB is parallel to CD, and BC is parallel to DA, forming one of the fundamental properties of a parallelogram.

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On the other hand, the intersecting lines in a rhombus are its two diagonals, AC and BD, which always cross at the center at a perfect 90°angle. These diagonals also divide the rhombus into four congruent right-angled triangles. As a result, a rhombus maintains a unique geometric structure, characterized by parallel opposite sides and perpendicular diagonals, creating a shape that is both symmetrical and well-balanced.

For the weavers of Amanuban, such visual balance is not merely a technical concern—it is deeply connected to their cultural understanding of harmony and order. When asked about the consistent use of these patterns, a weaver explained that "*if the shape is broken or off-pattern, it's not only the cloth that is ruined—it feels wrong, like life is out of balance*." This reflects how geometric symmetry, particularly in rhombus-based motifs, becomes a visual expression of local philosophies about balance and continuity in life. In repeating rhombus patterns found in Buna motifs, such as in Figure 1, these geometric properties remain consistent. In terms of reflectional symmetry, a rhombus has two lines of symmetry: one vertical axis that divides the shape into two mirror-image halves and one horizontal axis that also divides it symmetrically as shown in Figure 4.

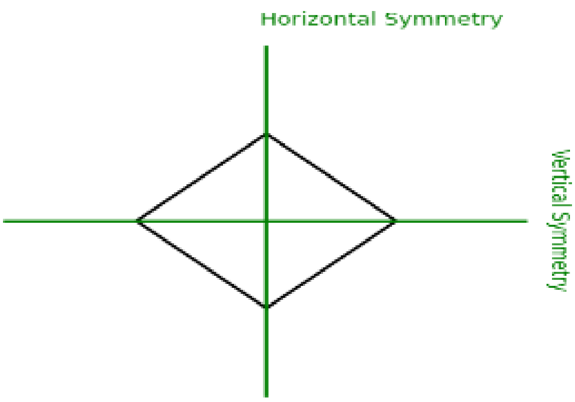

Figure 4. Line symmetry in a rhombus

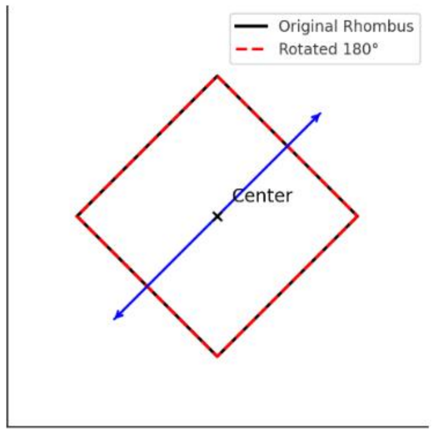

Figure 5. Rotation in a rhombus

In this fabric motif, the rhombus patterns are arranged in a sequence, forming a larger design that also exhibits reflectional symmetry within the overall composition. When the motif is repeated on a larger scale, the boundary lines between rhombuses can create additional symmetry, depending on the regularity of color patterns and their arrangement. Aside from reflectional symmetry, a rhombus also has rotational symmetry of order 2, meaning that if it is rotated 180° about its center, it remains unchanged. This means that each rhombus in the fabric motif will look identical after a half-turn rotation as shown in Figure 5. The rhombuses are arranged in a repeating pattern that creates additional symmetry in the overall fabric design.

The Tais Kaimnutu and Buna Panbuat motif exhibits various types of geometric transformations that can be analyzed in the context of mathematics. The transformations present in this motif include translation, reflection, rotation, and dilation, all of which are systematically applied in the fabric pattern as shown in Figure 6.

Weavers from Amanuban do not use formal mathematical terms, yet they demonstrate a clear intuitive understanding of geometric transformations. During interviews, several weavers explained how they "shift" or "turn" motifs so that the design flows continuously and remains consistent across the cloth. One weaver noted, "*we move the pattern step by step, so it connects properly—it must flow, not break*." This description reflects a working knowledge of translation and rotation, used intentionally to maintain visual continuity and aesthetic integrity

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within the fabric. From a mathematical standpoint, such actions align with the concept of geometric transformations—specifically translation (sliding a shape in a consistent direction) and rotation (turning a shape around a fixed point). In the repetitive structure of Tais Kaimnutu and Buna Panbuat, these transformations help preserve the orientation and spacing of the rhombus motifs across the length of the textile. However, it is essential to understand that these are not merely technical operations; they are embedded in practical weaving knowledge passed down through generations, guided by cultural standards of beauty, order, and spiritual alignment. Thus, the use of geometric transformations by the weavers should be seen not as accidental approximations of mathematical concepts, but as culturally grounded techniques shaped by lived experience and ancestral instruction.

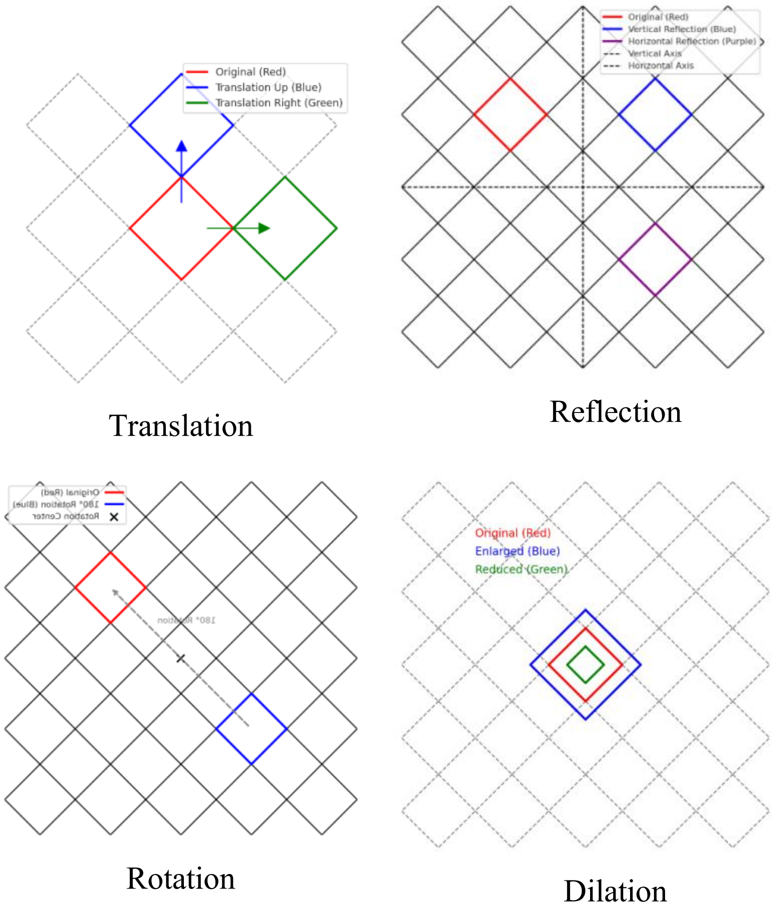

Figure 6. Geometric transformation in Buna motif

Beyond the emphasis on balance and flow, some weavers described their motifs in metaphorical or narrative terms. One elder explained that the repetition of shapes "*tells the story of a journey—of returning again and again to where we came from*." Another likened the rhombus motif to "*the eye of the ancestor, watching from both sides*." These metaphors suggest that motif construction is not merely decorative or functional, but deeply symbolic, embedding cosmological meanings and spiritual surveillance into the fabric itself. While the present study interprets these through a mathematical lens, it is crucial to recognize that for the Amanuban weavers, the act of pattern-making also serves as a medium for storytelling, remembrance, and ancestral dialogue.

Translation occurs in the repeated arrangement of rhombuses, which are shifted both horizontally and vertically. Each rhombus in the motif is a translated version of the previous

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one, maintaining a consistent distance without any change in size or orientation. Reflection is evident in the presence of lines of symmetry, both vertical and horizontal. When the motif is folded along a specific axis, certain shapes perfectly overlap with others, confirming the existence of reflection in the design. Rotation in this motif follows order 2 rotational symmetry, meaning that each rhombus remains identical when rotated 180 degrees about its center. Additionally, in the larger pattern arrangement, rotation occurs at specific central points, creating a pattern that remains consistent throughout the overall design. Dilation is also present in this motif, where the pattern can be enlarged or reduced while preserving its geometric proportions. In the fabric design, scaling changes maintain the arrangement of rhombuses and other elements proportionally, ensuring that this transformation does not alter the fundamental structure of the pattern. Although these transformations may appear to reflect abstract mathematical operations, they are grounded in practical knowledge and cultural discipline. The weavers apply them not from geometric theory, but from embodied experience—what has been observed, practiced, and passed down across generations. Thus, the mathematical structure of these motifs is inseparable from the cultural logic that sustains them.

The Tais Kaimnutu and Buna Panbuat motif features a structured pattern that can be analyzed using the concepts of relations and functions in mathematics. The repeating rhombus arrangement follows a predictable transformation rule, which can be represented as a function mapping coordinates to new positions. If we define the coordinates of a point in the motif as (x, y), the position of each rhombus can be described by the translation function: $f(x, y) = (x + k, y + m)$ where k and m are shift constants in the horizontal and vertical directions. Additionally, when mapped onto a coordinate system, the symmetry properties of the motif can be analyzed using reflection and rotation functions. For example, reflection across the y-axis is given by: $g(x, y) = (-x, y)$ and a 180° rotation is represented by: $h(x, y) = (-x, -y)$ indicating that the motif retains its shape after transformation.

However, it is crucial to contextualize these mathematical interpretations within the lived knowledge of the Amanuban weavers. While these artisans do not employ formal mathematical terminology, their weaving practices exhibit a sophisticated intuitive grasp of spatial transformations. Their understanding of how motifs must align, shift, and repeat is guided not by abstract computation, but by aesthetic coherence and inherited patterning rules. One weaver remarked, "*the pattern must follow the rhythm—if it's broken, it looks wrong, like a song out of tune*." This analogy highlights how the maintenance of geometric consistency is not merely technical, but deeply connected to cultural values of harmony and visual flow. Such embodied knowledge—passed down through generations by observation, correction, and practice—demonstrates how geometric transformations like translation and rotation are integrated into traditional craftsmanship through a culturally rooted, ethnomathematical lens.

Ethnomathematical research in Indonesia has revealed the presence of geometric concepts in various traditional textile arts, particularly in weaving techniques and fabric motifs which can be observed in Buna woven. Studies on weaving traditions in Baduy (Turmudi et al., 2016) and Timor Island (Dominikus et al., 2023) highlight the structured patterns found in both the weaving process and its final products. Meanwhile, research on Yogyakarta Batik (Prahmana & D'Ambrosio, 2020), Kawung Surakarta Batik (Abidin et al., 2023), and Sidomulyo Solo Batik (Uula et al., 2024) explores how geometric transformations such as translation, rotation, and reflection are embedded in their designs. Additionally, the motifs of East Nusa Tenggara woven fabrics (Sumartono, 2022), Uis Karo weaving (Nasution & Maysarah, 2024), and Ulos Ragidup cloth (Basmara & Yahfizham, 2024) demonstrate the systematic use of geometric patterns. These findings emphasize that traditional textiles are not only rich in aesthetic and cultural values but also inherently incorporate fundamental mathematical principles,

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particularly in symmetry, transformations, and repetitive motifs, patterns that are also evident in Buna motifs.

The Tais Kaimnutu and Buna Panbuat motifs exhibit structured and repeating patterns that can be analyzed through the lens of group theory, particularly the dihedral group D_2. This mathematical framework helps describe symmetrical operations such as reflection and 180° rotation, which appear consistently within the rhombus-based arrangements of these motifs. The D_2 group, consisting of four elements—identity (e), 180° rotation (r), vertical reflection (s), and horizontal reflection (t)—encapsulates the fundamental symmetry structure found in these designs (Fraleigh, 2003). However, while group theory offers a powerful tool for understanding symmetry in a formal sense, it is essential to contextualize such analyses within the lived practices and design intentions of the weavers themselves. The Amanuban weavers do not design with explicit reference to dihedral symmetries or mathematical group elements. Instead, their decisions about motif repetition, inversion, and orientation emerge from aesthetic judgments, cultural norms, and inherited weaving protocols. As one weaver explained, "*each part must fit the whole—it should feel balanced, not just look the same*." This perspective highlights how visual harmony and coherence—rather than abstract symmetry—is the driving force behind motif composition. Thus, the identification of D_2 symmetry should be understood as a retrospective mathematical classification rather than a reflection of intentional use by the artisans. It reveals latent mathematical structures that can aid in pedagogical or theoretical exploration but must not be mistaken as equivalent to the cognitive or cultural frameworks used by the weavers themselves. Moreover, applying group theory to cultural artifacts carries methodological limitations. While the D_2 model captures regularities in the motif layout, it may oversimplify or obscure the nuanced, often nonlinear decision-making processes involved in traditional weaving. Such formalizations risk reducing rich cultural expressions into rigid categories, overlooking variations, improvisations, or symbolic meanings embedded in the patterns. Therefore, mathematical modeling must be approached not as a definitive explanation, but as one lens among many—situated within, and respectful of, the broader ethnographic and cultural context. In this sense, the use of group theory in this study serves not to define the intent of the weavers, but to illuminate potential avenues for connecting mathematical education with indigenous knowledge systems, provided that such connections are framed with critical sensitivity to the epistemologies from which these traditions arise.

The connection between these motifs and group theory has been a subject of interest in previous studies. The Buna motif exhibits symmetry patterns associated with the dihedral group, particularly in terms of rotation and reflection that create geometric regularity. Research by Mingka et al. (2023) reveals that the design of the Malay Deli Songket motif is based on the concept of symmetry groups, incorporating operations such as rotation, reflection, and translation to create harmonious and repetitive patterns. Research by Nainoe et al. (2024) also revealed that woven fabric motifs from Timor Tengah Utara Regency follow symmetry patterns consistent with the Frieze group, which involves translation, reflection, and 180° rotation. While the Frieze and dihedral groups have distinct characteristics, both demonstrate the structured patterns found in traditional woven designs. These findings reinforce the idea that traditional woven motifs, including Buna, are not only aesthetically valuable but also inherently incorporate mathematical principles in their structural patterns, aligning with the concept of symmetry groups.

In general, some Buna weaving motifs share the same geometric structure as the Buna Panbuat and Tais Kaimnutu motifs, particularly in the repetitive arrangement of rhombus shapes. Both motifs also exhibit geometric transformations such as translation, reflection, and rotation, which create symmetrical and harmonious patterns. Additionally, both motifs feature repeating

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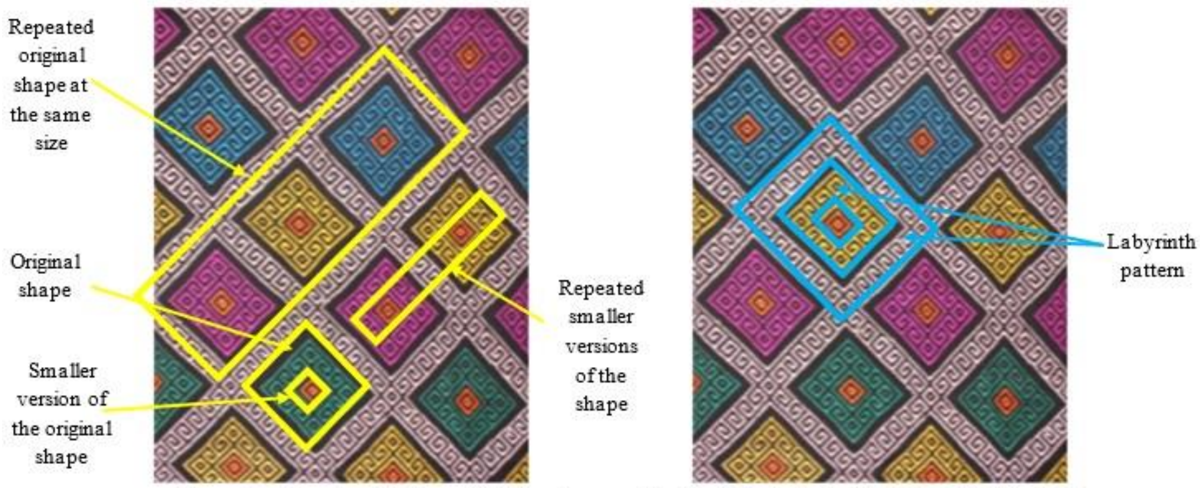
patterns arranged in an orderly manner, resulting in visual balance within the woven fabric. However, the difference lies in the ornamental details within the rhombus. The Tais Kaimnutu motif tends to be simpler, with repetitions of basic shapes, whereas the Buna Panbuat motif displays labyrinthine or small spiral patterns within each rhombus, giving it a more complex and dynamic appearance. This distinction shows that, although both motifs share the same fundamental geometric principles, each has its own unique aesthetic identity.

Fractal geometry, a branch of mathematics that studies shapes exhibiting self-similarity across different scales (Mandelbort, 1983), provides a framework for analyzing patterns within the Tais Kaimnutu and Buna Panbuat motifs. In the Buna Panbuat motif, self-similarity is evident in the repetition and scaling of geometric forms. This motif demonstrates self-similarity through smaller, nested rhombuses that mirror the main rhombus shape, along with the systematic repetition of details such as spirals (Figure 7). This aligns with the fractal concept of consistent patterns across scales. Similarly, the Tais Kaimnutu motif displays larger rhombuses containing smaller ones, illustrating visual recursion (Figure 8). While this repetition does not result from precise mathematical algorithms, it exhibits qualitative fractal characteristics like self-similarity and iteration.



Repeating Rhombus Pattern with Fixed or Changing Sizes　*The Small Labyrinth-Like Spiral Within Each Rhombus Is Systematically Repeated*

Figure 7. Self-Similarity and Iteration in the Buna Panbuat Motif

This complexity can be analyzed using fractal dimension theory, which quantifies the repetition of patterns at different scales. Peitgen et al. (2004) explain that fractal structures, characterized by recursive patterns and geometric repetition, frequently appear in various forms of art, demonstrating how these mathematical properties enhance visual balance and harmony. Research on fractal geometry in Tanimbar woven fabric by Darma & Ngilawajan (2015) reveals that its motifs exhibit self-similarity and repeating patterns, aligning with the principles of fractal geometry. These patterns emerge through the iterative arrangement of design elements in varying sizes, creating a distinctive sense of order within the fabric's structure.

This study also highlights how fractal geometry serves as a valuable mathematical framework for understanding and preserving cultural heritage, such as Tanimbar woven fabric. The presence of fractals in these motifs also supports the idea that traditional motif designers intuitively apply mathematical concepts in their designs. However, it is important to clarify that this interpretation remains exploratory. Unlike canonical fractals—such as the Sierpiński triangle or Koch curve—these weaving motifs do not exhibit mathematically defined recursive algorithms or exact scaling ratios. No fractal dimension has been calculated, nor have

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generation rules been formally derived, limiting the analysis to structural intuition and visual resemblance rather than rigorous quantitative confirmation. Furthermore, the cultural context of motif creation raises critical questions about the origins of these repeating patterns. It remains an open ethnographic inquiry whether these self-similar forms arise from deliberate design choices (inspired by nature or symbols) or emerge primarily through aesthetic preferences, weaving techniques, and practical constraints. One weaver's statement, "*we make it repeat, but not too much. It must feel alive—not stiff*," emphasizes rhythmic variation and organic flow rather than strict mathematical repetition.

Figure 8. Self-Similarity and Iteration in the Tais Kaimnutu Motif

Therefore, while these motifs can be described as fractal-like from a mathematical perspective, this does not imply conscious fractal logic on the part of the artisans. Instead, fractal geometry provides a heuristic framework that connects traditional design with modern mathematical concepts. This perspective has pedagogical potential, enriching discussions on pattern recognition in education. However, such integration requires careful contextualization; fractal geometry here is an analytical tool, not a definitive claim about the weavers' intentions, fostering appreciation for the mathematical beauty in cultural artifacts. We acknowledge the limitations due to the absence of fractal dimension calculations or formal recursive modeling. Future research could employ quantitative methods (e.g., box-counting algorithms) and computational modeling. Deeper ethnographic engagement with weavers is essential to understand their design rationales. An interdisciplinary approach would ground mathematical interpretations in cultural practice, enriching both ethnomathematics and design studies.

Implications for Mathematics Education

This study identifies that the fundamental geometric shapes embedded within the woven motifs include rhombuses and parallelograms, which can be explored in mathematical topics related to plane geometry and transformations. These shapes provide direct applications to the study of relationships and functions, reinforcing students' understanding of how geometric transformations affect coordinate-based representations. Research on traditional textiles in both Ghana and Indonesia highlights the rich mathematical structures found in woven motifs, including symmetry, geometric transformations, fractals, and recursive patterns. Badoe & Opoku-Asare (2014) and Ayesu et al. (2021) examined the geometric structures and cultural significance of Kente cloth, while studies in Indonesia (Prahmana & D'Ambrosio, 2020; Sumartono, 2022; Dominikus et al., 2023; Abidin et al., 2023; Uula et al., 2024; Nasution & Maysarah, 2024; Basmara & Yahfizham, 2024) identified similar mathematical concepts in Batik and woven textiles across the archipelago. These findings have significant implications for mathematics education, particularly in contextualizing learning from elementary to high

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school levels. They provide concrete applications for understanding geometric shapes, transformations, and numerical patterns, making abstract concepts more tangible. Incorporating traditional woven textiles into mathematics instruction also reinforces students' cultural identity and supports a local wisdom-based learning approach aligned with the Indonesian National Curriculum (Kurikulum Merdeka).

This study has significant implications for mathematics education, particularly in promoting a culturally relevant learning approach. The integration of ethnomathematics, as demonstrated in Tais Kaimnutu and Buna Panbuat woven motifs, provides an opportunity to contextualize mathematical concepts within students' daily experiences, making abstract ideas more concrete and meaningful. Since these motifs naturally incorporate mathematical principles such as symmetry, transformations, tessellations, group theory, and fractal geometry, they can serve as effective tools to enhance spatial reasoning and geometric comprehension.

For elementary school students (Grades 4-6 or phase B-C), these motifs can help develop basic spatial visualization and pattern recognition skills. The study of simple shapes, symmetry, and repeated patterns in woven motifs aligns with elementary mathematics topics such as plane geometry, fractions, and measurement (Badan Standar, Kurikulum, dan Asesmen Pendidikan Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2024). Younger students can engage in hands-on activities, such as drawing symmetrical patterns and creating tessellations using manipulatives, to reinforce foundational mathematical concepts interactively. Additionally, students can explore reflectional and rotational symmetries using physical models of woven motifs, deepening their understanding of transformation geometry. In middle school (Grades 7-9 or phase D), these symmetrical patterns can aid in comprehending reflection, rotation, and translation more intuitively. These topics align with Indonesia's geometry curriculum, particularly in symmetry, congruence, and transformations. Similarly, the fractal-like structures in Buna Panbuat motifs introduce students to scaling and recursive patterns, which are fundamental in understanding geometric sequences and series.

At the high school level (phase E and F), these concepts are incorporated into lessons on geometric progressions and transformations (Badan Standar, Kurikulum, dan Asesmen Pendidikan Kementerian Pendidikan, Kebudayaan, Riset, dan Teknologi, 2024). At the university level, particularly in mathematics education programs, ethnomathematics can be further explored through advanced mathematical modeling, symmetry groups, fractal geometry, and topology. Future mathematics educators can study the pedagogical implications of integrating cultural artifacts like woven textiles into their teaching, designing lesson plans and instructional strategies that align with the Indonesian National Curriculum (Kurikulum Merdeka). The interdisciplinary nature of ethnomathematics also enables cross-subject collaboration, allowing students to explore the historical significance of woven motifs while applying mathematical analysis. This supports the broader objectives of Science, Technology, Engineering, Arts, and Mathematics (STEAM) education, which emphasizes holistic learning experiences. Integrating these motifs into mathematics curricula also supports a constructivist learning approach, where students actively engage in problem-solving by analyzing, replicating, and creating their own patterns. Hands-on activities like creating woven-inspired tessellations using digital tools or sketching symmetrical patterns can help students develop a deeper understanding of mathematical concepts. This supports Orey & Rosa (2010) research, which emphasizes that working directly with cultural artifacts enhances student motivation and strengthens their grasp of mathematical ideas.

While mathematical modeling offers useful tools for identifying symmetry, transformations, and fractal structures, it must be applied with caution. The risk of reductionism—whereby rich

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cultural expressions are distilled into abstract formulas—remains significant. By privileging formal structures, researchers may inadvertently marginalize the very worldviews and epistemologies they seek to honor. Ethnomathematical inquiry, therefore, requires a reflexive stance—one that recognizes mathematics not as a neutral lens but as a culturally situated framework that must be dialogued with, rather than imposed upon, Indigenous knowledge. Acknowledging this, the study refrains from framing the Buna motifs as "examples" of Western mathematics, and instead treats mathematics as one possible language among many for engaging with cultural meaning.

Beyond the classroom, the recognition of mathematical knowledge embedded in traditional crafts holds broader social significance. It affirms the intellectual contributions of indigenous communities, strengthens cultural preservation, and empowers weavers as bearers of knowledge. By bridging academic research with community heritage, mathematics education can become a vehicle for cultural revitalization and intergenerational transmission of knowledge. Involving community members in interpreting and teaching the mathematical aspects of their crafts fosters mutual learning and may surface alternative, non-Western epistemologies that enrich the discipline. Thus, integrating the motifs of Tais Kaimnutu and Buna Panbuat into mathematics education is not merely a pedagogical choice but a meaningful step toward transforming education into a culturally sustaining practice. Future research should further explore how local communities perceive and participate in the mathematization of their traditional knowledge, and how these insights can inform curriculum development at both local and national levels. By doing so, ethnomathematics can move from observation to contribution—serving as a bridge between academic inquiry, educational practice, and community empowerment.

Conclusion

This study reveals that the woven fabric motifs of Buna from the Amanuban community not only contain mathematical concepts such as symmetry, geometric transformations, fractals, and group theory, but also represent cultural values, identity, and spirituality passed down through generations. The geometric structures and repeating patterns are part of an artistic and cosmological expression intuitively understood by the weavers, without the need to formally articulate mathematical concepts. The mathematical interpretation of the motifs is seen as a new form of cultural appreciation, as long as it respects the local context and meanings.

These findings have significant educational implications. At the elementary level, motifs can introduce symmetry, patterns, and spatial visualization. In middle school, they deepen their understanding of transformation geometry and congruence. High school students can explore fractal structures in Buna Panbuat motifs for insights into scaling and recursive patterns, while the symmetry in Tais Kaimnutu provides a foundation for dihedral groups and algebraic structures. At the university level, future educators can integrate ethnomathematics into mathematical modeling, topology, and symmetry groups, fostering culturally responsive teaching. This interdisciplinary approach supports STEAM education by connecting mathematics with cultural heritage and artistic expression.

Beyond pedagogy, this research invites reflection on the broader social and cultural significance of integrating indigenous knowledge systems into formal education. Recognizing the mathematical richness of traditional woven motifs affirms the intellectual heritage of the Amanuban people and supports the validation of local epistemologies within national curricula such as the Kurikulum Merdeka. Embedding ethnomathematics into the curriculum fosters inclusive, place-based learning while strengthening students' cultural identities and encouraging community involvement. It also opens a pathway for community empowerment,

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as local artisans and elders can participate in co-creating educational content, contributing their expertise to formal schooling. Therefore, this study not only contributes to the field of mathematics education but also highlights the transformative potential of ethnomathematics as a bridge between academic inquiry, cultural preservation, and community development. Future research should focus on participatory curriculum development, exploring how mathematical interpretations of indigenous crafts are perceived by the communities themselves, and how these perspectives can enrich both educational practices and cultural sustainability.

ORCID

Farida Daniel https://orcid.org/0000-0002-7584-9004

Turmudi https://orcid.org/0000-0001-7976-211X

Dadang Juandi https://orcid.org/0000-0001-6997-1399

Kusnandi https://orcid.org/0000-0002-8900-4563

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