

Geometric Structures in Sipirok Weaving Motifs as an Ethnomathematics-Based Context for Mathematics Learning

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ABSTRACT

Ethnomathematical studies of traditional Sipirok weaving, particularly the geometric structure underlying motif construction, remain limited. This study aims to explore geometric representations and the structural arrangement of two-dimensional figures in traditional Sipirok weaving motifs from an ethnomathematical perspective. A qualitative ethnographic design was employed in Sipirok District, South Tapanuli Regency. Data were collected through observation, semi-structured interviews, and documentation, validated through methodological and source triangulation, and analyzed using an interactive analysis model. The findings show that Sipirok weaving motifs represent squares, rectangles, parallelograms, rhombi, and triangles organized through repetition, parallelism, proportion, and symmetry. Several motifs also exhibit translation and reflection as forms of geometric transformation. These findings indicate that Sipirok weaving embodies geometric knowledge developed through community cultural practices and has the potential to serve as an authentic context for geometry learning while supporting awareness of local culture.



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INTRODUCTION

Mathematics functions not only as a system of formal symbols and procedures but also as a means of recognizing regularities, relationships, forms, and patterns encountered in everyday life. When instruction places excessive emphasis on abstraction without connecting mathematical ideas to students' experiences, those ideas may appear detached from reality. Cultural contexts therefore provide a relevant resource for creating more meaningful and contextualized learning experiences (Abdullah, 2017).

Ethnomathematics provides a framework for understanding this relationship. D'Ambrosio (1985) conceptualized ethnomathematics as the study of how cultural groups develop, use, and interpret mathematical ideas in their everyday practices. In educational settings, ethnomathematics is not limited to identifying mathematical forms in cultural artifacts; it also examines the activities, patterns, measurements, repetitions, and strategies through which communities produce cultural works. Research on Sundanese culture, for example, has identified estimating, measuring, and pattern-making activities that can be understood as mathematical practices (Muhtadi, D., Sukirwan, Warsito, & Prahmana, 2017).

Indonesia's cultural diversity offers a wide range of contexts for such inquiry. Batik, woven textiles, songket, traditional houses, and other cultural artifacts have been examined to reveal concepts of geometry, pattern, measurement, and transformation. Research on Yogyakarta batik has demonstrated connections between cultural patterns and geometry learning (Prahmana, R. C. I., & D'Ambrosio, 2020), while studies of Sukarara woven cloth, Patola Ratu textiles from East Sumba, and Palembang songket have shown that motif structures may contain two-dimensional geometric figures, repetitive patterns, and geometric transformations (Luda, H. A., & Nuhamara, 2026).

One cultural artifact with strong potential for further study is traditional Sipirok weaving from South Tapanuli Regency, North Sumatra. This textile tradition developed within the cultural environment of the Angkola community and is characterized by visually distinctive motif arrangements. The observed motifs contain regularly organized units resembling squares, rectangles, parallelograms, rhombi, and triangles. The Sipirok cultural context has previously been examined through an

ethnomathematical study of Sopo Godang, which showed that local cultural elements can be used to interpret concepts related to two-dimensional geometric figures (Siregar, 2025). However, Sipirok woven textiles themselves still require more focused investigation.

Previous studies of traditional textiles have generally demonstrated the presence of mathematical concepts in motifs, although their cultural settings and objects of analysis differ. Risdiyanti and Prahmana (2018) showed that Javanese cultural activities can be analyzed from an ethnomathematical perspective, while studies of Sukarara weaving and Palembang songket emphasized the identification of geometric concepts and their implications for learning (Musodiqoh, U. A., & Kusno, 2025). These findings indicate that analysis should move beyond simply recognizing shapes to examining how geometric units are organized into patterns.

The research gap addressed in this study concerns the limited number of studies that specifically analyze the relationship between representations of two-dimensional geometric figures and the structural organization of motifs in traditional Sipirok weaving. The novelty of the study lies in a two-level analysis: first, identifying the geometric forms visible in the motifs; and second, explaining how those forms are organized through repetition, parallelism, proportion, symmetry, and observable transformations. Accordingly, the contribution of this study extends beyond cataloguing types of geometric figures to mapping pattern structures as manifestations of mathematical knowledge embedded in cultural practice.

Based on this gap, the study aims to explore geometric representations and analyze the structural arrangement of two-dimensional figures in traditional Sipirok weaving patterns from an ethnomathematical perspective. Theoretically, the study is expected to enrich ethnomathematical scholarship on Indonesian traditional textiles. Pedagogically, the findings may provide a foundation for developing geometry-learning contexts that connect concepts of two-dimensional figures, patterns, symmetry, and transformation with students' local culture.

RESEARCH METHOD

This study employed a qualitative method with an ethnographic approach because its focus was on mathematical concepts embedded in cultural artifacts and community practices. The research was conducted in Sipirok District, South Tapanuli Regency, North Sumatra. This approach enabled the weaving motifs to be interpreted not merely as visual forms but as part of the cultural knowledge developed through weaving practices.

The research participants included Sipirok weavers and community figures who understood the history, production process, and cultural contexts in which the textiles are used. The research objects were motifs found in traditional Sipirok woven cloth that displayed geometric representations. The study focused on two-dimensional geometric figures and the structural organization of those figures in the documented motifs.

Data were collected through observation, semi-structured interviews, and documentation. Observation was used to identify the shapes, directions, positions, repetitions, and relationships among motif elements. Interviews provided supporting information regarding the production process and cultural context of the weaving, while photographs and field notes were used to strengthen the visual identification of motifs. The use of multiple data-collection techniques enabled the information obtained from different sources to be cross-checked (Sugiyono, 2023).

The researcher served as the primary research instrument, supported by observation and interview guides, a camera, an audio recorder, and an ethnomathematical concept-identification sheet. Data trustworthiness was maintained through methodological triangulation by comparing observation, interview, and documentation data, as well as source triangulation by comparing information obtained from different participants (Sugiyono, 2023).

Data were analyzed using the interactive model of Miles et al. (2014), which comprises data condensation or reduction, data display, and conclusion drawing. During data reduction, information was selected according to its relevance to geometric representations and pattern structures. The data were then grouped into categories of two-dimensional figures, repetition, parallelism, proportion, symmetry, and observable transformations. The findings were presented through analytical descriptions, motif images, and a synthesis table so that the relationship between geometric form and pattern structure could be interpreted systematically.

Conclusions were drawn by interpreting the relationship between the visual characteristics of the motifs and geometric concepts and then comparing these interpretations with findings from previous ethnomathematical studies. The analysis did not make claims about numerical patterns because the documented evidence was stronger with respect to two-dimensional geometric representations, pattern regularity, and geometric transformations. Within this limitation, the interpretation of the findings remained grounded in the documented motif data.

RESULTS AND DISCUSSION

Observation and documentation revealed five dominant representations of two-dimensional geometric figures in traditional Sipirok weaving motifs: squares, rectangles, parallelograms, rhombi, and triangles. The analysis addressed not only visual resemblance to these figures but also the manner in which each geometric unit was organized. The observed patterns exhibited repetition, parallelism, changes in direction, proportion, and symmetry. These structures indicate that geometric elements function as organizers of visual regularity within the woven motifs rather than as isolated forms.

Square

Square representations appear in motif units with four relatively equal sides that are repeated across particular sections of the textile. Visually, these units are positioned at relatively regular intervals, forming horizontal and vertical sequences. The important finding is not merely the presence of square forms, but the use of a single geometric unit as the basis for constructing a broader pattern.

The repetition of square units intuitively illustrates the concept of translation: the size and orientation of a form are preserved while the form is repositioned elsewhere. The pattern also displays parallelism and visual symmetry. These characteristics are consistent with the findings of Muhtadi et al. (2017) regarding pattern-making activities in Sundanese culture and with Risdiyanti and Prahmana (2018), who showed that regularity in cultural artifacts can be interpreted as a form of mathematical activity.

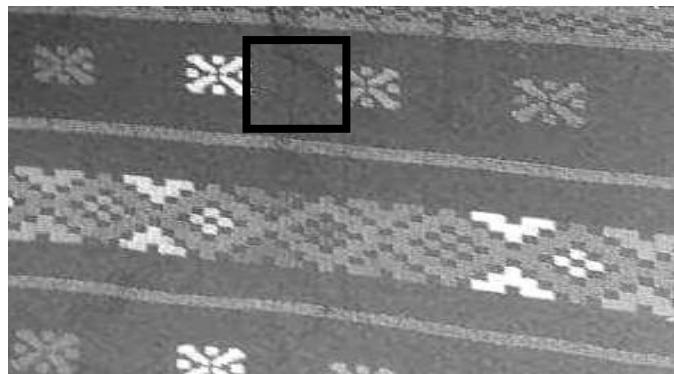


Figure 1. Square Motif

From an ethnomathematical perspective, this regularity indicates practical knowledge of position, spacing, and consistency of form. Weavers do not necessarily need to use the formal terms translation or symmetry to produce patterns that exhibit these characteristics. This distinction illustrates the difference between the formal language of school mathematics and the mathematical knowledge enacted through cultural practice.

For instructional purposes, the square motif can be used for more than simply identifying the properties of a geometric figure. Students may be asked to determine the basic unit of the motif, explain its repetition rule, predict the position of the next unit, and reconstruct the pattern through translation. Such activities position the cultural artifact as a context for developing geometric reasoning rather than merely as a decorative illustration (Fouze, A. Q., & Amit, 2018).

The findings concerning the square motif show that the mathematical value of Sipirok weaving extends beyond the presence of four-sided figures to the rules governing their placement. The same unit retains its size and orientation and is then repeated at relatively consistent intervals, producing a visual rhythm. This pattern demonstrates the relationship between a basic geometric form and the spatial relations among elements. Prahmana and D'Ambrosio (2020) showed that cultural patterns can be used to examine both geometric concepts and transformations, while Septiana et al. (2023) identified

repetition and transformation in Sukarara weaving motifs. In the Sipirok context, the square motif reinforces these findings by highlighting the relationship among regularity of form, spacing, and orientation. Thus, ethnomathematics in motif analysis should not be reduced to matching visual images with school geometry; rather, it should involve interpreting how geometric patterns are systematically constructed (Abdullah, 2017).

Rectangle

Rectangular representations appear in thread arrangements that form elongated fields and in sections that function as frames or boundaries between motifs. This feature indicates that rectangles perform a structural role in the woven composition: their elongated form helps organize visual space and separate motif units so that the overall arrangement remains orderly.

These forms reveal relationships among length, width, parallelism, and proportion. Weavers must maintain appropriate size ratios and spacing so that the elongated fields do not disrupt the balance of the overall composition. The concepts represented therefore extend beyond the defining properties of rectangles to include measurement and proportion. Emphasizing these relationships is important because students' understanding of two-dimensional figures can be problematic when it relies only on memorized properties without exposure to varied visual representations (Rahayu, N. S., & Afriansyah, 2021).

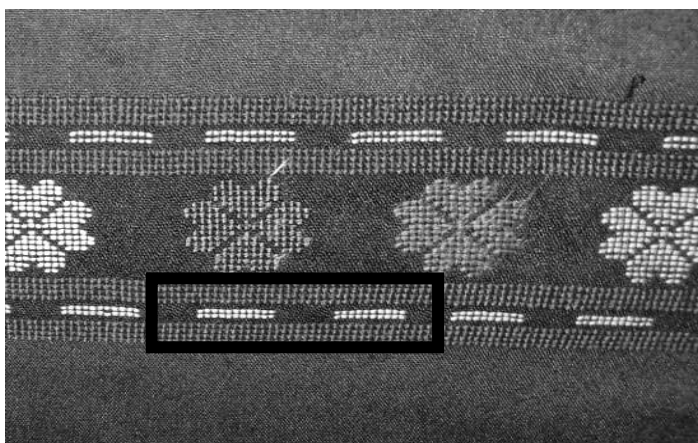


Figure 2. Rectangle Motif

Repeated and parallel rectangular arrangements demonstrate the presence of consistent visual rules. Within the motifs, elongated forms serve to bind the composition together, while parallel lines establish visual rhythm. This finding supports the view that cultural practices can integrate concepts of measurement and form rather than presenting them as separate mathematical topics.

In classroom learning, this context can be developed into tasks such as estimating length-to-width ratios, comparing several rectangular fields, or redesigning motif boundaries using specified dimensions. These activities connect the properties of two-dimensional figures with measurement and proportion, thereby engaging students with more authentic geometric problems.

Rectangles in the motifs also perform a spatial-organizing function because elongated forms are used as frames or boundaries between elements. This indicates that the concepts of length and width are related to proportion and position, rather than only to formulas for area and perimeter. Muhtadi et al. (2017) found that estimating, measuring, and pattern-making are integral to mathematical practices in cultural settings. Sipirok weaving exhibits a similar tendency because the relative dimensions of a field must be maintained for the motif composition to remain regular. Pedagogically, this context can be used to invite students to compare length-to-width ratios and explain how changes in dimensions affect the pattern. Such an approach is relevant to reducing understandings of quadrilaterals that rely solely on visual prototypes and memorized properties, both of which may contribute to misconceptions (Rahayu, N. S., & Afriansyah, 2021).

Parallelogram

A parallelogram is identified by two pairs of opposite parallel sides and an oblique orientation. In Sipirok motifs, this form is repeated to create a diagonal visual effect. The direction of inclination is important because even small changes in orientation or spacing can affect the continuity of the pattern.

Mathematically, this arrangement illustrates the relationship among parallelism, inclination, and translation. The parallelogram unit retains its form and is shifted in a particular direction and by a particular distance. A similar pattern was identified in research on Palembang songket, which showed that textile motifs can incorporate two-dimensional figures together with systematic structures of repetition (Musodiqoh, U. A., & Kusno, 2025).

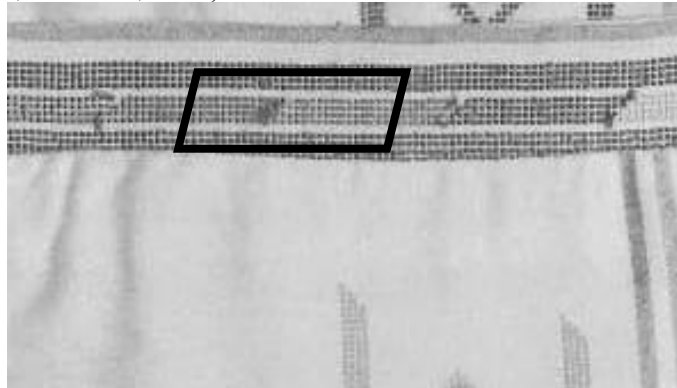


Figure 3. Parallelogram Motif

This finding shows that ethnomathematical analysis needs to consider relationships among geometric forms. A parallelogram at a single location does not by itself explain the pattern; its mathematical significance becomes clearer when the direction and spacing of its repetition are analyzed. In this way, a motif can be interpreted as a rule-governed geometric configuration.

For learning purposes, the parallelogram motif can be used to examine parallel sides, angles, base-height relationships, area, and translation within a single context. Students can compare an original form with its translated image to understand that translation changes position without changing the size or orientation of the figure.

Parallelograms in Sipirok weaving also demonstrate invariance of form when position and orientation change. The motif unit remains recognizable even when it is placed diagonally and repeated in different locations. This analysis extends discussion beyond the presence of two pairs of parallel sides to the relationship among form, direction, and displacement. Musodiqoh and Kusno (2025), in their study of Palembang songket, and Luda and Nuhamara (2026), in their study of East Sumba ikat weaving, both showed that traditional textiles contain geometric forms and patterns that can be interpreted through transformation. The Sipirok findings reinforce this tendency by showing that diagonal orientation contributes to visual continuity among motif elements. In learning, this feature can be used to assess students' understanding that changes in position do not alter the fundamental properties of a figure while simultaneously connecting quadrilateral geometry with the concept of translation.

Rhombus

The rhombus is one of the most prominent forms in Sipirok weaving motifs. Diamond-shaped units with four relatively equal sides appear repeatedly with consistent orientation. Their balanced placement produces a visually strong pattern and provides one of the clearest examples of geometric regularity in the textile.

The structure of the rhombus displays reflectional and rotational symmetry within each unit, while its repetition indicates translation across the motif arrangement. A single motif can therefore be used to address several geometric concepts simultaneously. This finding is consistent with Puspitarani (2025), who demonstrated the potential of cultural contexts for teaching the area of a rhombus, and with (Septiana, et, al. 2023), who identified relationships between woven textiles and concepts of geometry and transformation.

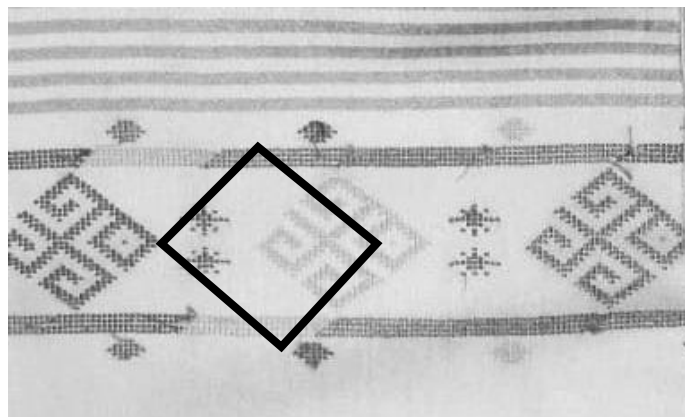


Figure 4. Rhombus Motif

From an ethnomathematical perspective, regularity in size, direction, and position indicates that motif construction requires spatial consistency. This knowledge is embedded in pattern-making practice and does not need to be expressed through formal definitions. This is a central feature of ethnomathematics: school mathematics can be used to interpret the structure of cultural practices without disregarding the cultural contexts from which those practices emerge.

For learning purposes, the rhombus motif enables students to identify axes of symmetry, determine the results of rotations, calculate area and perimeter, and extend a pattern. Such activities move learning beyond shape recognition toward analysis of geometric relationships and transformations.

In the rhombus motif, symmetry and translation can be observed at different levels. Symmetry occurs within the individual figure, whereas translation becomes visible when the unit is repeated in a larger composition. This distinction is important because a single motif may embody several mathematical ideas simultaneously. (Az-Zahra, et, al, 2024), showed that traditional textiles can serve as learning resources for geometry and patterns, while (Puspitarani, 2025), emphasized the integration of cultural contexts in learning the area of a rhombus. The present findings support both directions but further emphasize the importance of interpreting transformational relationships among forms. Accordingly, the use of motifs should not stop at calculating area; it can also involve identifying axes of symmetry, determining the outcomes of rotations, and explaining repetition rules so that the cultural context functions as a source of mathematical reasoning (Fouze, A. Q., & Amit, 2018) .

Triangle

Triangular representations appear as three-sided units resembling arrowheads or pointed forms. These units do not stand alone; instead, they are arranged in sequences, positioned face-to-face, or oriented in different directions. Variations in orientation therefore provide important information about the structure of the pattern.

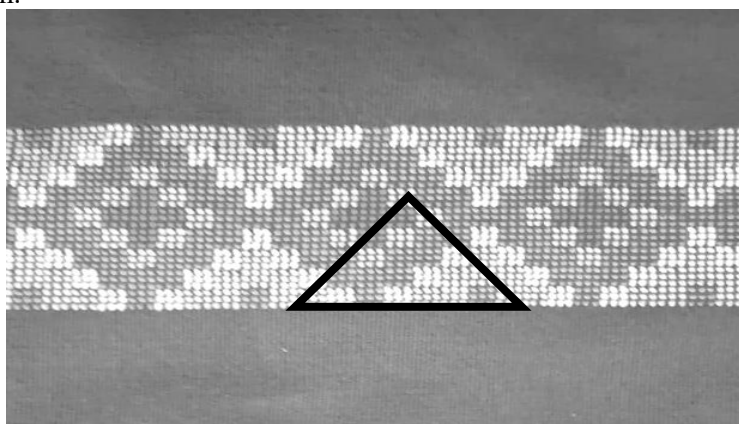


Figure 5. Triangle Motif

The repetition of triangular units indicates translation when the same form is shifted while retaining its orientation, whereas face-to-face arrangements display characteristics of reflection. These

patterns demonstrate that geometric transformations can be visually manifested through changes in the position and direction of a form. This result is consistent with studies of Sukarara woven cloth and Patola Ratu textiles from East Sumba, which also identified geometric regularity and transformational potential within motif structures (Luda, H. A., & Nuhamara, 2026).

The learning implications of triangular motifs can be developed through tasks involving triangle classification, orientation analysis, reflection, and pattern construction. Students can be asked to determine the transformation that relates one unit to the next. In this way, local culture becomes a source of geometric problems that require reasoning rather than merely a visual example.

The arrangement of triangles emphasizes that orientation is mathematical information that is as important as form. Two units may have similar geometric characteristics yet produce different pattern relationships when one is reflected or oriented in the opposite direction. Septiana et al. (2023) likewise identified implications of geometric transformation in Sukarara weaving motifs, suggesting that transformation is a recurring structural feature across different traditional textiles. In Sipirok weaving, the combination of sequential repetition and face-to-face arrangements makes it possible to distinguish translation from reflection through changes in position and orientation. This finding also extends local ethnomathematical research that previously identified geometric potential in Sipirok traditional houses (Siregar, 2025). Nevertheless, the present study limits interpretation to observable geometric structures and does not assign symbolic meanings to motifs that are unsupported by specific data.

Table 1. Mapping of Geometric Representations and Pattern Structures in Sipirok Weaving Motifs

Representation	Arrangement structure	Mathematical concepts	Learning potential
Square	Repeated horizontally and vertically	Parallelism, symmetry, translation	Shape properties, patterns, translation
Rectangle	Elongated fields used as frames/boundaries	Length-width relationships, proportion, parallelism	Measurement, ratio, area
Parallelogram	Repeated with diagonal orientation	Parallelism, inclination, translation	Angles, area, translation
Rhombus	Repeated with consistent orientation	Reflectional/rotational symmetry, translation	Symmetry, rotation, area
Triangle	Sequential, face-to-face, with varied orientations	Translation, reflection, orientation	Classification, reflection, patterns

Table 1 shows that the principal characteristic of Sipirok weaving motifs lies in the relationship between basic geometric forms and the rules governing their arrangement. Squares, rectangles, parallelograms, rhombi, and triangles function as geometric units, while repetition, parallelism, proportion, symmetry, translation, and reflection constitute the pattern structure. This finding reinforces ethnomathematical research in Indonesia showing that cultural activities involve mathematically structured ways of organizing form, size, and pattern (Muhtadi, D., Sukirwan, Warsito, & Prahmana, 2017).

The specific contribution of this study lies in its two-level interpretation of Sipirok weaving. First, the motifs are mapped according to their visible geometric forms. Second, the analysis extends to relationships among units so that a motif is understood as a structure rather than as a collection of separate forms. This approach clarifies that the mathematical value of weaving lies not only in the resemblance of motif elements to school-geometry objects, but also in the rules by which those forms are organized to produce visual regularity.

From a pedagogical perspective, the findings support the use of Sipirok weaving as an authentic context for geometry learning. Teachers can develop activities involving identification of basic motif units, pattern reconstruction, estimation of proportions, identification of axes of symmetry, and determination of translations and reflections. This approach is consistent with ethnomathematics-based learning, which connects formal knowledge with students' cultural experiences (Abdullah, 2017; Fouze & Amit, 2018). However, this study focuses on visual representations and the structural organization of motifs; the philosophical meanings of individual motifs have not yet been examined in depth. Future research may integrate richer ethnographic data concerning local terminology, motif meanings, and processes through which weaving knowledge is transmitted.

Synthesis of Findings and Learning Implications

When the five geometric forms are analyzed collectively, the principal finding is not simply the presence of squares, rectangles, parallelograms, rhombi, and triangles, but the relationships that organize them. Repetition is the most consistent characteristic, followed by parallelism, symmetry, changes in orientation, and the regulation of spacing. The mathematical structure of Sipirok weaving can therefore be interpreted at two levels: the representation of geometric objects and the rules connecting one object to another. The second level reveals pattern regularity more comprehensively and constitutes an important distinction between merely identifying shapes and conducting ethnomathematical analysis. This perspective is consistent with Prahmana and D'Ambrosio (2020), who showed that cultural patterns provide a context for learning geometry through the regularity and transformation of motif elements.

Comparatively, the findings are consistent with studies of Sukarara weaving (Septiana et al., 2023), Palembang songket (Musodiqoh & Kusno, 2025), and East Sumba ikat weaving (Luda & Nuhamara, 2026), particularly regarding the presence of geometric forms, repetitive patterns, and transformations. The distinction of the present study lies in its focus on the Sipirok cultural artifact and in an analytical approach that connects representations of two-dimensional figures with the structures by which they are arranged. The findings are not intended to claim that particular geometric forms are unique to Sipirok, but rather to demonstrate the geometric configurations present within the Sipirok cultural context. This positioning is important because the study's novelty lies in its object, analytical focus, and educational contribution rather than in claims of exclusivity for forms that also occur in other cultures.

From an ethnomathematical perspective, these results strengthen the view that mathematical ideas can be identified in cultural practices without being expressed through the formal symbols and terminology of school mathematics. D'Ambrosio (1985) described ethnomathematics as the study of how cultural groups develop and use mathematical ideas, while Abdullah (2017) and Muhtadi et al. (2017) demonstrated activities of measuring, estimating, and pattern-making within cultural practices. In this study, the terms translation, reflection, symmetry, proportion, and parallelism are used as academic analytical tools for explaining motif structures. The study does not assume that weavers describe these processes using the same terminology; rather, it identifies structural correspondences between motif-making practices and geometric concepts taught in school.

The pedagogical implication is that learning can be designed to progress from observing motifs to identifying basic units, determining geometric properties, analyzing repetition rules, and reconstructing patterns through transformation. Such a sequence enables students to move from visual experience to formal representation and encourages them to explain their reasoning rather than merely name geometric figures. This approach is consistent with Fouze and Amit (2018), who emphasized the potential of ethnomathematics to develop mathematical thinking. However, the learning potential proposed in this study remains conceptual because it has not yet been tested through classroom implementation. Future studies should develop instructional materials based on Sipirok motifs and examine their validity, practicality, and effects on students' understanding of geometry, while also deepening ethnographic data on weaving processes and the cultural meanings of motifs.

The novelty of this study should therefore be positioned proportionately. The study does not propose entirely new geometric forms, as squares, rectangles, parallelograms, rhombi, and triangles are also found in other cultural artifacts. Its contribution lies in mapping these forms within Sipirok weaving, explaining relationships among elements through repetition and transformation, and linking these structures to opportunities for contextual geometry learning. This position distinguishes the study from research that merely inventories forms without analyzing how they are structurally organized. Risdiyanti, I., & Prahmana, 2018 showed that ethnomathematical exploration becomes more meaningful when cultural practices are interpreted as mathematical activities, while Prahmana, and D'Ambrosio, 2020, demonstrated that cultural patterns can connect geometry with social context. Accordingly, the focus on pattern structure is an important element that strengthens the study's argument for novelty.

CONCLUSION

The findings indicate that traditional Sipirok weaving motifs represent a range of ethnomathematical concepts, particularly in geometry. The identified geometric forms include squares,

rectangles, parallelograms, rhombi, and triangles. These forms do not occur as isolated decorative elements; rather, they are organized through patterns of repetition, parallelism, proportion, and symmetry to create regular visual structures. Several motifs also show indications of geometric transformation through translation and reflection. These findings suggest that Sipirok weaving practices embody geometric knowledge developed through experience, skill, and cultural practices transmitted across generations. Sipirok weaving can therefore be understood not only as a cultural product and aesthetic work, but also as a representation of mathematical knowledge that remains active within the community. From an educational perspective, the motifs have the potential to provide an authentic context for mathematics learning, particularly for two-dimensional figures, patterns, symmetry, measurement, and geometric transformation. The use of local cultural artifacts in instruction can help connect abstract mathematical concepts with students' lived experiences. In addition to supporting contextual learning, the use of Sipirok weaving as a learning resource may strengthen recognition, appreciation, and preservation of Angkola local culture. The contribution of this study therefore lies not only in identifying geometric forms, but also in revealing the structural organization of motifs as an ethnomathematical practice that can be developed for culturally responsive learning. The findings concerning squares, rectangles, parallelograms, rhombi, triangles, and the structures of repetition and symmetry are also consistent with the results presented in the discussion section.

Mathematics teachers are encouraged to develop Sipirok weaving motifs as resources or contexts for geometry learning through activities involving shape identification, pattern analysis, measurement, symmetry, and geometric transformation that are appropriate to students' developmental levels. Such applications may be further developed as student worksheets, instructional modules, visual media, or project-based activities so that local cultural elements are not used merely as illustrations but are meaningfully integrated into mathematics instruction. Future research should investigate the cultural meanings of individual motifs, the mathematical processes involved in weaving, and the relationships between motif structures and other mathematical concepts in greater depth. Subsequent studies should also test the direct implementation of Sipirok weaving in classroom learning to determine its effects on conceptual understanding, geometric thinking, learning motivation, and students' appreciation of local culture. In addition, more systematic documentation of motifs and weavers' knowledge is needed to support the long-term preservation of Sipirok cultural knowledge.

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