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Exploring Geometry and Symmetry Concepts in Traditional Handicrafts of The Dusun Ethnic Group in Kiulu, Tamparuli, Sabah: An Ethnomathematical Approach

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Abstract

Mathematics and culture are interrelated things in human life. Culture is a way of life that develops and is shared within a community. Meanwhile, mathematics is the knowledge humans use to solve everyday problems. The use of technology in community life aligns with the development of cultural skills or environmental activities, symbolizing the advancement of mathematical skills within that society. The traditional handcraft is a heritage time immemorial, especially among the Dusun ethnic group in Kiulu, Tamparuli Sabah, as they used it in their daily activities, especially during the harvest seasons. This paper presents the appropriate geometric and symmetry concepts applied in the traditional handicraft products of the Dusun Kiulu community. This study employed a qualitative ethnographic approach using interviews, participatory observation, video recording, and documentation from the fieldwork to explore geometric and symmetry concepts in Dusun traditional handicrafts. The results showed that geometric concepts such as lines and angles, circles, transformations, and curved side geometry applied to the traditional handicrafts products, such as "Barait", "Sirung" and "Nurod" basket of the Dusun Kiulu community.

Keywords: ethnomathematics; cultural; Dusun Kiulu; handicraft; geometry.

1 Introduction

Ethnomathematics studies the cultural aspects of mathematics that receive considerable attention from many researchers to improve understanding a mathematical concept in everyday life. Despite the rich cultural tradition of the Dusun community, there is limited academic research and documentation on how their traditional craftsmanship reflects the mathematical principle. d'Ambrosio [3], describes ethnomathematics as the mathematical practices of particular cultural groups, as well as the investigation of mathematical concepts found across different cultures. Moreover, d'Ambrosio [4] also stated that there were many ways to understand mathematical knowledge developed by other sectors of society and by considering different modes in which different cultures negotiate their mathematical practices. In addition, Torres-Velasquez et al. [23] stated that to study mathematics naturally by connecting mathematical context to culture and experience. Meanwhile, Orey and Rosa [14] define ethnos as members of a group in a cultural environment identified by their cultural traditions, codes, symbols, myths, and any means that can be understood as reasons and taken as conclusions. Apart from this, they also [18] stated that ethnomathematics presents mathematical concepts related to cultural experiences and applicable connecting abilities that improve human understanding of Mathemtics.

Besides that, Albanese and Parales [2]obtained the ethnomathematics aims to give learners and researchers deeper insights into the concepts and relationships between mathematics and culture. Juandi et al. [10] observed that weaving cloth in the Baduy community of Banten Province applied mathematics. However, they never received a proper education from schools. Rubio [19] examined the ethnomathematics of the Kabihug Tribe in the Philippines and demonstrated how cultural artefacts reflect mathematical concepts. Hariastuti et al. [8] also found that the house of Using Banyuwangi construction shows mathematics concepts, especially geometry two dimensions Pythagoras, and similarity. Furthermore, Long and Chik [12] strongly agreed that there is a line relationship among mathematics, agriculture and cultural heritage in everyday life of the Melanau and Tellian ethnic groups in Mukah, Sarawak. Moreover, Umbara et al. [24] investigated the language system of the Cigugur community also related to ethnomathematics. Letchumanan et al. [11] explored the influence of cultural values on the development of higher order thinking skills in mathematics education. Recently, Mei et al. [13] proposed a problem solving learning model grounded in ethnomathematics to enhance creative thinking among elementary students. This study discusses the relationship between handicrafts and mathematics of the Dusun Kiulu ethnic group in Sabah, Malaysia.

2 The Kiulu, Tamparuli, Sabah

Kiulu is a small town located in Tuaran district, West Coast of Sabah, Malaysia. Kiulu town to Kota Kinabalu town is 60 kilometers while Kiulu town distance to Tuaran town is 23 kilometers. Kiulu's position under the foot of the Crocker Range and bordering the districts of Penampang, Tambunan, Nabalu, and Ranau highlands has affected the terrain of Kiulu. The hill terrain is covered nearly 70 percent of Kiulu's area [20]. Kiulu town has been around since the colonial era and is also a "mukim" in the Tuaran district. According to Paimin et al. [15], many plants' "Tulu" grew on rivers' banks when people explored this area. "Tulu" is a type of tree with a small reed that usually grows on the river bank. Due to this situation, the place was named Kiulu.

According to DOSM [5], Sabah's population consists of 32 ethnic groups. The largest ethnic group is the Dusun tribe, one-third of Sabah's population. The Dusun community clustered in the Kadazandusun group in Sabah is an indigenous ethnic group still observed today, rich in values and practices of cultural traditions. The categories of the Dusun ethnic groups according to sub-ethnicities based on their locality or dialect. There are other Dusun sub-ethnic groups. Among them are Liwan, Bundu, Tatana, Kimaragang, Tindal, Lotud, Tobilung and many more. The Dusun tribes that live on the west coast, such as Penampang, Papar, Tuaran, Kiulu, Tamparuli, Tenghilan, Kota Belud, and also in the hill valleys of Ranau, Tambunan, and Keningau, are farmers who grow paddy fields and huma [16, 22]. Most of the Dusun ethnic group location was around the west valley and rural areas. Dusun literally means orchard or people living in the village or a rural or remote location. Pugh-Kitingan and Jacqueline [17] stated that when the sultanate of Brunei dominated the west coast in the north Borneo region (Sabah), he referred to "Dusun" as ethnic peasants, especially those that grow paddy fields. The use of the term then expands and continues until nowadays.

Furthermore, Sansalu [21] stated that the British people during the reign of the British North Borneo Company called "Orchard" for indigenous people living in the highlands who engaged in farming Moreover, Ibrahim and Ling [9] stated that the Dusun ethnicity is rich in artistic products such as traditional attire, customs practices, and handicrafts. Generally, most indigenous people inherit local in various fields of wisdom for generations. The knowledge practiced is a valuable property to his community. Besides that, they also have common sense and creative thinking in producing traditional clothing and handicrafts with various designs. This study aims to investigate the mathematics concept applied in their handicraft products.

3 The Dusun Kiulu, Tamparuli, Sabah Ethnic

There are numerous theories regarding the origins of the Dusun people in Sabah. Some theories believe that the Dusun originated from the Indo-Malayan ethnic group, which migrated from southern China to the countries of Southeast Asia [25]. In their studies, social scientists and historians consider physical aspects, spoken language, blood groups, and the artistic materials created by the Kadazan-Dusun community. A theory also links the origins to the migration of Mongolian, Chinese, or Kanchin and Annam people from Myanmar [6].

According to the Government of Malaysia [7], Sabah comprises 32 ethnic groups. The largest ethnic group is the Dusun tribe, comprising one-third of Sabah's population. The Dusun community, which is part of the Kadazan-Dusun group in Sabah, is an indigenous ethnic group that is still observed today, rich in cultural traditions and values. The term Kadazan-Dusun originated from the amalgamation of the Kadazan and Dusun ethnic groups, along with several other smaller ethnicities. This amalgamation is a consequence of political conflicts. Furthermore, the differences between the Kadazan and Dusun communities are not significantly significant. When observed in terms of the number of speakers, it is found that the Dusun dialect has more speakers than the Kadazan dialect. The categories of the Dusun ethnic groups are based on sub-ethnicities, which are defined by their locality or dialect. Other sub-ethnic Dusun groups include Liwan, Bundu, Tatana, Kimaragang, Tindal, Lotud, Tobilung, and many more. The Dusun tribes that live on the west coast, such as Penampang, Papar, Tuaran, Kiulu, Tamparuli, Tenghilan, Kota Belud, and also in the hill valleys of Ranau, Tambunan, and Keningau, are farmers who grow paddy fields and huma [16, 22].

As for the Dusun people, farming is not just about growing rice; it is a way of life passed down from generation to generation. As for the Kiulu community, many people in those villages still grow paddy fields and dryland farming (huma), just as their ancestors did. Moreover, their daily life typically begins with planting and harvesting rice every year. The Dusun community celebrates the Kaamatan festival every May, which symbolizes the results of rice planting and harvesting and serves as a sign of gratitude from the community to the earth spirits for providing an abundant harvest. During the Kaamatan festival, many traditional activities will be presented and conducted, such as the Sumazau dance performed alongside the beating of the gong. The festival's highlight is the Unduk Ngadau pageant, where young women embody the legendary Huminodun, a figure of sacrifice and beauty in Dusun folklore. The Kaamatan festival is not just an event but a way to honor ancestors and share joy with the young generation. Besides farming, the Dusun are master artisans who preserve their traditional crafts. They create handicrafts, such as "Barait" (backpack carriers), each piece telling a story about their heritage.

In Kiulu, skilled hands continue to craft gongs and musical instruments, such as the "Sompoton," a bamboo mouth organ that produces hauntingly beautiful melodies. These instruments are the heartbeat of Dusun and will be played during weddings, gatherings, and spiritual rituals. As for belief, a few of the community still believed the spirits resided in rivers, mountains, and trees, guiding and protecting the community. Even today, some still practice ancient rituals like Monolibabow, a healing ceremony led by a bobolin (spiritual priestess) to seek blessings or protection. Over time, many Dusun have embraced Christianity and Islam, but they continue to hold onto elements of their ancestral traditions, blending the old with the new. Despite the fast-changing world, the Dusun people are determined to preserve their For Review Onlyheritage. Organizations like the Kadazandusun Cultural Association (KDCA) work diligently to preserve their history, arts, and language.

4 Methods

This study employs qualitative methods with an exploratory and descriptive approach to uncover the geometric concepts embedded within the traditional rattan handicrafts of the Dusun Kiulu community.

This study explores ethnomathematics through the traditional handicrafts of the Kiulu community, with Paka Kiulu village (Figure 1) selected as the location. The focus is especially on female rattan craftswoman, selected as a representative sample. Handicrafts were chosen as the medium due to their accessibility and cultural relevance. This study continues to describe and analyse the mathematical factors to gain insight into the associated geometric concepts. The results of the mathematical analysis provided a clearer understanding of the necessary geometric principles. The results of mathematical analysis offer insights into the required geometric concepts. Data for the study were gathered through observation, interviews, and documentation of the subject during her craftwork. The observations were conducted by recording rattan handicraft products to examine the ethnomathematical aspects of the community and documented the findings.

Additionally, interviews were carried out with the subjects to gather ethnomathematics related data on rattan handicraft products. This study utilized semi-structured interviews as a primary method. During the production process of rattan handicrafts, documentation was carried out through recordings and photographs of the completed products. The documented materials included images of rattan handicrafts products showcasing geometric concepts and their physical characteristics. Simultaneously, an ethnographic approach was employed as both an empirical and theoretical framework to provide a detailed description and in depth analysis of cultural practices based on intensive filedwork. The collected data were thoroughly reviewed and validated to examine the ethnomathematics components embedded in the patterns of the handicrafts.

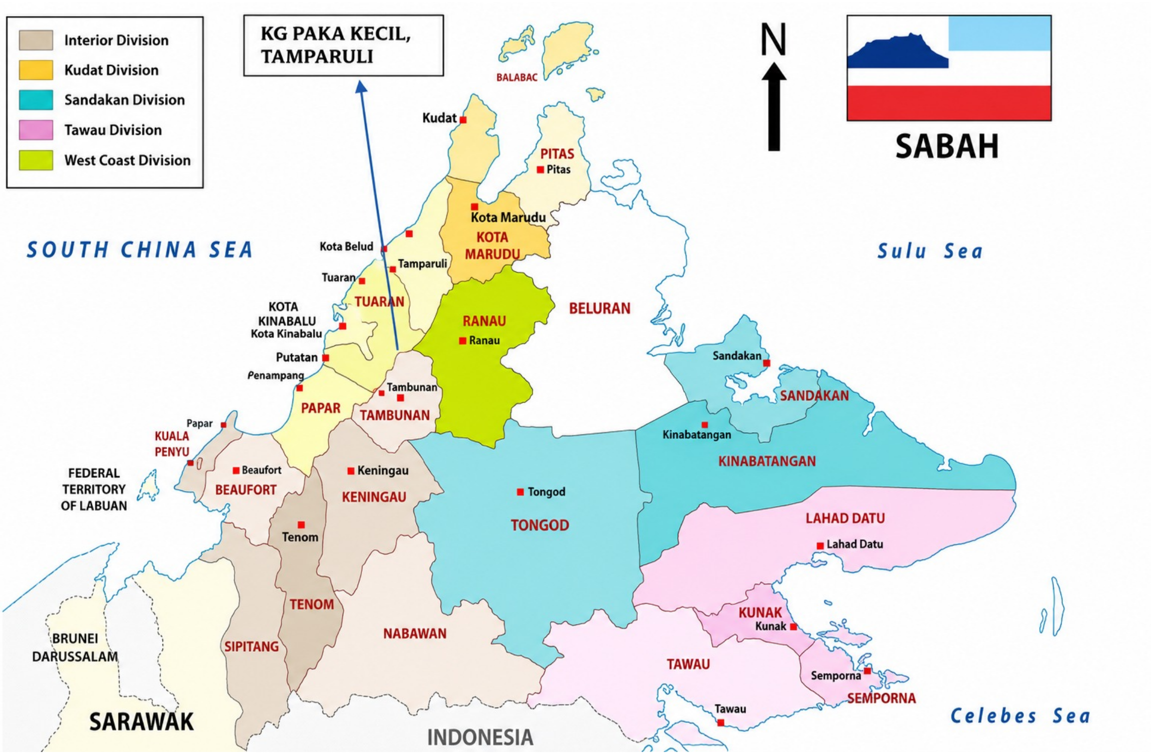


Figure 1: Map showing locations of village mentioned in this article.

5 Results and Discussions

There are three types of rattan handicraft products identified: the "Barait", "Sirung" and "Nurod" basket. The creation of these handicrafts does not rely on pre-made molds; instead, the craftswoman determines the measurements herself. She employs specific approximate values as a personal standard, which consistently results in rattan products that are uniform in shape. The findings reveal the presence of various geometric concepts within each type of rattan handicraft.

5.1 "Nurod" basket

The weaver prepares basic materials and equipment before starting the weaving process. Materials and equipment are ready to smooth the weaving process. "Nurod" baskets isolate paddy from rice in terms of function or use in the daily life of the Dusun community.

Figure 2 illustrates the beginning of the "Nurod" basket weaving process. In Figure 2(i), the weaver places bamboo sheets along the left and right sides, starting from the bottom edge and using the left side as a reference. The wall sheets follow a periodic pattern with a cycle of four, featuring alternating pairs of black and white strands woven in perpendicular directions, as shown in Figure 3. At this initial stage, the weaver forms a 3×3 sheet configuration.

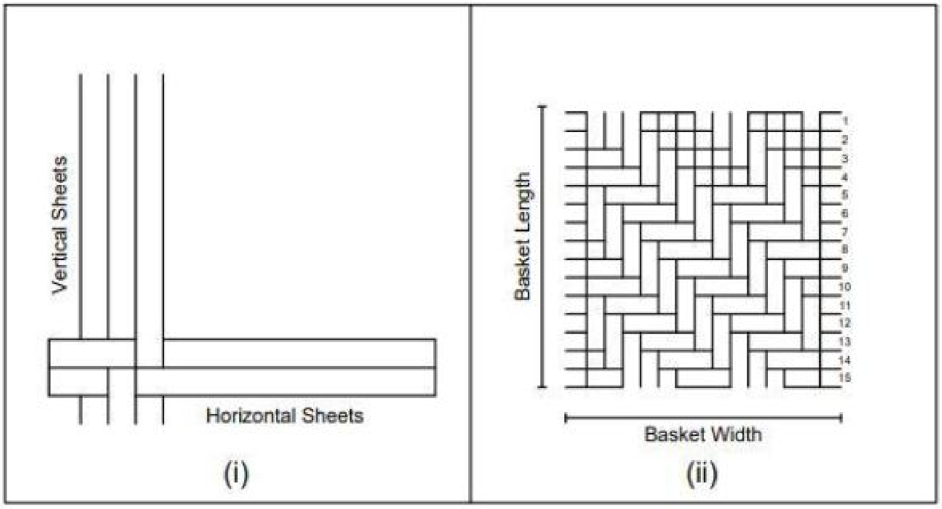


Figure 2: Weaving a "Nurod" basket on stage beginning.

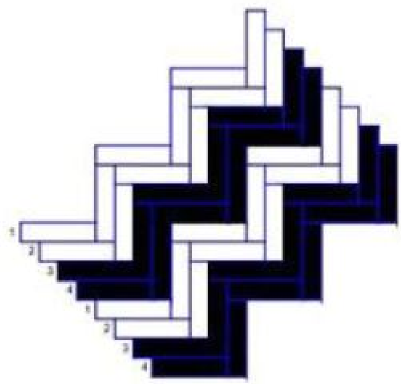


Figure 3: Perpendicular weaving direction.

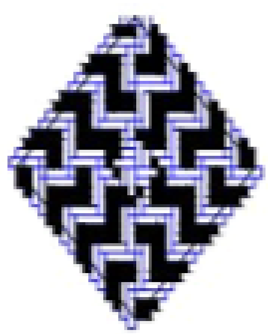


Figure 4: The square bottom of the "Nurod" basket.

As the weaving progresses, Figure 2(ii) shows the structure expanding to a 15×14 sheet arrangement. The square bottom of the basket is divided into four quadrants by vertical and horizontal midlines. Each quadrant shares the same shape, size, and weave pattern, confirming that the four quadrants are congruent. Figure 4 visually supports this observation.

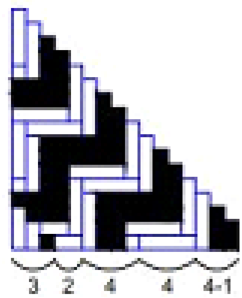


Figure 5: One quadrant of the bottom of the "Nurod" basket.

Figure 5 illustrates the structural sequence $(3, 2, 4, 4, 4-1)$ found in one of the bottom quadrants of the "Nurod" basket, referring to either the bottom-left or bottom-right section of its base. The weavers apply geometric transformations, including rotation, reflection, and translation, to construct the "Nurod" basket (Figure 6). These transformations generate zigzag-shaped geometric patterns (Figure 3), which the artisans embed within circular and square frameworks. Figure 7 presents the final woven form of the "Nurod" basket.

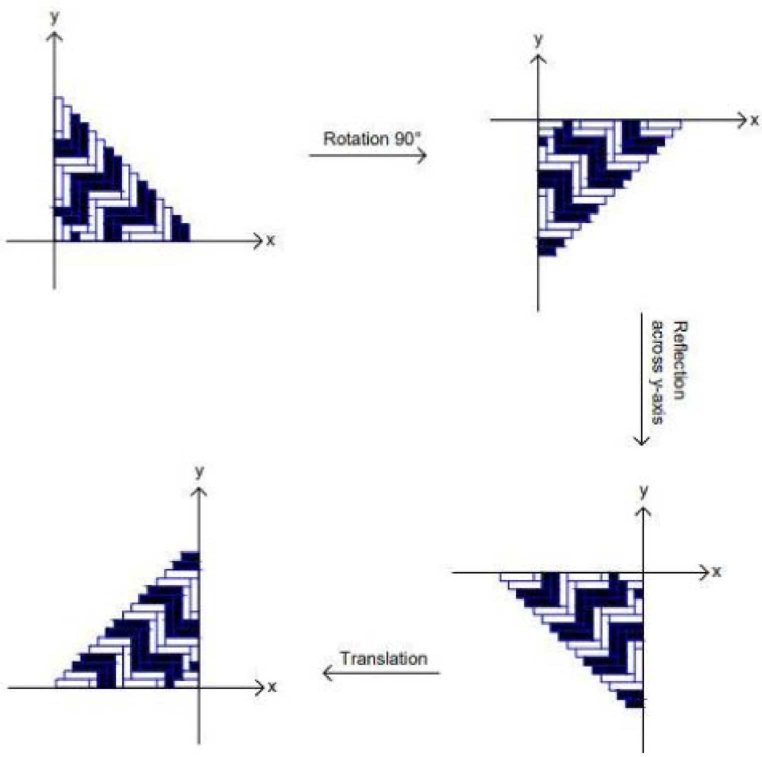


Figure 6: The geometry transformation of the "Nurod" basket.

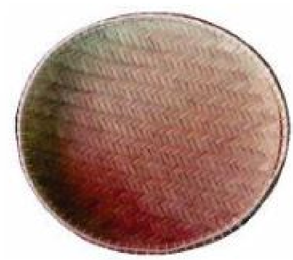


Figure 7: "Nurod" basket.

5.2 Sirung

The Dusun Kiulu community uses the "Sirung" to protect their heads from the scorching sun while performing "mongumo," a traditional practice of working or cultivating in the field or garden. The craftswoman started the steam weaving according to the design and pattern determined.

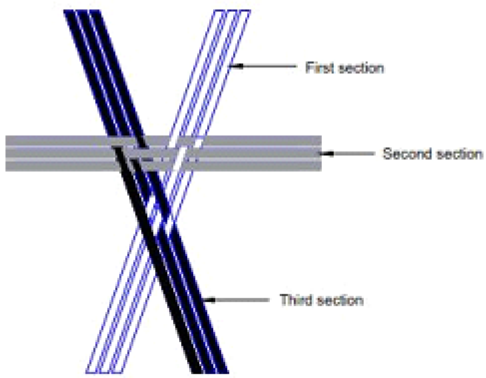


Figure 8: Triaxial weave technique.

Moreover, she weaved the sheets of stuffing and bamboo skin cut into the same size according to the desired shape. The craftswoman is incorporating the "Sirung" using a specific triaxial weave technique in three directions, namely sections 1,2 and 3 (Figure 8), with an interval of three strands. The craftswoman started the weaving by building a cone shaped framework of triaxial weaves.

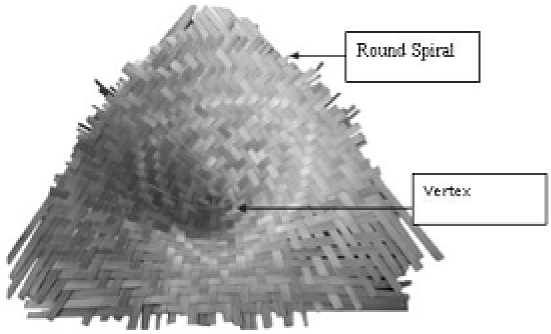


Figure 9: Hexagonal spaces.

She plaited five strands together to form a pentagonal opening, then interlaced another five strands at the pentagon's vertices to create hexagonal spaces (Figure 9).

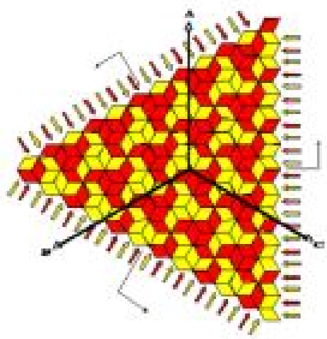


Figure 10: Pati Sekawan (Flock of Pigeons).

Table 1: The elements and symmetrical characteristics of the "Sirung" pattern.

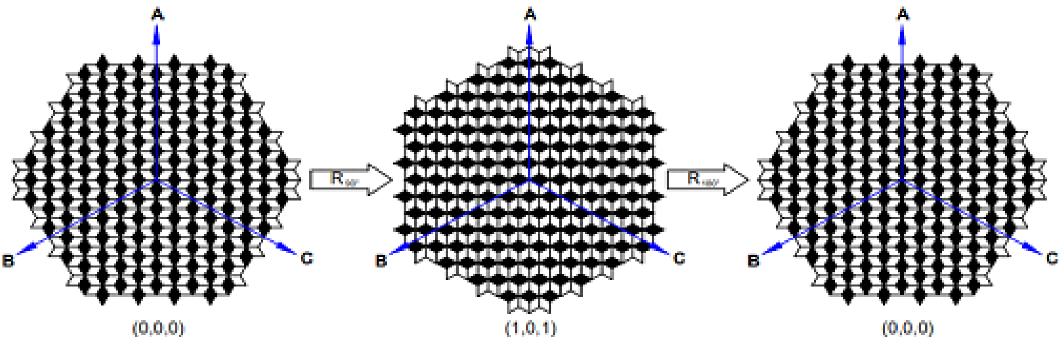
No. strand	Element	Symmetry operation	Geometrical representation	Symmetry element
3	(000), (101), (000)	Rotation	Line (axis)	Rotation axis

The weaver interwove additional strands to enlarge the structure, gradually forming a cone. The weaver also inserted strands upward and across the openings to generate patterns, resulting in hexagonal tessellations and the illusion of three-dimensional cubes. The weaving motifs are similar to the "Nurod" basket producing zigzag-shaped geometric patterns (Figure 3). Meanwhile, Table 1 shows elements and symmetry characteristics in the "Sirung" handicraft and Table

2 shows the analysis pattern of "Sirung" characteristics. There are three reference lines A, B and C intersecting at $120°$ are drawn in the centre of the template (Table 2). In the case of WB (W-White, B-Black) block, there exist only two possibilities, namely WB and BW (Table 1 and Table 2). Hence, the only digits that were used in the labeling process were 0 and 1, where 0 = White and 1 = Black. The number of emerging patterns is therefore given by all possible three-digit sequences of 0 and 1.

Table 2: Analysis of the characteristics of the "Sirung" pattern.

Template:



Characteristics:

(i) Element Structure:

The Sirung pattern contains three elements, consisting of the identity and its inverse,

$$S = \{(000), (101), (010)\},$$

- (000) represents the identity element.
- (101) is the inverse of (010).
- These three elements form a group under composition.

(ii) Inverse Relationship

Each element has an inverse within the set S. For instance, (010) and (101) are inverses of each other, satisfying,

$$(101)^{-1} = (010), (000).$$

(iii) Rotational Symmetry

The pattern preserves a $180°$ rotational symmetry at axes A and B.

(iv) Group Isomorphism

- This pattern is isomorphic to a subset of the dihedral group D_3 (order 6).
- The dihedral group D_3 represents the symmetries of an equilateral triangle (rotations and reflections).

(v) Isomorphism Mapping

Let:

$$S = \{R_0, R_a, R_b\}, \quad \text{and}$$
$$A = \{R_0, R_1, R_2\}, \quad \text{where} \quad A \subset D_3.$$

Here, the mapping shows a one-to-one correspondence between the "Sirung" pattern transformations and a subset of D_3.

Figure 11: Sirung.

Previously, there was a study about the practice of Malay food covering weaving and mathematics known as "tudung saji" by Zamri et al. [26] and Adam [1]. The "tudung saji" and "Sirung" designs and patterns are identical. Moreover, Adam [1] shows an example of a template pattern created with red and yellow bicolored strands (Figure 10). The print produced is Pati Sekawan (flock of doves). Meanwhile, Figure 11 is the final product of the "Sirung." Based on the findings, Adam [1] inferred connections between elements in the triaxial patterns of the "tudung saji" and elements in the groups. Based on this finding, there is a connection between group theory and the "Sirung" craft. By definition of a group, a group is a set G together with a binary operation which is

$$(a, b) \mapsto a * b \colon G \times G \to G,$$

satisfying the following conditions:

G1: Associativity
For all $a, b, c \in G$,

$$(a * b) * c = a * (b * c).$$

G2: Existence of an identity element
There exists an element $e \in G$ such that,

$$a * e = e * a = a \quad \text{for all } a \in G.$$

G3: Existence of inverses
For each $a \in G$, there exists an element $a' \in G$ such that,

$$a * a' = a' * a = e.$$

Thus, our study delves into the realm of symmetrical patterns of "Sirung" with the aid of Group Theory, building upon previous research in this field [1].

5.3 "Barait"

"Barait" is a traditional basket bag or knapsack. It is made of rattan that grows near river banks and streams. The frame of the base and top of a "Barait" are made from either rattan or softwood. Meanwhile, the body, back straps, and tying material are woven from rattan strips. Historically, it served multiple practical functions, including transporting water containers for collecting river water, carrying paddy from the fields, conveying harvested crops and assisting in hunting activities.

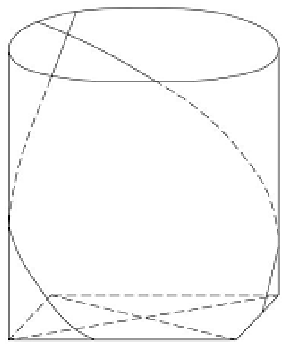


Figure 12: Three-dimensional Depiction of the "Barait".

Figure 12 provides a three-dimensional depiction of the "Barait". Meanwhile, Figures 13−16 offers alternative perspectives of the "Barait". The initial weaving of the "Barait" process resembles the "Nurod" basket, as demonstrated in Figure 2. Beginning at the center bottom of the "Barait", the weaver weaves until a smaller square shape is completed. The four triangles (Figure 12) are formed by the vertices and midpoints of the sides of the initial rectangular mat and are then folded upwards, becoming integrated with newly woven squares into the wall of the "Barait". As the "Barait" is constructed, the increasing height of the structure naturally guides the material to take on a cylindrical shape. Once the desired height has been reached, the weaver will then proceed to affix a small circular rim and add the finishing touches to the "Barait".

Figure 13: Side.

Figure 14: Top.

Figure 15: Bottom.

Figure 16: Front.

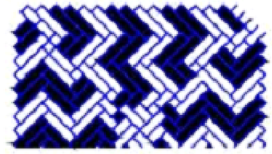


Figure 17: Bottom of the "Barait".

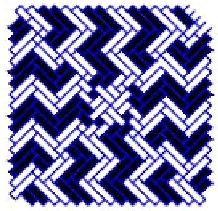


Figure 18: Top and wall of the "Barait".

The implemented methodology results in a cylindrical configuration that demonstrates both visual harmony and structural resilience, as depicted in Figure 16. It has been observed that the strands of the "Barait" ascend along the cylindrical wall in two helical families, each moving in a leftward and rightward direction at an angle of $45°$ with the horizontal plane. The overall pattern and geometric design of the "Barait" is strikingly similar to that of the "Nurod" basket. From Figures 17−18 the weaving motifs of the "Barait" produce zigzag-shaped geometric patterns. The four quadrants of the square top of the "Barait" are congruent (Figure 4). One quadrant top "Barait" (Figure 5) presents the structure $(3, 2, 4, 4, 4 - 1)$. The geometry transformation of the "Barait" is rotation, reflection, and translation (Figure 6). Besides that, the volume of the "Barait" can be calculated using the formula,

$$V = \pi r^2 h,$$

where r denotes the radius and h stands for the height of the "Barait" (Figure 19).

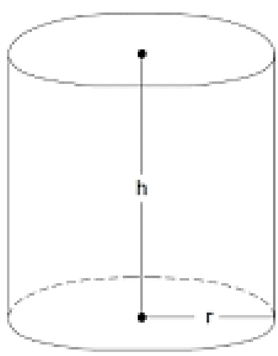


Figure 19: The three-dimensional shape of the "Barait".

Consider the radius of the "Barait" is x and the height of the "Barait" is y,

$$V = \pi(x)^2 y, \qquad \text{where } \pi = \frac{22}{7}$$
$$V = \frac{22}{7}x^2 y$$

6 Conclusions

The findings of this study reveal that the crafts of the Dusun Kiulu community, particularly the "Barait", "Sirung" and "Nurod", integrate a variety of geometric forms, including circles, squares, triangles, rectangles, polygons, cubes, and cones. These crafts also embody fundamental geometric concepts such as symmetry, rotation, translation, reflection, and tessellation. Additionally, the study identified a triaxial pattern that relates to group theory. This finding may help bridge the gap between indigenous knowledge and formal academic fields, such as mathematics. Revealing the mathematical concepts within this community may become a powerful tool for learning and appreciation, encouraging designers, anthropologists, and mathematicians to examine indigenous practices more closely. There is great potential in exploring other traditional crafts for their mathematical richness. Bringing this knowledge into classrooms could help students see math not as an abstract subject but as something alive in the world around them. These findings can also help young generations preserve and honor their culture. Future research may explore the ethnomathematical study of indigenous crafts by comparing the geometric and group theoretic properties of Dusun basketry with those of other cultural communities in Malaysia and beyond and integrating local handicrafts like the "Sirung" into mathematics education to contextualize abstract concepts such as symmetry, transformation, and group theory, thereby enhancing student engagement and cultural appreciation.

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Conflicts of Interest The authors declare no conflict of interest.

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