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Mathematics in Culture: Analysis of Mathematical Elements in *Buna* Woven Fabric

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Abstract

The purpose of this research is to analyze in depth the mathematical values contained in the buna woven fabric. The method used is a qualitative method with an ethnographic design because it will explain one of the cultural artifacts of the people of NTT, in this case the buna woven fabric. The results obtained are the motifs on the buna woven cloth that analyzed containing geometric and arithmetic concepts. From the analyzed quadrilateral characteristics, the quadrilateral found in the buna woven fabric is a rhombus. In addition, values or mathematical concepts on woven fabrics that can be taught to junior high school students include finding the formula for the area and perimeter of a rhombus using a triangle approach; calculate the area and circumference of a rhombus; arithmetic and geometric sequences and calculating the number of rhombic models on buna woven fabrics.

Abstrak

Tujuan dari penelitian ini adalah untuk menganalisis secara mendalam nilai-nilai matematika yang terdapat pada kain tenun buna. Metode yang digunakan adalah metode kualitatif dengan desain etnografi, karena akan menjelaskan mengenai salah satu artefak budaya masyarakat NTT, dalam hal ini kain tenun buna. Hasil yang diperoleh adalah motif pada kain tenun buna yang dianalisis memuat konsep-konsep geometri dan aritmatika. Dari sifat-sifat segiempat yang dianalisis maka dapat diketahui bahwa bangun datar segiempat yang terdapat pada kain tenun buna adalah belah ketupat. Selain itu nilai-nilai atau konsep-konsep matematika pada kain tenun buna yang dapat diajarkan pada siswa SMP antara lain: menemukan rumus luas dan keliling belah ketupat menggunakan pendekatan segitiga; menghitung luas dan keliling belah ketupat; barisan aritmatika dan geometri serta menghitung banyaknya model belah ketupat pada kain tenun buna

Keywords*: buna, culture, mathematics*

INTRODUCTION

Daily life is closely related to culture. Culture could be a medium to help teach mathematical concepts by introducing cultural elements in the learning process (Li, 2019). In these days and age, implementing cultural elements into the classroom learning process is imperative for

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preserving culture by handing them to the student of the nation (Labudasari & Rochmah, 2019). Cultural practices facilitate the implementation of mathematical concepts. These are called ethnomathematics. Ethnomathematics gives rise to cultural practices capable of motivating students to learn mathematics (Fajriyah, 2018). The following is a visual representation of the relationship between local culture and mathematics. The intersection between local culture and mathematics is usually referred to as local culture-based mathematics.

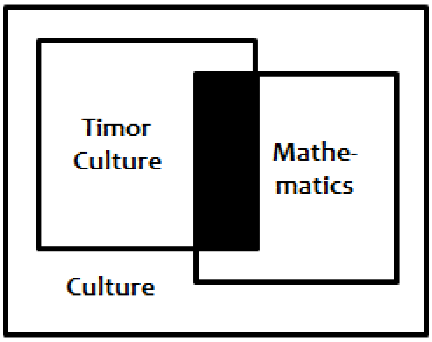

Figure 1: Local Culture Based Mathematical Concept [Author's Analysis is Based on (Supriadi et al., 2018)]

There are two forms of learning activities in a local culture based mathematically, which are mathematical activities and ethnomathematical forms. Mathematical activities consist of the abstraction of daily life activities into mathematics and vice versa, as a classification activity, counting, measuring, creating a pattern, and more. While ethnomathematical form is all kinds of mathematical activities practiced or developed within certain communities (Sudirman; Rosyadi; Lestari, 2016).

Woven fabrics are a cultural heritage and clothing of the Indonesian people ever since ancient times developed as an improvement to using grass and bark as clothing (Saputra, 2019).

The origin of Timor's traditional woven fabrics is largely unknown. However, multiple oral sources depict Timor's traditional woven fabrics being used to protect from the elements. It is remembered vividly still to this day by the community's female member that Timor's cultural heritage is weaving, which are observable in Timor's people life cycle.

Buna, *sotis/ lotis/ songket*, and *futus* are types of woven fabric from Timor island. This study uses buna as their object of study for their utilization of geometrical concepts. Buna weave originates from Timor Tengah Utara regency, specifically the palace area. According to Tas'au, the types of motifs imprinted on buna woven fabric are geometric motifs. Each motif represents different tribes inhabit the royal territory within the customary structure of the *sonafmaubes* (*Maubesi* Kingdom) community (Uskono et al., 2020)

People of Indonesia in general (especially Timorese) have implemented mathematics in their daily activities, particularly when choosing a combination of color, dots, lines, and shapes to create patterns on to their woven fabric and batik characteristic. This is in line with the opinion that through observation of the *Jogjan* batik motif, students are able to identify its shape, area, circumference (Rudyanto, 2019). A study (Hartoyo, 2013) states that although the communities do not have a good understanding of mathematics, they can apply mathematical concept (geometry) into their woven fabric's motif and weaves. In general, Timor people are aware of mathematics in an abstract way, in which mathematics is only considered a science that can only be used to solve problems in class. For instance, several cultural activities outside the classroom, such as building a *lopo* (Timor traditional house), are never considered to contain any mathematical elements. The community's understanding of building a cone-shaped *lopo* is only based on cultural values. Hence, the measurement is inconsistent, not in accordance with the actual cone model. In this case, *lopo*is not built with a fixed mathematical calculation that leads to differences from one *lopo* to another (e.g., the width of the outer circle, inner circle, etc.). In other words, the mathematical measurements are not considered in detail; thus, several elements are not in their actual size. In conclusion, mathematical concepts are not fully applied in traditional architecture because the traditional community emphasizes more on cultural values and aesthetics elements (Lapenangga et al., 2020).

According to the statement above, the research team is interested in analyzing mathematical aspects that can be found in *buna* woven fabric's motif and their relation to geometry and arithmetic's. The purpose of this *buna* woven fabric research is to identify relationships between culture and mathematics so that it may be better understood, preventing the students from seeing their culture as something 'foreign' and shifting the community's perception of mathematics to be more accurate. In addition, mathematics applications can be optimized in the community and students' daily activities, that they may benefit from their mathematical studies. Another objective of the study is for students to know, maintain, and preserve the local cultures around the community (Rewatus et al., 2020)

METHODOLOGY

This is a qualitative study with an ethnographic design to explain one of East Nusa Tenggara's cultural artifacts, in this case, *buna*. The initial step of this research was choosing the study object. The chosen object is buna woven fabric due to its geometrical elements that can be analyzed. Next, a preliminary survey was conducted to determine the topic of this study. The research team conducted the preliminary survey by observing multiple types of *buna* woven fabrics that may have a geometrical concept. The results of the survey were used to determine the topic of this study, which is the geometry of *buna* woven fabric. This study collected data by interview (unstructured) and measuring the fabrics. The data collected from interviews and measurement was then analyzed to obtain a detailed description of *buna* woven fabric by describing and classifying the geometrical concept on *buna* woven fabric. Finally, translating and writing the mathematical concept into written text. In general, the steps of this study can be seen in the Figure 2.

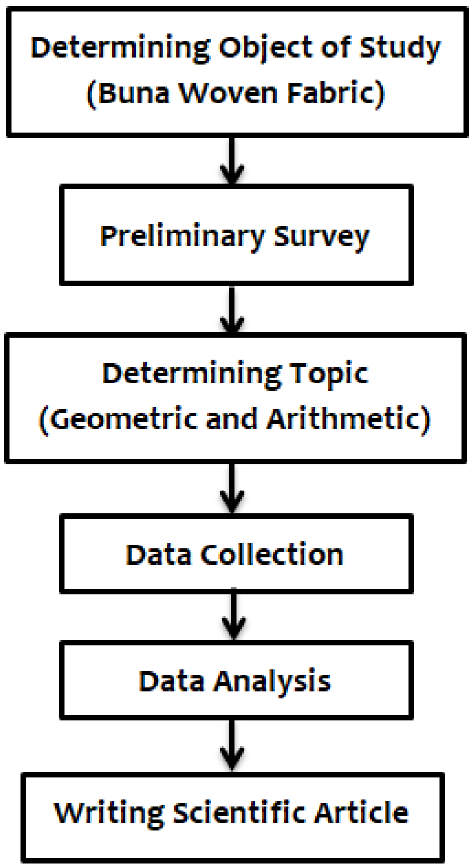

Figure 2: Research Flowchart (Author's Analysis, 2020)

This study's limitation is that it only uses one type of woven fabric as the object of the study. There is no other object that can be used as a comparison.

RESULTS AND DISCUSSION

Below are patterns of woven fabric that are used as the object of this study. This *buna* woven fabric originates from the North Central Timor Regency of the East Nusa Tenggara province.

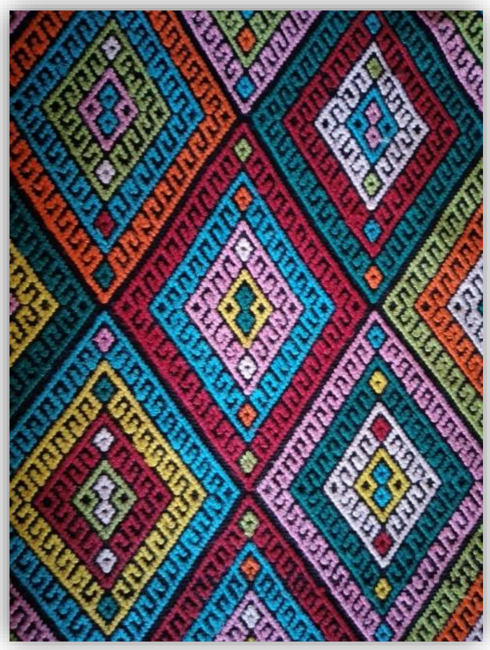

Figure 3: Buna Woven Fabric (Doc. Author, 2020)

The following is a motif found in *buna* woven fabric that can be geometrically modeled:

Figure 4: BunaWoven Fabric (Author's Doc, 2020)

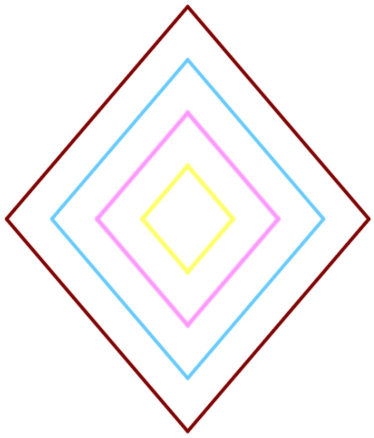

Figure 5: Buna Woven Fabric Modeling (Author's Analysis, 2020)

The modeling in Figure 5 shows that the four shapes are quadrilateral because each of them has four sides and four vertices. A further detailed analysis was then conducted regarding the rectangular shapes on *buna* woven fabrics, especially in the red square.

The following were the properties of the rectangular shapes.

Property 1: All sides have equal length.

According to measurement results, length of $AB = BC = CD = DA = 8\ cm$

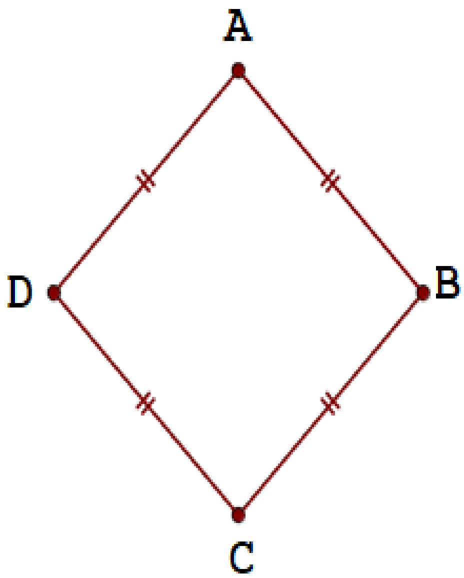

Figure 6: Buna Woven Fabric Modeling (Author's Analysis, 2020)

Property 2: Both diagonals are axes of symmetry

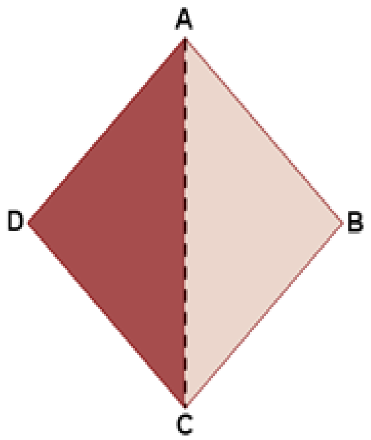

Figure 7: *Buna* Woven Fabric Modeling
(Author's Analysis, 2020)

Analysis of Figure 7

If folded at *AC* then point *A* is located at point *A*, point *C* is located at point *C* and point *B* is located at point *D*; therefore, *AC* is an axe of symmetry.

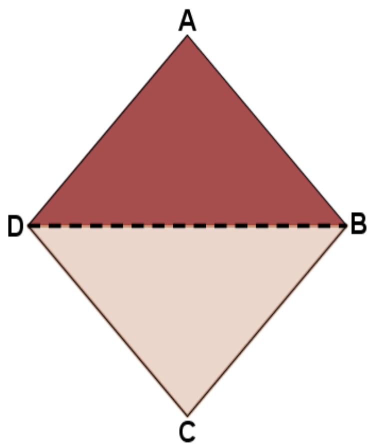

Figure 8: *Buna* Woven Fabric Modeling
(Author's Analysis, 2020)

Analysis of Figure 8

If folded at *BD*, then point *B* is located at point *B*, point *D* is located at point *D* and point *C* is located at point *A*; therefore, *BD* is an axe of symmetry.

Property 3: Two vertices next to each other are equal to180°

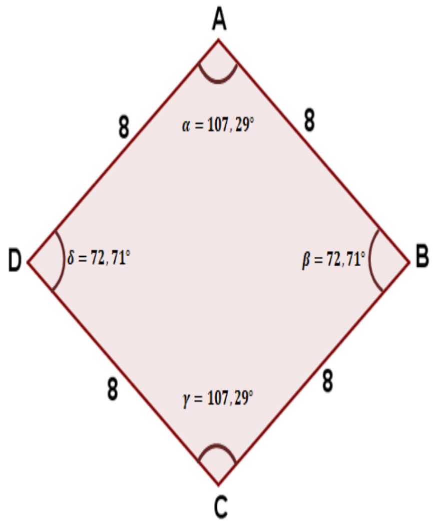

Figure 9: Buna Woven Fabric Modeling
(Author's Analysis, 2020)

Based on the measurement taken:
$m\angle A + m\angle B = 180^{\circ}$;
$m\angle B + m\angle C = 180^{\circ}$;
$m\angle C + m\angle D = 180^{\circ}$; and
$m\angle D + m\angle A = 180^{\circ}$.

The angle of each vertex can be divided equally by their diagonals.

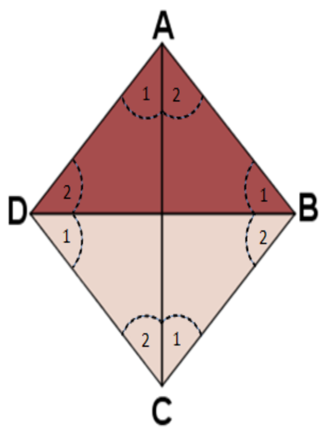

Figure 10. Buna Woven Fabric Modeling (Author's Analysis, 2020)

Based on measurement taken: $\angle A_1 = \angle A_2 = 53,645^{\circ}$; $\angle B_1 = \angle B_2 = 36,355^{\circ}$; $\angle C_1 = \angle C_2 = 53,645^{\circ}$; $\angle D_1 = \angle D_2 = 36,355^{\circ}$.

Property 4: The diagonals are perpendicular to each other and divide both diagonals into two lines of equal length.

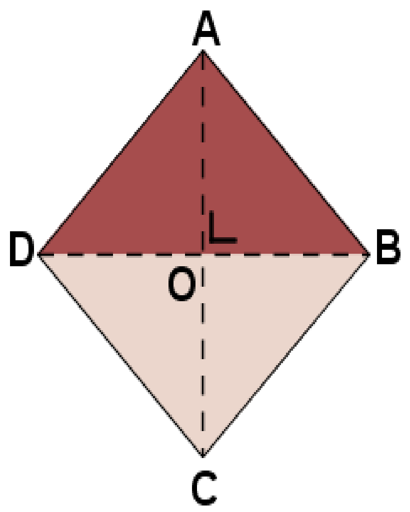

Figure 11: *Buna* Woven Fabric Modeling (Author's Analysis, 2020)

It can be analyzed that: (a) The intersection of AC and BD shows that AC is perpendicular to BD ($AC \perp BD$); (b) The diagonal BD is divided by the diagonal CA into two lines of equal length, $DO = OB = 6{,}2\ cm$; and (c) Diagonal CA is divided by the diagonal BD into two lines of equal length, $CO = OA = 5\ cm$.

The analyzed properties are the properties of a rhombus. Some of the theories used to analyze this shape's property are measurements, axes of symmetry, and angles. (Siswoyo, 2011; Ilham, 2015; and Rohayati, S., Karno, W., & Chomariyah, 2017)

In addition to the findings above, the mathematical aspect of *buna* woven fabric can be used in the primary school classroom activity. This finding can be used as a source of study by students to learn the sub-topics below:

Topic 1: Determining the formula of area and perimeter of a rhombus using a triangular approach.

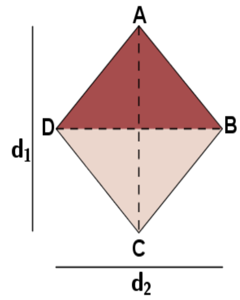

Figure 12: Buna Woven Fabric Modeling (Author's Analysis, 2020)

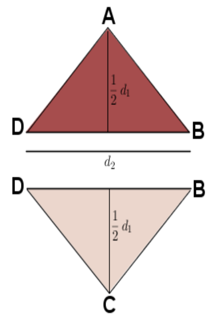

Figure 13: *Buna* Woven Fabric Modeling (Author's Analysis, 2020)

Area of Rhombus $ABCD$

$= \text{Area } \Delta\ ABD + \text{Area } \Delta\ BCD$

$= \left(\frac{1}{2} \times d_2 \times \frac{1}{2} d_1\right) + \left(\frac{1}{2} \times d_2 \times \frac{1}{2} d_1\right)$

$= \left(\frac{1}{4} \times d_1 \times d_2\right) + \left(\frac{1}{4} \times d_1 \times d_2\right)$

$= \frac{2}{4} \times d_1 \times d_2 = \frac{1}{2} \times d_1 \times d_2$

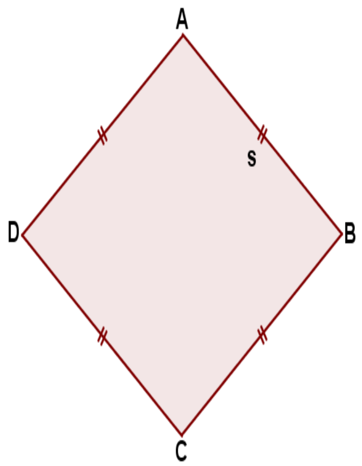

Figure 14: *Buna* Woven Fabric Modeling (Author's Analysis, 2020)

Perimeter of Rhombus$ABCD$
$= \text{Total length of all its sides}$
$= AB + BC + CD + DA$
$= s + s + s + s = 4s$

Topic 2. Calculating the Area and Perimeter of Rhombus

Figure 15. Buna Woven Fabric (Doc. Author, 2020)

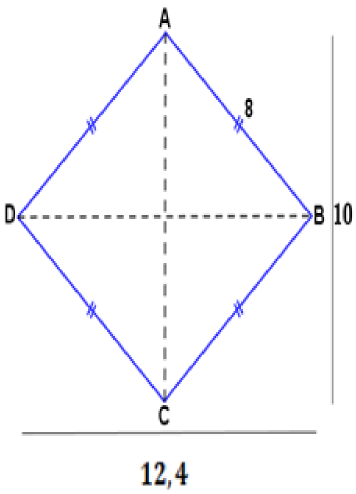

Figure 16: *Buna* Woven Fabric Modeling (Author's Analysis, 2020)

Area of Rhombus$ABCD$
$= \frac{1}{2} \times d_1 \times d_2 = \frac{1}{2} \times 10 \times 12{,}4 = 62$

Perimeter of Rhombus $ABCD$
$= 4s = 4 \times 8 = 32$

Topic 3. Arithmetic and Geometric sequence: forming pattern from the rhombus model.

Figure 17: *Buna* Woven Fabric (Doc. Author, 2020)

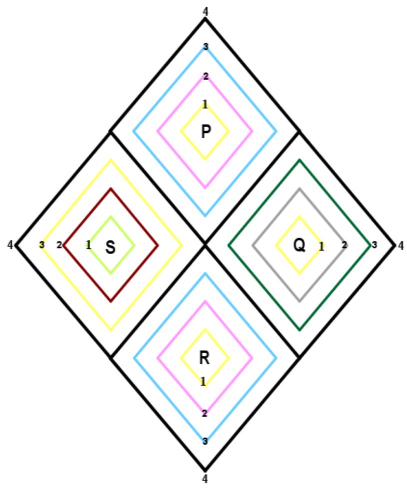

Figure 18: *Buna* Woven Fabric Modeling (Author's Analysis, 2020)

The measurement result of the rhombus model of buna woven fabric (Figure 18) shows that $P_1 \cong Q_1 \cong R_1 \cong S_1$; $P_2 \cong Q_2 \cong R_2 \cong S_2$; $P_3 \cong Q_3 \cong R_3 \cong S_3andP_4 \cong Q_4 \cong R_4 \cong S_4$

Because each sided opposite to each other has equal length and angle, the area and perimeter of the rhombus can be written as:

$$KP_1 = KQ_1 = KR_1 = KS_1 = 8;$$
$$KP_2 = KQ_2 = KR_2 = KS_2 = 16;$$
$$KP_1 = KQ_1 = KR_1 = KS_1 = 24;$$
$$KP_1 = KQ_1 = KR_1 = KS_1 = 32$$

The perimeter of rhombus $1, 2, 3$, and 4 can be written as an arithmetic and geometric sequence as follows:

Topic 4. Limited Arithmetic Sequence

$K = 8, 16, 24, 32$
Difference: $b = 8$
First term: $a = 8$
Pattern:

$$\begin{aligned} U_n &= a + (n-1)b \\ &= 8 + (n-1)8 \\ &= 8 + 8n - 8 \\ U_n &= 8n \end{aligned}$$

With $n = 1, 2, 3, \ldots$

Numbers of terms of K is:

$$S_n = \frac{n}{2}(a + U_n) = \frac{n}{2}(a + 8n)$$

$$S_4 = \frac{4}{2}\big(8 + 8(4)\big) = 80.$$

Topic 5. Limited Geometric Series

$K = 8, 16, 24, 32$
Ratio: $r = 2$
First term: $a = 8$
Pattern:

$$\begin{aligned} U_n &= ar^{n-1} \\ &= 8 \times 2^{n-1} \\ &= 2^3 \times 2^{n-1} \\ &= 2^{3+n-1} \\ U_n &= 2^{n+2} \end{aligned}$$

With $n = 1, 2, 3, \ldots$

Numbers of terms of K is:

$$\begin{aligned} S_n &= \frac{a(r^n-1)}{r-1} \\ S_n &= \frac{8(r^n-1)}{2-1} \\ S_n &= 8(2^n - 1) \\ S_4 &= 8(2^4 - 1) \\ S_4 &= 80 \end{aligned}$$

The numbers of term of K $(S_4 = 80)$ shows that the thread used to make the four rhombi $(1, 2, 3, 4)$which is more than $80\ cm$ (because the weaving process of *buna* requires the weaver to do a tying process).

Topic 6. Calculating the amount of rhombus model in *buna* woven fabric

From the rhombus model in Figure 18, there are 17 rhombi in its entirety. The following is a list of rhombi in figure18:

$P_1, Q_1, R_1, S_1, P_2, Q_2, R_2, S_2, P_3, Q_3, R_3, S_3, P_4, Q_4, R_4, S_4$ and rhombuses formed from multiple rhombuses P_4, Q_4, R_4, S_4

The following are the preparation steps and process of traditional weaving, in this case using manual weaving tools: Firstly, the tread (*abas*) are prepared using the needed color and are rolled (*naunu*) (into each color) until it is round, then the treads are arranged (*nonot*) in the weaving tools according to the desired design, then using a weaving wood called *atis, ut, sia, nekan* are arranged so that the prepared treads are ready to weave into a woven fabric using *senu, mona, niun* (other weaving tools). According to the *buna*'s motif, what has become a characteristic while weaving a buna woven fabric is its tying tread (*na'bun*). For instance, if the *buna* motif that is woven is shaped like a rhombus, as shown in Figure 3, the weaver needs to count the amount of tread that needs to be tied to achieve the desired result.

In this study, the researcher also compared the size of multiple rectangular shapes of buna woven fabric used as the object of this study. The following is an example of rectangular shape model that was compared:

Figure 19: *Buna* Woven Fabric (Doc. Author, 2020)

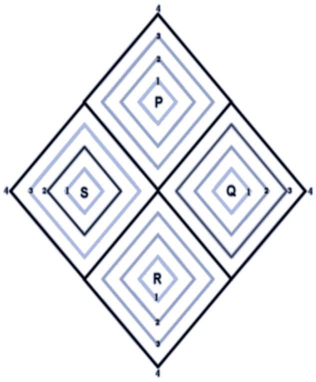

Figure 20: *Buna* Woven Fabric Modeling (Author's Analysis, 2020)

Immediately (without measuring), some sides correspond to the shape model that shares the same size; however, upon measurement using measuring tools, the corresponding sides do not have the same size. For example, perimeter$S_4 = 32{,}4\ cm, P_4 = 32\ cm,\ Q_4 = 32{,}4$ dan $R_4 = 32$.This due to the tying of the tread during the weaving process; there is an unevenness of strength of each strand of the tread.

The results of this study, as shown above, is supported by the previous studies as follows: (1) Previous Study (Hardiarti, 2017) shows that within a certain culture, we are able to analyze mathematical concepts that can be used as a concrete mathematical study material; (2) Another study (Arwanto, 2017) show that Cirebon's *trusmi batik* contains mathematical elements, including the geometrical concepts of symmetry, transformation, and congruency (Zayyadi, 2018; Disnawati and Nahak, 2019); (3) study by (Lapenangga et al., 2020)shows that size in mathematics in certain cultural elements are not acknowledged in detail; thus, some elements shift from its initial design because of the weaver or the community in general emphasizes cultural aspect more than aesthetics; (4) Study by Senita and Neno (Senita & Neno, 2018) shows that traditional fabric manufacturing (using weaving tools) causes some mathematical concept to be obscured due to the weavers focus on motif they are weaving. Further, by understanding the ethnomathematics of Batik will increase the student critical thinking (Martyanti and Suhartini, 2018; Febriani et al, 2019).

CLOSING

Conclusion

Based on the results of this study, it can be concluded that the motives found in *buna* woven fabrics have geometric and arithmetic concepts. From the rectangular shape properties that were analyzed, it can be concluded that the rectangular shape on *buna* woven fabric is a rhombus. Such properties are as follows: each side has equal lengths; both diagonals are axes of symmetry; the sum of two angles of neighboring vertices are$180°$; each angle can be divided equally by the diagonal, and both diagonal perpendicularly intersect while dividing themselves into two equal lengths line. In addition, mathematical elements, or concepts on *buna* woven fabric that can be taught to middle school student are as follows: determining the formula of area and perimeter of a rhombus using the triangular approach; calculating area and perimeter of a rhombus; arithmetic and geometric sequence and counting the amount of rhombus model within *buna* woven fabric.

Suggestions

Suggestions for future studies are as follows: (1) more object of study could be added or expanded so that more mathematical elements can be; and (2) there is a need for an in-depth interview (structured) to increase the amount of data collected.

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