A study of ethnomatematics on Tulungagung marble craft

B M F Pratama¹, Mardiyana¹, D R S Saputro¹

¹Department of Mathematics Education, Faculty of Teacher Training and Education, Universitas Sebelas Maret, Surakarta, Indonesia

Abstract. Mathematics has become a compulsory subject that is widely taught in every educational level, and generally the concept of mathematics as a subject is only taught formally without being matched to everyday’s life in the environment or society. The concept of mathematics in fact is tightly related to everyday’s life. Not only in terms of daily life activities, the concept of mathematics without being consciously realized is related to the culture of a society as well. Mathematical aspects and concepts in relation to culture are known as what is called Ethnomathematics. The current study aims at examining and investigating the ethnomathematics on ornament patterns on Tulungagung marble crafts. The method employed by this research is qualitative explorative. Data is collected from the observation method, interviews, and documentation from informants who are experts on the subject; among them are mathematics teachers and lecturers, community leaders, and marble artists. Ethnomathematics is a branch of mathematics that focuses on studying the way mathematics is perceived within a cultural perspective. Therefore, it is obvious that mathematics has its correlation to culture and used in daily life activities by people in a society. The results of this study found that Tulungagung marbles, especially the ornament patterns, contain elements of mathematics. Some elements in the patterns are geometrical, making them a culturally meaningful pattern that was created through geometric and symmetrical transformation. Geometry transformation includes translation, reflection, rotation, and dilation.

1. Introduction

Mathematics has become a compulsory subject that is widely taught in every educational level. Contrary to the general belief that mathematics is simply a subject that is only taught formally without being implicated in everyday life of a society, the concept of mathematics intertwines with everyday life. Not only in terms of daily activities, the concept of mathematics is unconsciously related to the culture of a society as well. Mathematical aspects and concepts that are intertwined with a culture can be studied through Ethnomathematics. According to [2] Ethnomathematics aims to give learners and researchers deeper insights on the concepts and relation between mathematics and culture.

According [10], Ethnomathematics is a study that focuses on the relationship between culture and mathematics; in other words, a study on mathematical aspects and concepts that are related to a culture. D’Ambrosio in [14] defines ethnomathematics as follows: the word ethno defines 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. As for the term Ethnomathematics itself, it is defined as the mathematics practiced among the identified cultural groups such as the people of a national tribe, labor group, the children of a certain age, and even professionals [7]. Ambrosio argues that the word Ethnomathematics is also used as a mode, style, and technique (tics) to explain, understand, and deal with the natural and cultural environment (mathema) in different
cultural systems (ethnos) [9]. According to [15], culture provides the study of mathematics naturally by connecting mathematical context to culture and experience. While According to [13] mathematics is regarded as a cultural construction, hence, Ethnomematics is regarded as a product of cultural development. In contrast, [6] argues that culture is created, developed and debated through mathematical systems. This means that culture is also created through mathematics.[5] states that nowadays, ethnomatematics is integrated into every class of mathematics.

Albanese in[3] state that various forms of mathematics exist in different cultures, this results in a deep bond between mathematics and human culture. Adding up to that, [8] emphasizes that mathematical concepts based on cultural perspectives allow learners to not only reflect and appreciate their own culture, but also the culture and traditions of others. Various cultural traditions exist in various regions. Each tradition in a region has its own unique characteristics that can hardly found in other places, such tradition becomes the symbol of a culture. One of the cities with such astounding cultural traditions in Indonesia is Tulungagung.

Some of the well-known cultural arts of Indonesia come from Tulungagung, a city that is also known through the name kota marmer (marble city), among them are: mantenkucing, jaranan, reog kendang, kentrung, jamasan kyai upas, as well as marble arts, the most admired craft of Southeast Asia. According [16], marble is the result of the sedimentation of a certain type of limestone. The sedimentation tends to be formed by inorganic waste that usually comes from the process of seawater precipitation. Marble consists mostly of calcite (calcium carbonate), [4]. According to data from the Department of Industry and Trade of Tulungagung in 2017, in terms of the city’s craft entrepreneur potential, there are about 267 businesses on marble or onyx, and 44 businesses that craft marble wall floor, marmo. As for the capacity of marble/onyx, the city is able to produce 3.110.389 pieces year and 298,500 m² marble wall floor per year. It can be seen that many business units in Tulungagung focuses on the marble crafts production, and keep increasing as the year goes by.

Some crafts are produced from basic marble materials, such as Onyx, marble tables, marble inscriptions, and marble floors with geometric ornaments. The patterned floor is often called Border Inlay or marble inlay; an original masterpiece from Tulungagung. The ornaments on the marble floor form a geometric pattern. Not only as decorations, but as culturally meaningful geometrical patterns possessing interesting geometric transformations and symmetries [12]. The beauty of the craft can be seen on the pattern and structure due to the enchanting symmetrical motifs. According to [11], a culturally meaningful geometric motif is resulted from a symmetrical geometric transformation. In other words, ornaments patterns which geometric shapes are mathematically symmetrical and culturally beautiful is the result of a fusion between mathematics and culture, thus, it can be considered as a geometric transformation. Geometric transformations include shift (translation), reflection, rotation, and enlargement (dilation) found on a marble craft.

2. Methods
This research is a study and exploration of Ethnomathematics on the ornament patterns on Tulungagung marble craft. The method used in this research is explorative qualitative research. Through the research approach, information about Ethnomathematics in Tulungagung marble patterns is collected. Information is collected from the observation method, interviews, and documentation from informants who are experts on the subject; among them are mathematics teachers and lecturers, community leaders, and marble artists. Sources of data are interviews, observation results and documentation results. The data were reviewed and validated in order to study the Ethnomathematics component found in Tulungagung marble ornament patterns. By using the qualitative method, the data obtained will be studied completely so that the purpose of this study can be achieved.
3. Result and Discussion
The results of ethnomatematic studies on Tulungagung marble patterns shows that the geometric transformations are in the form of reflection, dilation, translation, and rotation. The concept of transformation is also summed up through term or terminology. According to [17] the terminology for geometric transformation concept is presented in Table 1.

| Term       | Term       | Term       | Term       |
|------------|------------|------------|------------|
| Translation| Dilation   | Reflection | Rotation   |
| • Vector   | • Dilate   | • Flip     | • Turn     |
| • Slide    | • Reduction|            | • Rotary Motion |
|            | • Stretch  |            | • Rotation Motion |
|            | • Scale model |       | • Clockwise |
|            | • Scaling  |            |            |
|            | • Scale drawings |  | • Counterclockwise |
|            | • Expand   |            |            |
|            | • Enlarge  |            |            |

3.1 Reflection Concept
In making marble ornament patterns, the concept of reflection is applied. In sense, reflection is a transformation that moves images through the reflecting properties of a mirror. Reflecting the ornament patterns to certain positions clearly illustrates that the concept of reflection has been applied in the making of marble ornament patterns.
Figure 1. The application of geometry transformation in motif ornament patterns of the marble

Figure 1 describes the application of geometry transformation in the motif of the marble, to making this motif can the applied reflection of several ornaments using y-axis in Cartesian coordinate system.

Definition 3.1. Reflection is a type of rigid transformation where the figure appears to be flipped over an axis or line on a plane that is called a reflection; the line may be the x-or y-axis, or a line other than the axes. This line is called the line of reflection. The object and its reflection are congruent but the position and alignment of the figures are reversed. A mental picture of the reflection motion would be described as lifting the shape out of its plane and flipping it over an indicated line and then putting it back down on the plane. When a reflection figure is viewed in a mirror, the mirror edge becomes the line of reflection, or the line over which the preimage is reflected. The terms "flip or flipping" are often used to describe this type of transformation. [17]

Another statement is from [1] in which Reflection transformation is also the basis of the comprehension of the topics in Analytic geometry. The reflection of any geometric shape is made up by intersecting lines from every angle on the shape and projecting these angles on the other side of the axis. The projected geometric shape and the reflected according to axis are of equal length and they are the same in basic properties, but different in terms of location and direction.

Figure 2. Reflection

On the ornament patterns of the marble, the pattern movement resembles those of a reflection, showing that the geometrical transformation applied was in the form of a reflection.

3.2 Dilation Concept

In figure 2 the marble ornament motif is made using the concept of dilation. Dilation is a geometric transformation that moves a point along a straight line according to certain distance and direction. By enlarging the patterns to a certain position, it can be seen that the concept of dilation is applied on the creation of Tulungangung marble ornament patterns.
Figure 3. The application of geometry transformation in motif ornament patterns of the marble

Figure 3 describes the application of geometry transformation in the motif of the marble, to making this motif can to applied dilatation of an ornament, so can get the motif that has the same form but have different size.

Definition 3.2. Dilation is a transformation that reduces or enlarges a figure. Dilation stretches or shrinks the original figure and alters the size of the preimage; hence, it is not rigid because it does not satisfy the condition that the image is congruent to the preimage. Dilation is a similarity transformation in which a two dimensional figure is reduced or enlarged using a scale factor (≠ 0), without altering the center of dilation [17].

Dilation may also be understood as the transformation that changes the spacing of points by a certain scale factor at the particular dilation center. If the dilated object is a structure, the dilation process will resize it without changing its shape.

Figure 4. Dilation

On the ornament patterns in the marble figure above, the distance between each figure is shifted depending on certain scale towards the dilation center, showing that the geometrical transformation of dilation occurs in the creation of patterns.

3.3 Translation Concept

Another concept used in the creation marble patterns is the concept of translation. The application of translation concept is illustrated through reflecting the marble ornament patterns to a certain position.

Figure 5. The application of geometry transformation in motif ornament patterns of the marble
Figure 5 describes the application of geometry transformation in the motif of the marble, to making this motif can the applied translation of an ornament in the motif using an axis in the Cartesian coordinate system

**Definition 3.3.** Definition the translation is a geometric translation that consists of moving a point, line, or figure to a new position on a two dimensional surface. The definition of translation specifies that each point of the object is moved the same distance and in the same direction. Usiskin et al. [17] calls a geometric translation "the sliding of an object from one to another place without changing its orientation." The simplest of the transformations is the translation, sometimes called a slides, or a shift. The symbolism for a point translation may be labeled as $A \rightarrow A'$. The arrow indicates that the point A is being moved to a new position labeled A prime (A'). An arrow may be illustrated on a graph to indicate the direction for movement of the object, and the shaft of the arrow indicates the intended distance of the movement [17].

Translation transformation is the image taken according to the described function in a straight line and in the same direction of a vector or a geometric object. Zembat in [1] Namely, it is function that matches the plane with another by means of one to one correspondence. The movement of a geometric shape or an object from one place to another in a specific rotation and direction is called translation transformation, Aksoy & Bayazit [1].

The marble ornament pattern on the figure above shows a shift in the pattern, moving it to certain distance and direction. Thus, the geometrical transformation seen on the marble ornament above is translation.

### 3.4 Rotation Concept

The making of marble ornament motif can also be attributed to the concept of rotation on two-dimensional figures. The concept of rotation is applied by rotating the patterns that are in accordance with the axis. Rotation is applied on a certain axis that has the same length to the figure that will be rotated, allowing each point in the desired figure to be rotated. Despite being rotated, the size in the ornament motif is not altered at all. For example, consider the marble ornament motif in Figure 7.

![Figure 7. The application of geometry transformation in motif ornament patterns of the marble](image)
Figure 7 explains the application of geometry transformation in the motif ornament patterns of the marble. To making this motif can applied rotation with $0^\circ$, $90^\circ$, $180^\circ$, and $270^\circ$ toward $x$ or $y$-axis in the Cartesian Coordinate.

**Definition** rotation is a type of rigid transformation where a two-dimensional figure is turned into a specified angle and direction about a fixed point called the center of rotation. A rotation is also called *turn*. The rotation turns the figure and all of the points on the figure through a specific angle measuring where the vertex of the angle is called the center of rotation. For a description of rotation, two pieces of information are needed: the center and angle of rotation, and the direction of the rotation; the center of rotation is the only point that is not affected by the rotation Wesslen & Fernandez[17].

While according to[1], Rotation transformation is the function that fixes every one of the points on the plane with another point on the plane. Martin in[1] describes rotation transformation as a function that covers and one to one correspondences all points on the plane with the help of a central point and angle with the points on the plane. Rotation transformation keeps angles and distances which are the dynamics of the plane.

![Figure 8. Rotation](image)

In the ornament patterns the motifs rotate from the axis in a clockwise rotation, indicating that the ornament’s geometrical transformation is created through rotation.

From the statements above, it can be concluded that the patterns in Tulungagung marble are created through geometrical transformations. It cannot be denied that there are still many other forms of geometrical transformation concepts that are applied on the creation of other patterns including the Tulungagung marble ornaments. Therefore, on making marble ornament patterns, Tulungagung has applied the concept of geometrical transformations. Even in the creation of marble ornament patterns, more than one transformation concepts are applied; some geometrical transformation concepts can also be applied at the same time on the same object, such as reflection, dilation, translation, and rotation that are seen on the figures above. From the marble ornament, design student can easily to learning the concept of geometry transformation especially to a student in senior high school because the motif is familiar in the daily life of a student. If the mathematical concept of geometry transformation being understood then can improve student’s achievements in mathematics of the senior high school student.

**4. Conclusion**

The results of this study found that Tulungagung marbles, especially the ornament patterns, contain elements of mathematics. Some elements in the patterns are geometrical; making them a culturally meaningful pattern that was created through geometric and symmetrical transformation. In other words, culturally beautiful ornaments that have mathematically symmetrical geometric shapes are the result of a fusion between mathematics and culture, in which the patterns were created through various geometrical transformations. Geometrical transformation includes shift (translation), reflection, rotation, and enlargement (dilation). The result of this study can be used as a reference to develop learning subject and created an ethnomathematics product on amarble craft so that it can give a significant effect on the learning achievement in mathematics of the senior high school student.
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