Ethnomatematics in Majapahit’s Culture: Geometry Concepts and Pedagogy Reviews in the Life of Mlaten Trowulan Villagers

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Abstract. This study examines the elements of culture, especially the manufacture of pottery of Mlaten Trowulan, East Java Indonesia. It can be used to review the mindset of the Majapahit tribe from the point of view about the pottery artisans show how to make the pottery to the next generation craftsmen. This research is a qualitative research with ethnography method. The results showed that there are 25 types of pottery which has a symmetrical geometric shape. The artisans show how to make the pottery to the elementary school student with some techniques, such as rotating, plating, pushing, and twisting. All techniques have been taught by learning by doing method. The symmetrical pottery model can be obtained from rotating a function f against the x-axis. The function f is obtained from a three-point cubic interpolation with its midpoint as the peak point. In order to develop another pottery model, another transformation function can be used.

1. Introduction
According to Ascher (1991), ethnomathematics is a study of mathematical ideas from the standpoint of traditional society. Meanwhile, other experts define ethnomathematics as mathematics practiced by a cultural group. This practice refers to mathematical concepts that are embedded in certain cultures. This practice also recognizes that all cultures and everyone who develops unique methods can be understood as an attempt to change the reality of the community of a culture (D'Ambrosio, 1990; Orey, 2000). In this perspective, ethnomathematics can be described as a way in which societies from certain cultures use ideas and concepts mathematically through quantitative, relational and spatial aspects of people's lives (Chahine and Kinuthia, 2013). The mathematical perspective validates and determines the whole experience of the community in mathematics which shows that mathematical thinking is in accordance with people's lives. Further proof of this assessment was provided by Orey (2000) who stated that "different cultural paradigms use or work with unique interactions between language and culture in their environment". With this view D'Ambrosio (2006) considers that in the ethnomathematics view, mathematical thinking is developed in different cultures depending on the problems determined through the cultural context.

Ethnomathematics is mathematics related to social, economic and cultural backgrounds (Orton, 1992) practiced by certain societies (Shirley, 1995). Classification can be based on ethnicity, occupational level, age, gender and so on (Gerdes, 1994). A specific society might have been using the concept of math in everyday life, but not formally. As seen in indigenous Zulu society, South Africa,
they use to produce the bead bracelets, cloth, a necklace, picture frames, a belt, marker book, and a headband with a variety of motives (Chahine and Kinuthia, 2013).

Some researchers have also explored ethnomathematics in various regions of Indonesia. As performed by Sabilirrosyad dan Budiarto (2013) who examined about geometry motive woven of Sasak, Budiarto (2012) explored the geometry of traditional house and in carving tongkonan, and Budiarto (2012) explored ethnomathematics in Sidoarjo Indonesia that have implemented the concept of mathematics in building a temple and an inscription, selling in markets, and traditional games. Besides, Kuquk (2013) in his research, explored geometry that exist in motive of carpet produced by Anatolian, Turkey. He found decorative values such as hope, situation, sadness, and belief of Anatolian from line, curve, triangle, rectangle, and circle.

Java is major and native ethnic live in East Java. In Mlaten Trowulan, there are some unique arts and crafts. The famous one of art is Celengan. Celengan is a competition that challenge 2 men who have brave to fight physically. Featured with a shield and little stick made from twisted banana’s bark, those both men fight until one of them run out of energy and get defeated. While the unique crafts in this ethnic group are Kendi and pottery. People make kendi for household object that is used in daily life. Kendi is made from a kind of plant that grows on water. This craft is more made by people in Mlaten Towulan Mojokerto, East Java. While pottery is centered in some region in east Java, they are Tondowulan, Jombang.

Trowulan is one of tourism object in east Java, located in Mojokerto. It’s about 55 km from central city, Surabaya. The village is exited tourism destination mainly for tourist that have interesting in culture. Mainly related to Majapahit relics such as Brahu temple, Tikus temple and Wringin Lawing temple. About 80% of inhabitant of Mlaten Trowulan are pottery craftsman. Therefore, more people here are expert in making potteries with export quality. In the past, making pottery is purposed as daily life need such as gentong for retaining water, kendi as bottle, etc. However, time by time and the development of tourism in Trowulan, value sifted and more directed to decoration that means potteries are produced and used for decoration. For instance decorating park or hotel room. The more exciting is in the village, can be seen process of making pottery from beginning until burning process.

Though the handicrafts workers that is in this village do not understand geometry formally through the level of education, but indirectly they have understand in a different way and can even applied it to produce merchandise that has high selling values. Based on the explanation, it is need to study the ethnomathematics existed in Mlaten Trowulan, especially about geometry concept which is exist in the life of local community.

2. Methods

This type of research is a qualitative research with an ethnographic approach. Qualitative research is used because researchers want to intensively participate in the field, note carefully what happened, conduct reflective analysis of various documents found in the field, and make detailed research reports. Whereas the ethnographic approach is an empirical and theoretical approach that aims to get a description and in-depth analysis of culture based on intensive fieldwork. The results obtained in the form of a description and interpretation of a culture or social group system. Researchers observe these groups and learn about patterns of behavior, habits, and ways of life. As a process, ethnography involves a fairly long observation of a group, in which researchers are involved in the daily lives of respondents or through interviews one by one with members of the group. Researchers study the meaning or significance of each behavior, language, and interaction in groups and examine the cultural elements of Mlaten Trowulan villagers that include aspects of the knowledge system, social system, living equipment system, livelihood system and the arts system.

3. The Results and Explanation

Based on the analysis of the domain and taxonomy, obtained from 16 kinds of pottery that existed in Mlaten Trowulan, there are 12 kinds of them included in geometrical shape. Potteries had a main shape of square, rectangular, equilateral triangles, ellips, circle, polygon, tube, beams, cube, pyramid, cone, ball, semisphere, truncated cone, and truncated pyramid. Unfortunatelly, there are 6 categories of pottery that included in non-geometric shape. Those potteries had a major in the form of animal, a genus of
plants, as natural element part of the body, and a tool. In the other words that variety of ornamental in
the form of pottery as a certain symbols. So, it is not contain the geometrical shape.

Pottery on a Mlaten has its own concept of some geometry shape such as a circle, a square,
and equilateral triangle. They made the shapes by using simple tools such as thread, sticks, and boxes,
and apply ways that nobody on learning mathematics. The concept of geometry that were on the pottery
are: a circle, a triangle, square, rectangular, ellips, polygon, a tube, a ball, cone, pyramid, half of a sphere,
cut cone, and cut pyramid. While the concept of geometry that was found in pottery motives namely: a
line, a triangle, square, rhombus, rectangular, trapezoid, circle, and half circle, and the use of the
principle of symmetry, rotation, translation, and reflection. Besides, pottery craftsman have their own
concept about some geometry shape such as circle, square, and equilateral triangle.

The results of research supported by the findings Rachmawati (2012) who explored
ethnomathematics of Sidoarjo. It is mentioned that the mathematical conception as a result the activity
of designing an instrument as well as makes patterns that are found on earthenware traditional and
equipment, some of them are basic form irik, kalo, and ebor if that is shaped half of a sphere with ledges
patterned circle, layah (cobek) with a circular shape, gentong with ellips shaped, capil with cone-shaped,
ilir and kelasa shaped like a rectangle, as well as of relics culture having other forms of geometry. In
addition, Hopper (2000) also mentions that pottery is solid geometry or to the geometry of three
dimensions. It means that the pottery have the values of geometry.

This research on the motive was supported by the findings Sabilirrosyad (2014) who examines
motives on a fabric woven of Sasak Sukarara, Central Lombok. His research in the form of 40 motives
that have the concept of geometry namely points a line, triangle, square, rectangle, a hexagon, octagon, reflection; translation, of rotation, and dilatation. Result of this research was also
supported by the findings of Embong (2010) has namely in weaving there are in the form of a
mathematical conception of the application of the concept of transformation, measurements, estimation;
accuracy and equality. The concept of transformation, reflection, in the form of translation, of rotation,
and dilatation often used in makes patterns motives. Besides, historical study conducted by Ascher
(1991) on Incas pottery also shows that motif on that pottery have the geometry concept as translation,
reflection and rotation.

Mathematically, symmetrical earthenware models can be obtained by rotating a function \( f \) against
the x-axis. The function \( f \) is obtained from a cubic interpolation of three points with their midpoints as
the top points. To develop into another pottery models, function transformation can be used.

![Picture 1](image)

Every handicrafts can be formed by the graph of a function \( f \) (for example, as Picture 1) which is rotated
toward x-axis. Let given five points \((x_1,y_1), (x_2,y_2), (x_3,y_3), (x_4,y_4), (x_5,y_5)\) with \(x_1 \leq x_2 \leq x_3 \leq x_4 \leq x_5\). By using cubic interpolation three points with the midpoint as its extreme point (Hamming,
1973; Bartels, et all: 1998; and Burden, et all: 1997), the function can be written by the following formula

\[
f(x) = \begin{cases} 
    ax^3 + bx^2 + cx + d, & \text{if } x \in [x_1, x_3] \\
    px^3 + qx^2 + rx + s, & \text{if } x \in [x_3, x_5] 
\end{cases}
\]

with

\[
\begin{bmatrix} 
    x_1^3 & x_1^2 & x_1 & 1 \\
    x_2^3 & x_2^2 & x_2 & 1 \\
    x_3^3 & x_3^2 & x_3 & 1 \\
    3x_2^2 & 2x_2 & 1 & 0 \\
\end{bmatrix} \begin{bmatrix} 
    a \\
    b \\
    c \\
    d 
\end{bmatrix} = \begin{bmatrix} 
    y_1 \\
    y_2 \\
    y_3 \\
    0 
\end{bmatrix} \quad \text{and} \quad \begin{bmatrix} 
    x_4^3 & x_4^2 & x_4 & 1 \\
    x_5^3 & x_5^2 & x_5 & 1 \\
    3x_4^2 & 2x_4 & 1 & 0 \\
\end{bmatrix} \begin{bmatrix} 
    p \\
    q \\
    r \\
    s 
\end{bmatrix} = \begin{bmatrix} 
    y_4 \\
    y_5 \\
    0 
\end{bmatrix}.
\]
Now, let \( A = \begin{bmatrix} x_1^3 & x_1^2 & x_1 & 1 \\ x_2^3 & x_2^2 & x_2 & 1 \\ x_3^3 & x_3^2 & x_3 & 1 \\ 3x_2^2 & 2x_2 & 1 & 0 \end{bmatrix} \) then by using Cramer’s Rule (Anton, & Rorres, 2010), we get
\[
a = \frac{\det A_1}{\det A}, \quad b = \frac{\det A_2}{\det A}, \quad c = \frac{\det A_3}{\det A}, \quad d = \frac{\det A_4}{\det A}
\]
Where, \( A_j \) is the matrix obtained by replacing the entries in the \( j \)th column of \( A \) by the entries in the matrix \( \begin{bmatrix} y_1 \\ y_2 \\ y_3 \\ 0 \end{bmatrix} \). On the other hand, if we let \( B = \begin{bmatrix} x_3^3 & x_3^2 & x_3 & 1 \\ x_4^3 & x_4^2 & x_4 & 1 \\ x_4^3 & x_4^2 & x_5 & 1 \\ 3x_4^2 & 2x_4 & 1 & 0 \end{bmatrix} \) then by applying Cramer’s Rule,
\[
p = \frac{\det B_1}{\det B}, q = \frac{\det B_2}{\det B}, r = \frac{\det B_3}{\det B}, s = \frac{\det B_4}{\det B}
\]
Where, \( B_j \) is the matrix obtained by replacing the entries in the \( j \)th column of \( B \) by the entries in the matrix \( \begin{bmatrix} y_3 \\ y_4 \\ y_5 \\ 0 \end{bmatrix} \). By moving the provided points in two dimensional direction which satisfy \( x_1 \leq x_2 \leq x_3 \leq x_4 \leq x_5 \), then we would obtain various form of different graph or other graph. In the following graphs (Picture 3 – 6) are the examples of the function resulted by moving the points.

Example 1.
Given function \( f: [0,5] \rightarrow \mathbb{R} \) with
\[
f(x) = \begin{cases} \frac{-1}{4}(x - 2)^3 - \frac{3}{4}(x - 2)^2 + 2, & \text{if } x \in [0,3] \\ \frac{1}{4}x^2 - 2x + \frac{19}{4}, & \text{if } x \in [3,5] \end{cases}
\]
The graph of the function is shown as picture 7.

![Picture 7]

By rotating the graph toward x-axis, we would obtain the following surface as presented in Figure 8. We are also able to elicit the other graph by conducting function transformation.

Pedagogically, the pottery craftsman had a concept of how to make a circle and determine its center and how to make squares and triangles. The pottery’ artisans teach their knowledge about geometry to the next generation through the activity of making pottery to elementary school children. The technique used to make pottery that has curved sides with the technique of turning, slabling, pushing, and twisting with a learning approach while doing. This learning conditions that allow contextual meaning based on experience as a member of a cultural society are one of the basic principles of the theory of constructivism (Zhang and Zhang, 2010).

Educators and researchers conclude that mathematical knowledge is also obtained outside of structured systems of mathematics learning such as school (Bandeira & Lucena, 2004; Duarte, 2004; Knijnik & Oliveira, 1993; Rosa & Orey, 2010). In this perspective, mathematical ideas applied in a unique socio-cultural context refer to the use of mathematical concepts and procedures obtained outside of school and the acquisition of other mathematical skills apart from school.

Budiarto (2015) proposed five possibilities for ethno-mathematics to enter the curriculum and have the same relative role in mathematics formally namely; (1) school mathematics substitute; (2) school mathematics supply; (3) stepping stones into school mathematics; or (4) motivation for school mathematics and (5) as a local content of school mathematics and a means of developing character. The results of ethno-mathematics research in Indonesia, shows that ethno-mathematics can promote more culture and at the same time for learning mathematics.

4. Conclusion
Mathematical concepts that emerge as a result of the culture of the Mlaten Trowulan community group indicate that there has been a relationship between mathematics and their culture, that is, the culture of majapahit, which has always been hereditary, always shapes mathematics and so does mathematics also forms culture so that they interact and form ethnomatematics. Through ethnomatematics, people can see various cultures in a mathematical perspective. Efforts to preserve this culture are carried out pedagogically through learning in primary schools and its development through a three-point cubic interpolation with its midpoint as the high point.

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