Ethnomathematics: Mathematics in Batik Solo

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Abstract. All people in the world have their culture in living the life. These culture is built of activities they do every day in a long time. Batik is one of traditional art of Indonesia’s cultural heritage. It has many varieties, one of them is Batik Solo. It also has many motifs. Ethnomathematics is a study about culture and mathematics concepts. This research is to explore Batik Solo and to find the mathematics concept in it. Using ethnography method, the data collection uses principles in ethnography namely observation, interview, and documentation. The results of the research in this article are twofold. Some Batik Solo motifs contain mathematical elements, especially geometric material, namely the principles of translation and reflection. Besides, that there are vertical and horizontal lines as well as perpendicular and parallel lines included. The mathematical concept, especially the geometry used in the making of Batik, is the use of the tessellation or tiling principle. The tessellation principle is the basis for the development of the Solo batik motifs.

1. Introduction
The lack of students’ mathematical abilities in solving reasoning and problem-solving problems due to the lack of giving a portion of reasoning and solving problems in teaching materials and practice questions to students is one of the reasons why Indonesia is ranked low [1]. This results in concerns about the ability of students to apply mathematics to solve problems in everyday life, because the purpose of studying mathematics in school is not only to equip students with conceptual mathematics as a preparation for students in facing school exams and national exams, but also to prepare students to be able to use mathematics and mathematical thinking patterns in everyday life and learn various knowledge [2]. Mathematics was created to solve problems. Mathematics exists in every human activity even though it does not appear explicitly [3].

The role mathematics is even important for someone because those who understand and can do mathematics are seen as having more opportunities and choices in determining their future. Mathematical skills open the door to a productive future, but on the other hand a weak mathematics keeps the door closed. Mathematics has actually been used by everyone in his life. However primitive
a society is, mathematics is part of its culture. Therefore, mathematics learning today must be linked to
the real context of students' daily lives [4]. Learning mathematics would be well when a teacher in
educating him/her social and cultural interactions through dialogue, language, through the
representation of symbolic meaning in mathematics. Learning that is relevant to that is contextual
learning. Learning with a contextual approach is a learning concept that helps teachers relate the
material they teach to students' real-world situations and encourages students to make connections
between the knowledge they have and apply it in their lives as family and community members [5].

Teaching mathematics for everyone should be adapted to their culture. For that we need a
connection between mathematics outside of school and school mathematics [6]. One of the ways
it offers is by utilizing the ethnomathematics approach as the beginning of formal mathematics teaching
that is in accordance with the level of development of students who are at the concrete operational
stage [7]. The same thing was put forward that the presence of culture-based mathematics would make
a big contribution to school mathematics, because schools are different social institutions so that it
allows socialization between several cultures [8]. Culture will influence individual behavior and have
a big role in the development of individual understanding, including learning mathematics [9].
Ethnomathematics connects mathematics and culture [10].

Mathematical activities are activities in which there is a process of abstracting from real
experiences in everyday life into mathematics or vice versa such as grouping, counting, measuring,
making patterns and so on. Meanwhile, ethno-mathematical forms are various results of mathematical
activities that are owned or developed in the life of a particular society. Ethnomathematics which is
meant in this research is a mathematical activity that develops in Solo society which includes
mathematical concepts in cultural heritage in the form of batik cloth motifs. Solo is the other nam of
Surakarta, a small city in central Java province of Indonesia.

Indonesian batik was officially recognized by UNESCO as an intangible cultural heritage since
2009 [11]. Batik in Indonesia is considered to have a wealth of symbols and philosophies of life for
the Indonesian people. However, Batik is rich in national culture and philosophy. Batik Solo is one of
the cultural products of Surakarta. There are various kinds of Surakarta batik patterns including Parang
Motif, Kawung, Kawat, Sidomukti, Truntum, Satrio Manah, and Batik Semen Rante. Each of the
various features has its own meaning. Mathematics is also a cultural product. Therefore, it is necessary
to research the mathematical concepts contained in Solo batik. It is hoped that the typical Solo batik
motif artwork can be used as a medium of learning which is a learning resource to add insight and
learning motivation for students.

Solo Batik motifs are arranged in a rhythmic and dynamic pattern, with a batik background filled
with cocohan, namely dots, and short fine lines. Solo Batik motifs depict many natural themes in the
form of flora and fauna typical of the Keraton region. The factors that strongly influence the
emergence of various Solo batik motifs are the geographical location, nature, beliefs and customs, and
the life style of the area, the surrounding natural conditions and the relationship between the batik
areas. The background of the farmer's life becomes the identity of Batik Solo itself.

The main elements of art in Batik Solo are more determined by colors, fields, combinations of lines
and points, and textures. Furthermore, the artistic art elements in the Solo batik cloth create a complete
and harmonious beauty. The brief description of Solo Batik above, illustrates that the Solo people have
used mathematics in their survival, especially in determining the combination and location of colors,
fields, lines and points, and textures so as to create a complete and harmonious beauty in the batik
painting that is their trademark. These things are of interest to explore the mathematical concepts
contained in the Solo Batik motifs in relation to the geometry of transformation.

2. Research Methods
This research is an exploratory research type, which explores the form of batik motifs that can be used
in the process of learning transformation geometry. While the approach used in this research is an
ethnographic approach, namely an empirical and theoretical approach that aims to obtain an in-depth
description and analysis of culture based on intensive fieldwork [12].
According to the type and approach of this research, namely the ethnographic approach, the research instrument is the researcher himself (human instrument). In this case the researcher acts as a data collector and his role cannot be replaced, so that the role of the researcher is as the main instrument. The researcher as the main instrument is also supported by other instruments, namely: field notes, interview guidelines, observation guidelines, and documentation. This research was conducted from January 2018 to June, in the Solo region, including Solo Batik production house with 2 resource persons managing production houses or batik craftsmen; and Solo batik art cultural heritage sites.

After the data is collected and reduced until valid data is obtained through triangulation of sources, methods and time, the next stage is domain and taxonomic analysis. Domain analysis was conducted to obtain a general and comprehensive picture of the object of research, Batik Solo, along with determining the category and grouping the data according to the domain. Furthermore, the taxonomic analysis is carried out by describing the selected domains into more detail based on the mathematical concepts found in Batik Solo which are presented in a matrix form. The mathematical concepts referred to in this study are mathematical concepts.

### 3. Result and Discussion

#### 3.1. Mathematical concepts in Solo Batik Artwork

In general, batik motifs consist of four types, namely geometric motifs, non-geometric motifs, samplers, and coastal batik [13]. This study explores the geometric types of batik originating from Solo, namely Batik Parang, Batik Kawung and Truntum.

A point is a constituent of lines, fields, spaces, and even Hyperspaces. The concept of a point was first put forward by Euclid in his book Elements which defines a point as something that has no part - that which has no part. A point is a 0-dimensional mathematical object that can be specified in the n-dimension by using certain coordinates [14]. A line is a two-dimensional object that can be made by connecting two points, some even say that a line is a collection of dots. A plane is a two-dimensional object which is a flat surface that has no sides and can be extended in any direction [15] bounded by a number of line segments or sides [14]. Planes are for example ellipses, circles, and rectangles. Artistic forms in batik are generated through the transformation of points, lines or flat planes through translation and reflection. The geometry concept contained in batik is in the form of points, lines and flat planes. These flat areas are for example ellipses, circles, and rectangles. The artistic form in batik is produced through the transformation of points, lines or flat planes through translation, reflection, and tessellation.

#### 3.1.1. Translation, Reflection, and Tessellation of Batik Solo

Translation is a shift or displacement of all points on the geometric plane in the same extent and direction. In learning the concept of translation, the teacher could use the products of batik activities such as making the batik Parang above into the mathematics learning process. Observing the shape and size of each line motif on the Parang batik, there are lines that shift and do not change in shape and size, but only the location of the motif changes, meaning that the coordinates of the batik motif after experiencing a shift will change from the original coordinates.

![Figure 1. Translation in Motif Parang](image)
If the position of the first line motif is located at the center point O (0,0) then with a shift that is 3 cm away, the position of the second line motif can be known through the concept of translation. If point A (x, y) is translated by T (a, b), the coordinate of the translation result is A'(x + a, y + b), the notation is written:

\[ A(\begin{array}{c} x \\ y \end{array}) \xrightarrow{T(a,b)} A'(\begin{array}{c} x+a \\ y+b \end{array}) \]

Reflection is the reflection of all points on the geometric plane towards a line with the same distance. In learning, teachers can use Kawung and Truntum batik motifs as examples of the application of reflection in culture. The Kawung batik motif has a shape in the form of circles like Kawung fruit which are arranged neatly and geometrically. The Truntum batik motif consists of the body and tail of an eagle placed between two wings. Mathematical elements in Kawung batik can be approached from elliptical shapes while Truntum batik can be approached from semi-circular shapes. In Kawung batik, an ellipse is reflected with vertical and horizontal lines so that the Kawung batik motif is formed. This is also the case with Truntum batik making, which is a semi-circular shape reflected vertically.

![Figure 2. Reflection in Motif Kawung](image)

Tessellation is a special pattern consisting of geometric shapes arranged without dividers or distances to cover a flat plane. Geometry shapes that can correlate for example squares, triangles, regular pentagons, regular hexagons and can also be curves. There are only three regular polygons that can correlate flat planes, namely triangles, squares, and regular hexagons.

![Figure 3. Tessela in Motif Siodomukti](image)
The application of tessellation in Sidomukti batik is that there are squares of the same size which are arranged without dividing to cover the surface of the batik. Batik design with the application of tessellation in Sidomukti batik is able to help students to achieve competence in understanding geometric shapes based on existing tessellation principles.

3.1.2. Batik Solo in Learning Mathematics
Mathematical and ethomathematical concepts that contain cultures must be integrated in the curriculum. The learning tools also need to be prepared [16]. Culture-based learning is a model of learning approach that prioritizes student activities with a variety of cultural backgrounds, is integrated in the learning process of certain fields of study, and in the assessment of learning outcomes, various forms of assessment can be used. Furthermore this learning is known as ethnomathematics. Culture-based learning is divided into 3 things, namely learning about culture, learning with culture, and learning through culture.

Culture-based learning must pay attention to four things, namely the substance and competence of the field of study, meaning and learning process, assessment of learning outcomes, and the role of culture. Culture-based learning emphasizes the achievement of an integrated understanding rather than just a deep understanding. The process of creating meaning through a culture-based learning process has several components, namely meaningful tasks, active interactions, explaining and applying science contextually, and utilizing various learning resources.

Some Solo Batik motifs such as Parang, Kawung, Sidomukti, Sawat, truntum and Satrio Manah motifs can be used as a medium that uses the principles of translation and reflection in transformational geometry. Students can be asked to identify any motives that utilize the principles of translation and reflection. In addition, students can be asked to identify what geometric shapes are contained in the batik motif. Several other mathematical elements that exist in the Solo Batik motif include vertical and horizontal lines, perpendicular lines, and parallel lines.

The use of Batik in learning has been done, among them in basic learning used in line identification, angle identification, and plane geometry introduction in Pasuruan, East Java [10]. Batik motif also plays an important role in supporting students in implementing transformation learning and increasing student motivation to learn in Sidoarjo, East Java[17]. Ethnomathematics using batik art in learning the concept of translation and reflection on transformation geometry, as well as the use of tiling principles are also carried out in schools in Indramayu, West Java [18]. Learning not only aims to improve students' cognitive abilities but also to enhance student creativity. Student creativity could be improved by culture-based learning by utilizing batik motifs on student worksheets [19]. Learning in schools that relies on the ethnic cultural approach of the local community will be able to foster innovation and creativity [20]. The children's innovations and creations will be able to encourage leadership skills and character in the era of global communication [21]. Solo batik motive and creativity are two causal entities between mathematical abilities and the culture of the Solo people in engaging in entrepreneurship.

4. Conclusion
Ethnomathematics is carried out using a broad range of mathematical concepts related to various mathematical activities. Activities carried out include grouping, counting, measuring, designing buildings or tools, playing, determining locations, and so on. Mathematical activities that are usually considered abstract by students become more concrete by being associated with elements of local culture. Solo batik is one of the local cultural products. In Solo batik motifs, mathematical concepts are found, especially in geometry, namely points, lines and planes. This line motif can be used in learning transformation geometry, namely translation, reflection, and the principle of tessellation.

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