

Exploring Mathematical Concepts in Batik Sidoluhur Solo

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Abstract

Many ethnomathematical studies examine the existence of mathematics concepts in Indonesian cultural products, in which batik is one of them. However, there is a lacuna from previous studies that examine the existence of mathematical concepts in Batik Sidoluhur. Therefore, the current study explores mathematical concepts in Batik Sidoluhur, such as geometry, algebra, arithmetic, and statistics. The study used ethnography as an approach by answering four principal questions, namely "where do I start looking?", "how do I find it?", "how do I recognize that it has found something significant?" and "how to understand what it is?". By answering the questions, researchers managed to examine the mathematical concept contained in Batik Sidoluhur. From the four mathematical concepts explored, namely geometry, algebra, statistics, and arithmetic, only the geometry concept is contained in Batik Sidoluhur and confirmed by a geometry expert. Sub-concepts of geometry found are (1) sub-concepts of geometry transformations such as translation and reflection, (2) plane geometry such as rhombuses, rectangles, triangles, and circles, and (3) congruence. Hopefully, the findings can be used to promote Batik Sidoluhur to students from elementary school level to secondary level through contextual and meaningful mathematics learning. This article also explained how to use the context of Batik Sidoluhur in mathematics learning.

Keywords: Batik Sidoluhur, Ethnography, Ethnomathematics.

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INTRODUCTION

Batik is an Indonesian cultural heritage with a very distinctive meaning and philosophy, the result of unique and beautiful artwork with each region has its own characteristics. Dhenabayu et al., (2018) stated that after being established by the United Nations Educational, Scientific and Cultural Organization (UNESCO) as a native culture of Indonesia, people's interest in batik increases. It can be noticed by the increasing use of batik in various types of clothing, both formal and nonformal, and various decorations containing batik elements. Therefore, the effort to conserve batik needs to be proclaimed continuously to maintain its sustainability, one of them is Batik Sidoluhur.

Batik Sidoluhur

Batik is an Indonesian technique of wax-resist dyeing applied to the whole cloth (UNESCO, 2009). This technique originated from the island of Java, Indonesia (Gaffney, 2021). In the perspective of its history, Ningrum (2020) stated that the motif of Batik Sidoluhur was created by Ki Ageng Henis, grandfather of Panembahan Senopati, the founder of the Islamic Mataram kingdom, as well as the grandson of Ki Ageng Selo. It is said that Ki Ageng Henis specially made Sidoluhur's motif for his descendants. The hope was that the wearer could be careful and think noble. According to KRT Winarso Kalinggo (2010), the motif was then manifested into a piece of cloth by Nyi Ageng Henis.

Therefore, it is intended that the concentration is maintained, and all prayers and hopes can be poured out in full to the batik cloth.

Philosophically, the Batik Sidoluhur motif has a philosophy of nobility. This in line with the opinion of Taufiqoh et al., (2018), which states that the Batik Sidoluhur motif has a meaning that is in the form of hope that the person who wears it can be a role model in society and can reach a higher position. The color on Sidoluhur fabric is *soga* or brown color. At first, the color *soga* instead of orange color is a combination of red and yellow. Sidoluhur motif symbolizes glory; the meaning is similar to Sidomulyo motif because noble means equal to noble.

Batik Sidoluhur has a distinctive motif with various decorations in the form of houses (*joli*), wings of garuda birds, and flora-fauna. Although the number of batik makers in Indonesia certainly makes decorative motifs on batik sidoluhur has an unequal shape, each batik has a different way, and point of view in making batik, especially with batik has been developed in the community. Regardless, batik makers will not leave the characteristics that exist in Batik Sidoluhur motifs.

Based on the results of an interview with Agus Triwarso (owner of Sidoluhur Boutique, Laweyan) on September 23, 2020, the difference from Batik Sidoluhur (Figure 1) motifs with other Sido Batik such as Sidomulyo Batik (Figure 2) and Sidomukti Batik (Figure 3) is located in the background color used in Sidomulyo set in cream and Sidomukti set in *ukel* (see Figure 3). However, the three types of batik have the same shape in the term of pattern.



Figure 1. Batik Sidoluhur



Figure 2. Batik Sidomulyo



Figure 3. Batik Sidomukti

Batik Sidoluhur Conservation Efforts

In some areas in Surakarta, most people use Batik Sidoluhur motifs, specifically at a traditional wedding party. According to the authors' interview result with Asti Suryo Astuti, SH, KN, as assistant manager of the Museum Danar Hadi Surakarta on January 14, 2021, Mrs. Asti said that many people nowadays could not distinguish Batik Sidoluhur from other batiks. This is very concerning because Batik Sidoluhur, as an Indonesian cultural entity, especially the people of Surakarta (Central Java), is not well recognized. So it is likely that efforts for the conservation of Batik Sidoluhur culture become very heavy.

The uniqueness of Batik Sidoluhur is seen in the patterns, colors, ornaments, and fillings on each sheet, where each region has its uniqueness. Based on its uniqueness, Batik Sidoluhur needs to be conserved to maintain its uniqueness, where one of the ways is to introduce it to the younger generation. One of the strategies used is to integrate Batik Sidoluhur in learning materials in schools, specifically in mathematics education. As a result, students will be more familiar with Batik Sidoluhur motifs so that the efforts to preserve the batik motifs can be made as early as possible. In this case, the role of mathematics education researchers becomes crucial to explore what

mathematical concepts are contained in Batik Sidoluhur. The concepts that were successfully dug can be the material to introduce Batik Sidoluhur more easily. In addition, mathematics learning that uses Batik Sidoluhur as the context in it makes the learning process more meaningful because the context used is close to the daily life of students, especially students in the Surakarta area. Therefore, ethnomathematics is relevant to be used to examine mathematical concepts contained in Batik Sidoluhur.

Ethnomathematics

In a terminological aspect, ethnomathematics comes from the word "ethno" which means sociocultural context, and "mathematics," which means mathematical context (Katsap, 2017). While by definition aspect, D'Ambrosio (1999) defines ethnomathematics as a study that connects mathematics and culture. In another literature, Powell (2009) defines ethnomathematics as a discipline that emerged from a politically engaged multicultural perspective on mathematics and mathematics education. Based on those two definitions, it can be drawn the common thread that ethnomathematics is a study of the interrelationship between culture and mathematics or mathematics education. Furthermore, D'Ambrosio also stated that ethnomathematics' purpose is to contribute to understanding culture from a mathematical point of view and, more importantly, as an appreciation to connect these two things.

In the current study, the context of ethnomathematics is used as an effort to explore and unveil the mathematical concepts of Batik Sidoluhur. These concepts can later be used as materials to introduce Batik Sidoluhur as a national culture, and in the context of mathematics, learning can make it more contextual to study by students.

From previous research, there have been many studies that examine the mathematical concepts of batik. Some of which are research conducted by (1) Samijo & Yohanie (2017), who studied the mathematical concept of Batik Tenun (Non-Machine Looms / ATBM) typical of Kediri City, (2) Arwanto (2017) who studied the mathematical philosophy of Batik Trusmi Cirebon, (3) Sudirman et al., (2018) who studied the mathematical concept of Batik Paoman, (4) Mahuda (2020) which examines the philosophical aspects of Batik Lebak, and (5) Afifah et al., (2020) who studied the mathematical concept of Batik Gajah Mada Motif Sekar Jagad Tulungagung. However, from many previous types of research related to the excavation of mathematical concepts in batik culture, no research has been found related to the exploration of mathematical concepts in Batik Sido, especially in Batik Sidoluhur has a strong meaning in cultural values in Indonesia, especially in Surakarta. Therefore, it is considered necessary to conduct studies related to mathematical concepts in Batik Sidoluhur as an effort to conserve batik as a culture in Indonesia. Conservation efforts of Batik Sidoluhur require intervention from various sectors, one of which is sector education, so that from an early age, student have known their cultural roots, namely Batik Sidoluhur.

From the description above, the research questions that arise are exploring mathematical concepts in Batik Sidoluhur and the mathematical concepts contained in Batik Sidoluhur. Therefore, this research aims to describe the process of exploration of mathematical concepts in Batik Sidoluhur and describe the mathematical concepts contained in Batik Sidoluhur.

RESEARCH METHOD

The current study is ethnomathematics by using an ethnography approach where four principal questions must be answered namely "where do I start looking?", "how do I find it?", "how do I recognize that it has found something significant?", and "how to understand what it is?" (Prahmana & Ubiratan, 2020). Therefore, the design of this study is based on these four questions (see Table 1).

Table 1. Research Design

Principal Questions	Initial Answer	Specific Point	Specific Activity
Where do I start looking?	Observation begins by analyzing the place where There is Batik Sidoluhur Solo	Culture	Conducting interviews with people who know Batik Sidoluhur Solo Analyzing how Batik Sidoluhur motifs.
How do I find it?	Investigating the motif of Batik Sidoluhur directly	Alternative Thinking	Determining what mathematical concepts are contained in Batik Sidoluhur motifs.
How do I recognize that it has found something significant?	Evidence (results) think alternatives are processed beforehand	Philosophy Mathematics	Identify what mathematical concepts are contained in Batik Sidoluhur motifs. Motif inside Batik Sidoluhur Solo, there is a mathematical concept in it.
How to understand what it is?	It is essential for culture, and it is crucial for maths.	Anthropological Methodology	Describes the connectedness that occurs between two systems of knowledge (culture and mathematics) Describing mathematical concepts in Batik Sidoluhur Solo motif

The data collection process was conducted from September 23, 2020, to January 15 2021, in various places such as batik shops, universities, and batik museums in Surakarta. The object in this study is the mathematical concept contained in Batik Sidoluhur. The concepts studied are based on four prominent mathematics branches: geometry, algebra, arithmetic, and statistics (Rubenstein & Schwartz, 1999). In addition, the subject of this study was Batik Sidoluhur.

The type of data in this study is qualitative data consisting of observation data, interview data, and documentation data. To obtain the data, the data collection technique is observation techniques to observe mathematical forms/concepts in Batik

Sidoluhur, semi-structured interview techniques used to strengthen observation data, and documentation techniques to document both the interview process and batik motifs observed. Specifically for the interview technique, the interview was conducted with four mathematicians (who hold the title of doctor) from a private university in Indonesia consisting of one geometry expert, one arithmetic expert, one algebraist, and one statistician four concepts in Batik Sidoluhur.

In addition to researchers as the primary research instrument, another instrument was also used to obtain desired data, namely a semi-structured interview draft that consisting of two points which are (1) the existence of mathematical concepts in Batik Sidoluhur and (2) the possibility of whether Batik Sidoluhur can be used as a context to teach mathematics (geometry, algebra, arithmetics, and statistics). The instrument was conducted a validity test using Aiken's Value validity test by involving two experts to assess the draft (Retnawati, 2016). The content validity index (CVI) obtained an average value of all instrument items was 0.81 or classified as high to be used in this study.

The data obtained will be processed through three stages: data reduction, data presentation, and conclusion drawing (Sutama, 2019). Then the data were analyzed based on mathematical and Sidoluhur Batik knowledge by authors to see the existence of mathematical concepts in the batik. Next, the experts confirmed the analysis results as a form of data validity test (triangulation of data sources).

RESULTS AND DISCUSSION

Where do I start looking?

This research began by finding out where Batik Sidoluhur can be found, which finally found a boutique named Butik Sidoluhur, located at Kampong Batik Jl. Sidoluhur No. 36, Laweyan, Kec. Laweyan, Surakarta City, Central Java 57148, Indonesia. Furthermore, the authors conducted interviews with boutique owners named Agus Triwarso (72 years), who has more than 50 years of experience in the field of batik typical of Solo, related to the value and philosophy of Batik Sidoluhur and obtained results as described in the introduction section of this article. In addition, this interview was also conducted to see samples from Batik Sidoluhur, which was later used as a study material in this study.



Figure 4. The Interview Process with Agus Triwarso

Based on the results of interviews related to samples from Batik Sidoluhur that will be studied in this study, the chosen Batik Sidoluhur is the one that has a black background and is a type of batik made by stamping. The motif of batik is divided into

three parts, namely the flora motif (Figure 5.), Garuda bird wing motif (Figure 6.), and house/loji motif (Figure 7.).



Figure 5. Batik Sidoluhur with Flora and Fauna Motif



Figure 6. Batik Sidoluhur with Garuda Bird Wing Motif



Figure 7. Batik Sidoluhur with House Motif (Loji)

How do I find it?

Of the three batik motifs that have been chosen, the authors began to make observations related to what mathematical concepts are contained in the three motifs. Then, authors consisting of two people, analyze the relationship of the motifs of the three batiks with the mathematical concept that has been determined. The summary of the authors' observations can be seen in Table 2.

Table 2. Mathematical analysis of concepts by authors

Concept	Concept Existence	Sub-Concepts	Topic
Geometry	Yes	Geometry Transformation	Reflection Translation
		Plane Geometry	Rhombus Rectangle Triangle Circle
Algebra	No	-	-
Arithmetic	No	-	-
Statistics	No	-	-

How do I recognize that it has found something significant?

Based on the results of initial analysis by authors related to mathematical concepts as in Table 2, it was found that the four mathematical concepts studied, only the concept of Geometry were found. As for the obtained concept of geometry, the authors found two sub-concepts: geometry transformation consisting of reflection and translation and plane geometry consisting of rhombus, rectangle, circle, and triangle.

According to the authors' analysis results, the sub-concept of geometry transformation on the topic of reflection is found in the motif of the house/joli. Principally, reflection is one of the geometric transformation shapes in which a mapping from a Euclidean space is an isometry with a hyperplane as a set of fixed points; this set is called the axis plane of reflection (Martin, 1982). In the motif, if it is drawn a vertical imaginer line from the top end of the house to the midpoint of the house's base, then it can be seen that the line becomes a symmetrical line that divides the motif of the house into two equal parts. So, if taken any point on one side of the house motif, then the point will have the closest distance to the imaginer line, which is the same as the corresponding point's distance on the reverse side (see Figure 8.). The topic of reflection can also be seen in the flora motif (see Figure 9.) and fauna (butterfly) motif (see Figure 10.). The concept of reflection on batik is also found in the results of previous research, namely in Batik Bali, Batik Kawung, and Batik Ngawi (Faiziyah et al., 2021; Fathikhin & Wijayanti, 2020; Irawan, Lestari, Rahayu, & Wulan, 2019).

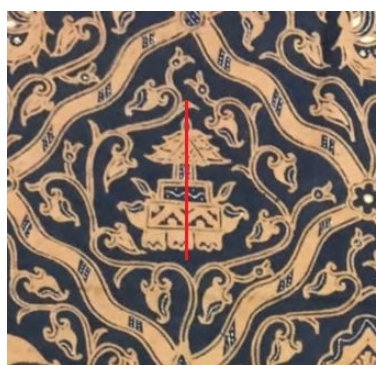


Figure 8. House Motif

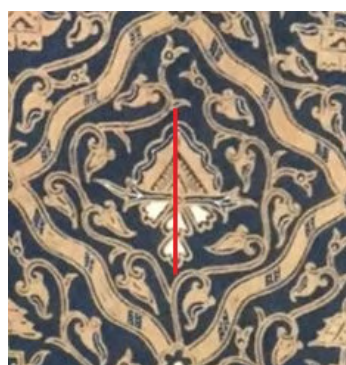


Figure 9. Flora Motif

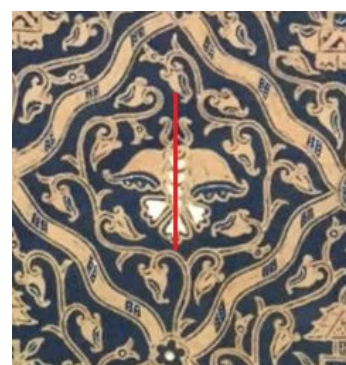


Figure 10. Fauna (Butterfly) Motif

Another topic of geometry transformation found in Batik Sidoluhur is the topic of translation. The translation is a geometric transformation that moves every point of a figure or space by the same distance in a given direction (Berg, Cheong, Kreveld, & Overmars, 2008). Shifting or moving the batik motif to a specific position clearly illustrates that the concept of translation has been applied in the manufacture of batik motifs. Translation on Batik Sidoluhur can be found in some motifs such as Rumah/Joli (Figure 11.), Flora (Figure 12.), Fauna (Figure 13.), and Garuda Bird Wing Motif (Figure 14.).



Figure 11. Translation in House Motif



Figure 12. Translation in Flora Motif



Figure 13. Translation in Fauna Motif

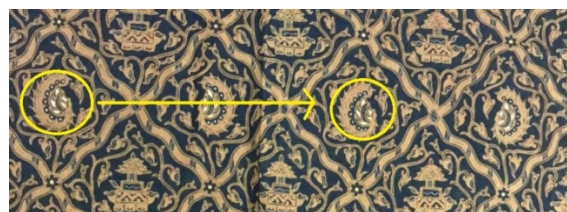
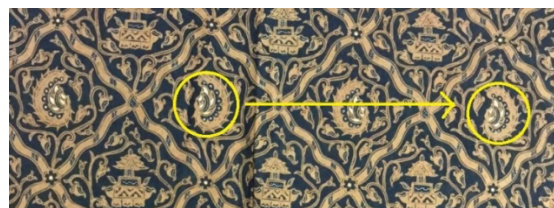


Figure 14. Translation in Garuda Bird Wing Motif

Another geometry concept found is plane geometry, where shapes are found resembling rhombus, rectangle, circle, and triangle. By definition, a rhombus is a quadrangular split with two parallel sides (Tavener, 1933). While the rectangle is quadrangular, which has two pairs of parallel sides, and the size of one of the angles is 90° (Tulloch, 1997). The next is the definition of a circle as a set of points equally distanced to a given point (Johnson, 1929). Lastly, a triangle is a polygon consisting of three lines and three corners (Yiu, 2002). Based on the results of the review by the authors related to the type of Batik Sidoluhur studied in this study, it was found that

there are several forms of motifs in the batik that correspond to the four definitions that have been submitted. For more details can be seen in the motif Of House / Loji (see Figure 15).

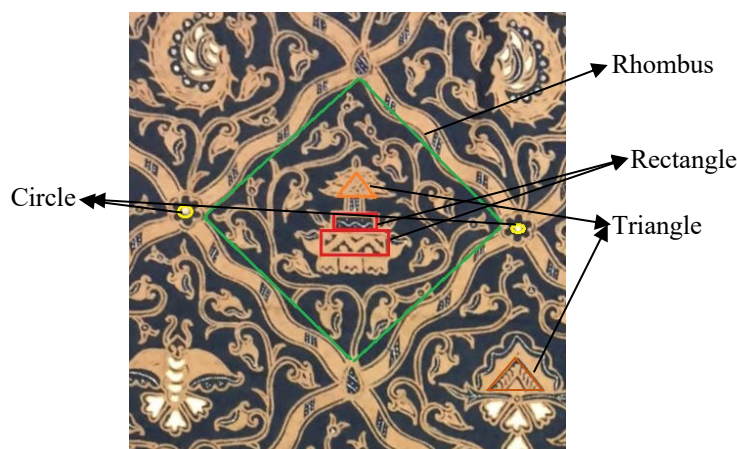


Figure 15. Rhombus and Rectangle Form in The House Motif

Figure 15. shows that some plane geometries formed in it as in the plane given a green line, the shape resembles a rhombus. While at the top of the house motif given an orange line resembles the shape of a triangle. The exact shape is also seen in the flora motif, where the orange line on the motif indicates forms a triangle. For the motif that is given a red line, it appears that the motif forms two rectangles. Lastly, the area that is given the yellow color on the left and right sides of the rhombus resembles circles.

How to understand what it is?

As an effort to test the validity of data, a process of triangulation of data sources had been done by comparing assumptions from authors related to mathematical concepts in Batik Sidoluhur as found in Table 2, with the viewpoint of experts in the field of geometry, algebra, arithmetic, and statistics. The triangulation process is done by the walkthrough interview method, where the authors communicate directly with the experts to compare what the authors find with the experts' opinions (Fitri & Prahmana, 2020). There are two fundamental questions to be asked to the experts related to (1) their perspective on the concept of mathematics on the batik (this point is used to confirm whether they find the same mathematical concepts as what are found by the authors), and (2) whether the context of Batik Sidoluhur can be used in mathematics learning.

The first concept confirmed is the concept of geometry that is asked directly to a geometry expert. Responding to the first question, the expert found the same sub-concept as what the authors found, namely geometry transformation and plane geometry. However, there was an additional sub-concept found by the member, namely the concept of congruency. This sub-concept is found in all motifs in the batik. One example is in the motif of the house/loji where all the motifs of the house have the same size and shape. According to the expert analysis, it can happen because making it done by using a stamp so that the shape and size of the image can be the same and precise, and indirectly the process applies the concept of image translation. Mathematically, translation is the operation changing the positions of all points (x, y, z) of an object according to the formula $(x, y, z) \rightarrow (x + \Delta x, y + \Delta y, z + \Delta z)$ where $(\Delta x, \Delta y, \Delta z)$ it is the

same vector for each point of the object (Smith, 2000). According to what was found by the authors when interviewing with the owner of Batik Sidoluhur, Agus Triwarso, related to making batik as the subject of research on the current study where the manufacturing process uses a stamp (see Figure 16.).



Figure 16. Stamps Used to Make Batik Sidoluhur

For the second question, the geometrician believed that Batik Sidoluhur could be used as an essential context to teach mathematics comprehensively. According to him, teachers can employ GeoGebra (a dynamic geometry software to visualize mathematical objects (Judith & Markus, 2008; Setyawan, Kristanto, & Ishartono, 2018)) during the learning process of geometry transformation where the teacher sketches a motif of Batik Sidoluhur in the Geogebra. Then, students will be able to transform it geometrically (translation and reflection) by using GeoGebra. The same condition can be applied to the sub-concept plane geometry and congruency where the students, for instance, analyze the use of malam (batik ink) based on the area of the used motif drawn in the GeoGebra. The use of GeoGebra as a model of using batik context in the learning of mathematics also be found in the previous studies (Lisnani, Zulkardi, Putri, & Somakim, 2020; Putra, Wijayanto, & Widodo, 2020; Suprayo, Noto, & Subroto, 2019).

The second concept confirmed by the experts is the concept of algebra which is based on the first and second question points of the interview; the algebraist states that he did not find any algebraic concept that can be excavated on the motif contained in Batik Sidoluhur, so he is not sure if Batik Sidoluhur can be used as a context to teach algebra. This condition is similar to the results of the authors' confirmation to the arithmetic expert and the statistician. The two experts did not find anything that could be unearthed related to arithmetic and statistic concepts. So that both of them have typical opinions related to the second interview question point that they are not sure they can use the context of Batik Sidoluhur to teach the concept of arithmetic or statistics. This in line with D'Ambrosio's (1985) statements that the concept of mathematics in a culture cannot be forced to exist. This means that if indeed a mathematical concept is not found in a cultural product, then the cultural product cannot be forced to be used as a context to teach the concept of mathematics that is not found.

Of course, there is still much to be studied from the results of this study such as how to apply Sidoluhur Batik-based mathematics learning, and how effective it is. So that the benefits of this research can have a broader and comprehensive impact to improve students' understanding of mathematics on the one hand, and on the other hand to simultaneously promote Batik Sidoluhur.

CONCLUSION

As one form of effort to conserve Batik Sidoluhur by promoting it through mathematics learning, researchers must study what mathematical concepts can be excavated from Batik Sidoluhur through Ethnomathematics study. In this study, the process of studying mathematical concepts contained in Batik Sidoluhur was conducted with an ethnographic approach by answering four principal questions, namely "where do I start looking?", "how do I find it?", "how do I recognize that it has found something significant?", and "how to understand what it is?". To resume, the authors began this study from a boutique called Butik Solo to take samples of some batik that has Sidoluhur motifs. After obtaining some batik, the authors analyzed the mathematical aspects of what is in the motif of Batik Sidoluhur which then the results of the analysis was confirmed to experts as a form of triangulation and as an effort to deepen the understanding of mathematical concepts contained in the motif of Batik Sidoluhur. By answering the four questions, the authors successfully examined the mathematical concepts contained in Batik Sidoluhur. Of the four mathematical concepts explored, namely geometry, algebra, statistics, and arithmetic, only the geometry concept is contained in Batik Sidoluhur and confirmed by a geometry expert. The sub-concepts found are (1) sub-concepts of geometry transformation such as translation and reflection, (2) plane geometry such as rhombus, rectangle, triangle, and circle, and (3) congruence.

This research has managed to uncover what concepts are contained in Batik Sidoluhur, so that it is expected that the mathematical concept that has been found can be a material to promote Batik Sidoluhur through mathematics learning in schools' level from elementary to secondary level. Therefore, the conservation efforts of Batik Sidoluhur can run more optimally. This research can be expanded on effectiveness tests related to the application of Batik Sidoluhur-based learning in improving students' understanding of mathematics.

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