

Mathematical Interpretation of the Geblek Renteng Batik Theme: Exploring Geometric Transformations

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ABSTRACT

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This research seeks to explore the connection between ethnomathematics and Geblek Renteng Batik, a unique cultural symbol of Kulon Progo. UNESCO's recognition of Batik as part of Human Heritage underscores its cultural significance. This acknowledgment offers the potential to use Batik as an alternative educational tool in mathematics, enhancing the understanding of mathematical concepts in everyday contexts. The study utilizes a qualitative descriptive methodology within an ethnographic framework. Data collection was carried out through interviews, observation, and documentation and the research instrument was a questionnaire. Data validation is performed through qualitative descriptive analysis. The study's results indicate that Batik Geblek Renteng themes incorporate mathematical concepts such as triangles, polygons, translations, reflections, rotations, and dilations. The integration of these mathematical concepts with the cultural aspects of Batik Geblek Renteng aims to foster a culturally enriched approach to learning mathematics.

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Keywords

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Introduction

Batik is recognized as part of ancestral heritage, created by writing and painting on a sheet of leaf [1]. At that time, batik themes or patterns were generally inspired by images of plants and animals. However, batik themes evolved into various abstract forms depicting elements such as temple reliefs, shadow puppets, and others. According to Siswanto et al. [2],

by combining elements of painting with fashion design, handwritten batik art developed into the form known today. Although traditional batik patterns and types exhibit a rich variety, their styles and variations often reflect the diverse philosophies and cultures of different regions in Indonesia.

Batik is an inseparable part of Indonesia's traditional textile heritage, giving rise to numerous variations with unique themes and meanings from each region [3]–[5]. UNESCO officially recognized Indonesian batik as part of the Intangible Cultural Heritage of Humanity in 2009, which not only elevated batik's cultural value on the international stage but also reaffirmed its importance in preserving national identity [6]. According to Artikasari [7], batik is not only regarded as a high-value artistic craft but has also become an integral part of Indonesia's cultural heritage. Some batik themes, such as Geblek Renteng batik from Kulon Progo Regency, reflect the underlying philosophy of local culture and contain wisdom values passed down through generations.

In the modern era, public interest in culture has generally declined, while awareness of the importance of regional cultural heritage, particularly among younger generations, has also diminished [8]. For instance, traditional activities such as batik-making are increasingly being abandoned due to perceptions that they are less profitable and require significant capital and time. As a result, many have left the profession of batik-making, causing Kulon Progo's distinctive batik to become marginalized due to the lack of regeneration. If this trend continues, certain regional batik themes may disappear, remaining only in historical records without concrete efforts for preservation. Therefore, concrete steps are needed to revive public interest in batik, particularly through more innovative approaches relevant to modern developments.

On the other hand, in the context of mathematics, culture can serve as a learning medium that connects more closely with everyday life. Practical mathematics encompasses various cultural groups, including workers, rural and urban communities, children of different age groups, and indigenous communities, as studied in the concept of ethnomathematics [9], [10]. Students are more interested in learning mathematics when it is linked to their surrounding conditions and culture [11]–[13]. Thus, this approach enables the integration of culture into mathematics education, known as ethnomathematics. Through ethnomathematics, students can understand how mathematical concepts are formed and developed in society and how the relationship between culture and mathematics can be contextually explained.

Ethnomathematics focuses on researching how mathematics can be adapted to specific cultural contexts and understanding the interaction between culture and mathematical practices [14], [15]. This approach offers a new perspective on understanding mathematics,

not only as an abstract discipline but also as a cultural product that continues to evolve with changing times. Additionally, the concept of ethnomathematics can provide students with insights that mathematics is not only found in textbooks but also in various aspects of daily life, including traditional arts and crafts such as batik.

Integrating ethnomathematics into the mathematics curriculum is generally regarded as a strategy to address and mitigate students' challenges in understanding mathematical concepts [16], [17]. Mathematics education in schools has often overlooked culture as a learning context, making students perceive mathematics as something detached from their lives. By incorporating cultural elements into mathematics learning, students can more easily connect theoretical concepts with real-world applications. Therefore, further exploration is needed regarding the potential of ethnomathematics in enhancing the effectiveness of mathematics education, particularly through cultural media familiar to students' daily lives.

A concrete form of applying ethnomathematics in mathematics education is through the exploration of batik themes as a learning medium. For instance, Geblek Renteng batik features geometric patterns that can be linked to mathematical concepts such as geometric transformations. By utilizing batik themes in learning, students not only gain knowledge about local cultural values but also develop a better understanding of mathematical concepts through a more visual and contextual approach [18]. This approach can also help increase students' appreciation of local culture and foster a sense of pride in their regional heritage.

Furthermore, incorporating batik themes in mathematics education not only enriches teaching methods but also provides students with opportunities to enhance their creativity. Additionally, the integration of culture into learning can create a more enjoyable and meaningful learning environment for students. By understanding the relationship between batik themes and mathematical concepts, students can internalize the learning material more effectively and relate it to real-life experiences [19]. Ultimately, this approach can enhance students' comprehension of mathematics while motivating them to appreciate and preserve their local cultural heritage.

In conclusion, integrating ethnomathematics into mathematics education, particularly through the exploration of Geblek Renteng batik themes, holds great potential in improving students' understanding of geometric transformations. Additionally, this approach can serve as a solution to the declining public interest in batik while contributing to the preservation of an increasingly marginalized cultural heritage. Therefore, further research on the application of ethnomathematics in education is necessary to implement it effectively in schools and establish it as an innovation in contextual and meaningful mathematics teaching.

Literature Review

A. Ethnomathematics

Ethnomathematics, introduced by D'Ambrosio in the late 20th century, is a field that explores the relationship between culture and mathematics. This field explores how various cultural groups understand and use mathematical concepts in their daily lives and traditional practices. Ethnomathematics aims to broaden the conventional view of mathematics by recognizing and appreciating the mathematical practices embedded in diverse cultures worldwide [20].

The theoretical foundation of ethnomathematics is based on the idea that mathematics is a series of diverse practices deeply connected to cultural, historical, and social contexts [21]. This theory challenges the Eurocentric view that mathematics is solely a product of Western civilization, highlighting the contributions of non-Western cultures to the development of mathematical knowledge. In education, ethnomathematics has significant implications, particularly in creating more inclusive and culturally relevant curricula [22]. Studies show that integrating ethnomathematical perspectives in education can help students see the relevance of mathematics in their own cultures, thereby enhancing their engagement and understanding.

Various applications of ethnomathematics have been documented in different cultural contexts, such as geometric patterns in traditional African architecture and textiles, Polynesian navigation, and Andean weaving. Ethnomathematics also plays an important role in the preservation and revitalization of cultural identity by documenting and analyzing the mathematical practices of indigenous and marginalized communities [23]. However, the field also faces criticism and challenges, including the risk of oversimplifying cultural practices and reinforcing stereotypes. Future research in this field needs to further explore the intersection of mathematics and technology and involve interdisciplinary collaboration to enrich the study of ethnomathematics.

B. Batik

Batik is a traditional textile art rooted in Indonesian society. Its intricate dyeing technique involves the use of wax to create beautiful and meaningful patterns. Recognized by UNESCO as an Intangible Cultural Heritage of Humanity, batik embodies historical and cultural values [18]. Its use extends beyond traditional clothing to ceremonial purposes and artistic expression.

The history of batik in Indonesia dates back to ancient kingdoms, where it symbolized status for royal families and nobility [24]. Over time, batik techniques and themes evolved alongside cultural interactions and cross-border trade. Each region in Indonesia boasts unique batik styles, such as Batik Parang from Central Java and Batik Kawung from Yogyakarta. The

development of batik also mirrors the social, economic, and political dynamics throughout Indonesia's extensive history.

The production process of batik is central to its uniqueness as an art form [25]. Using traditional tools like canting and stamps, batik artisans apply wax to protect certain areas of the fabric from dye. The fabric is then repeatedly dyed in various colors to create intricate and beautiful patterns. The high level of precision and skill required at each stage underscores Batik's status as a highly esteemed cultural heritage.

C. Geblek Renteng Batik

Batik Geblek Renteng is a unique and culturally significant textile art specific to Kulon Progo, Indonesia. Known for its intricate patterns and historical significance, this form of batik reflects the local traditions and artistic heritage of the region [26]. UNESCO [27] recognition of batik as an Intangible Cultural Heritage underscores its importance in preserving cultural identity and history. Batik Geblek Renteng has deep roots in the cultural history of Kulon Progo. Originating from traditional practices passed down through generations, this art form has evolved alongside the social, economic, and political changes in the region. It serves not only as a form of artistic expression but also as a symbol of community identity and pride.

The production of Batik Geblek Renteng involves meticulous techniques that distinguish it from other forms of batik. Artisans use specific tools and methods to create repetitive geometric patterns, often with symbolic meanings related to local beliefs and values [28]. The intricate detailing and precise execution highlight the craftsmanship and skill required to produce these textiles. In the modern era, Batik Geblek Renteng faces challenges such as cultural preservation and adaptation to changing market demands. Efforts to safeguard this cultural heritage involve education, community engagement, and support for local artisans [27]. Despite these challenges, the art continues to thrive, adapting traditional techniques to contemporary designs and expanding its presence in the global market.

Batik Geblek Renteng exemplifies the richness of Indonesia's cultural diversity and artistic heritage. Through its intricate patterns and historical significance, this unique form of batik not only preserves local traditions but also contributes to the broader cultural landscape. Further research and appreciation of Geblek Renteng Batik are essential to understanding its role in Kulon Progo's cultural identity and its continued evolution in a globalized world.

D. Geometric Transformations

Geometry Transformation for Grade XI plays a crucial role in upper-secondary mathematics education. Transformations such as translation, rotation, reflection, and dilation are fundamental to understanding how geometric shapes change in space [29]. Mastery of transformational geometry not only enhances spatial reasoning skills but also provides a foundation for understanding advanced mathematical concepts. The theoretical framework of

geometric transformations includes principles and mathematical representations that explain the movement and changes of shapes relative to different operations. Each type of transformation has specific properties and rules governing its application, which affect the geometric properties and relationships between shapes before and after transformation.

Understanding geometric transformations enables students to solve real-world problems involving spatial relationships and symmetry [30]. Its applications are wide-ranging, from architectural design to computer graphics, where transformations are used to manipulate images and models. Problem-solving exercises in class help reinforce conceptual understanding and practical application of transformational geometry. Effective teaching strategies for transformational geometry involve practical activities, visual aids, and interactive software tools that allow students to dynamically explore and manipulate geometric shapes. Educators often use worksheets, geometric models, and interactive simulations to engage students and strengthen key concepts.

Challenges in teaching transformational geometry include abstract thinking, visualizing transformations in multiple dimensions, and understanding the algebraic representations of transformations [31]. By mastering transformations such as translation, rotation, reflection, and dilation, students not only enhance their mathematical abilities but also prepare themselves for various applications across different fields. Further research and innovative teaching methods will improve the effectiveness and relevance of transformational geometry education in secondary schools.

Material and Methods

This study employs a qualitative descriptive approach using ethnographic methods. Descriptive data is collected in various forms, such as texts, images, and non-numeric materials, while the ethnographic method is used to understand, analyze, and explain an ethnic community. Data collection is conducted through in-depth documentation and literature reviews, including primary references such as books, journals, conference proceedings, dissertations, and research reports. The data analysis process consists of four stages, beginning with data collection through literature reviews and documentation to obtain valid information. The second stage is data reduction, which involves organizing and selecting essential information. The third stage is data presentation in a coherent and systematic narrative form. The final stage is drawing conclusions based on the analyzed data. To ensure data validity, triangulation techniques are used by comparing information from various informants relevant to the research context.

Results

Kulon Progo Regency is known as a region that produces batik with unique patterns resembling mathematical objects, one of which is Geblek Renteng batik [32]. This theme is inspired by the traditional food Geblek and the region's natural wealth. A deep meaning is embedded in its patterns, such as the number eight used to symbolize the number of villages and the Renteng theme representing unity. Additionally, the BINANGUN symbol and mangosteen fruit are incorporated to represent growth and the region's distinctive plants.

A. Translation

Translation in geometry involves uniformly shifting every point within a shape or space by a specified direction and distance [33]. Translation can also be understood as the process of adding or shifting the origin point in the Euclidean geometric coordinate system [34]. This process involves displacing or moving all points on a geometric plane equally in both direction and distance. For example, points K, L, and M will be moved to points K', L', and M' with a distance and direction as illustrated in the following Fig. 1.

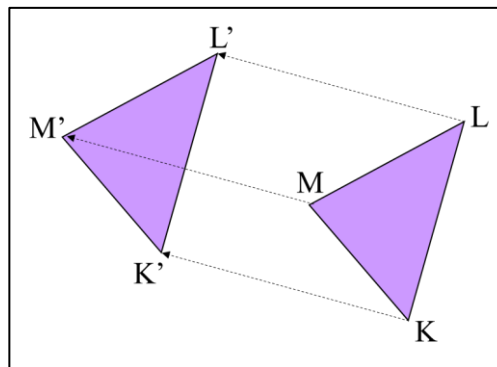


Fig.1. Translation Concept

Translation can be observed about the x-axis (abscissa) and y-axis (ordinate).. A shift by a distance of n parallel to the abscissa (to the right for $n > 0$, to the left for $n < 0$), and a shift by a distance of m parallel to the ordinate (upward for $m > 0$, downward for $m < 0$) is represented as:

$$K(x, y) \begin{pmatrix} n \\ m \end{pmatrix} \rightarrow K'(x + n, y + m)$$

The batik theme Geblek Renteng illustrates the concept of translation, as shown in Fig.2. It can be seen that if the triangle theme in the image above is shifted vertically by m units, then shifted upwards again by n units, you will see the basic concept of translation.. In this theme, it can be observed that the triangle KLM is translated twice by m units and n units upward, parallel to the ordinate, resulting in the structures K'L'M' and K''L''M''.

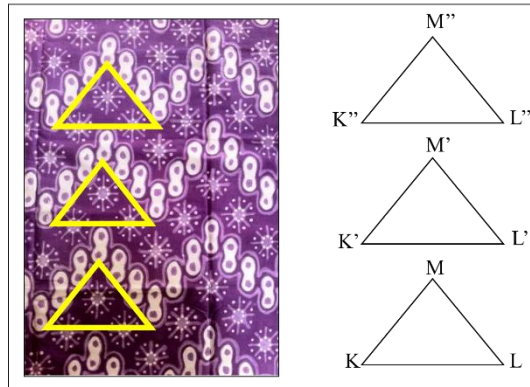


Fig. 2. Translation Concept in Geblek Renteng Batik

The properties of translation found in the design of Geblek Renteng batik include the fact that the planes KLM, K'L'M', and K''L''M'' have the same size, distance, and direction.

B. Reflection

Reflection is a transformation that involves taking an initial shape and flipping it across certain lines and forming a new shape that produces an image [35]. This process resembles how an object appears when reflected in a mirror. When an object reflects, the mirror produces its image. In the Cartesian plane, the way an object reflects depends on the axis chosen as the mirror. Reflection fundamentally involves repositioning all points based on the characteristics of a flat mirror. As an illustration, this concept can be observed in the following Fig. 3, where a triangle is reflected across the ordinate.

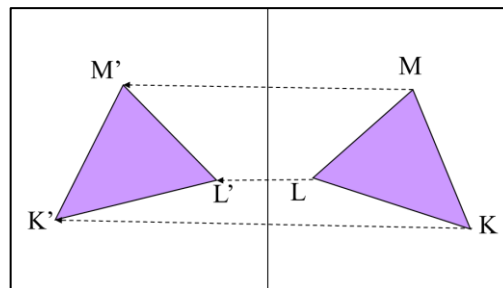


Fig. 3. Reflection Concept

The reflection concept in the Geblek Renteng batik theme can be seen in Fig. 4, where there is a reflection on the plane KLM resulting in K'L'M'.

If we put a vertical line in the middle of the theme in the image, we can see the basic reflection concept. In Fig. 4, the triangle KLM is reflected across the ordinate y , resulting in the image K'L'M'. Mathematically, the reflection matrix related to the ordinate $-y$ is $\begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}$. Therefore, if the point K (x, y) is reflected across the ordinate, then

$$R(K) = K' = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} -x + 0 \\ 0 + y \end{pmatrix} = \begin{pmatrix} -x \\ y \end{pmatrix} \dots \dots \dots (1)$$

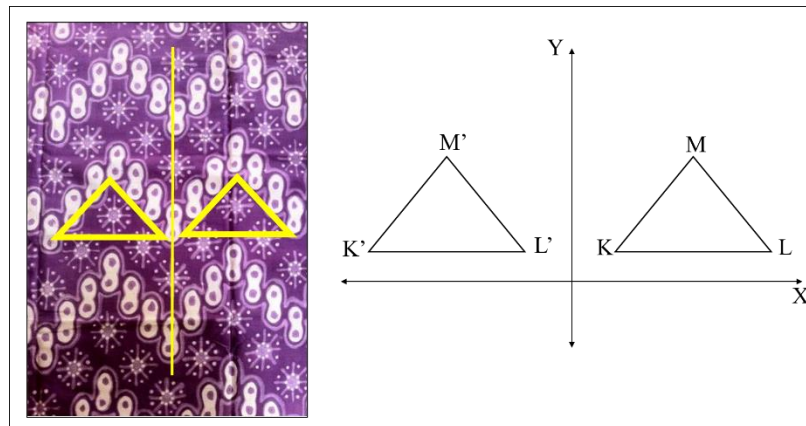


Fig. 4. Reflection Concept in Geblek Renteng Batik

The reflective properties of the GeblekkRenteng cloth theme are as follows: the size of the plane KLM is the same as the size of the plane $K'L'M'$. Every point to its mirror image is the same distance, and the orientation of plane KLM is opposite to that of plane $K'L'M'$.

C. Rotation

Rotation is the act of repositioning an object by pivoting it around a center point at a designated angle. The principle behind rotation involves pivoting an object at a specified angle around a center point, ensuring that each point undergoes the same distance of rotation. In geometric transformations, the angle of rotation, α , conventionally represents a counterclockwise rotation [36]. If the object rotates in a clockwise direction, the formed angle will be expressed as $-\alpha$, so it can be seen that the result of rotating an object does depend on the center and the specified rotation angle. Observe the positional transformation of the triangle KLM undergoing a 180° rotation with rotation $O(0,0)$ in the following Fig. 5.

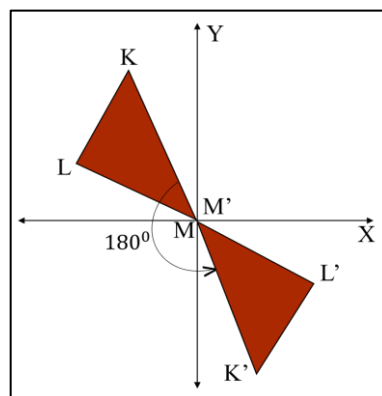


Fig. 5. Rotation Concept

Fig. 6 shows the concept of rotation in the Geblek Renteng batik theme. α is a symbol of the amount of rotation in a geometric transformation whose direction is counterclockwise.

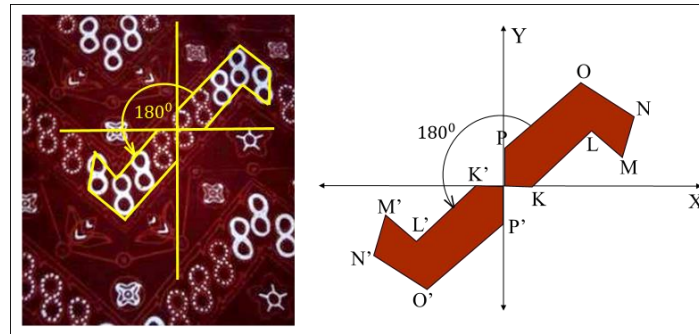


Fig. 6. Rotation Concept in Geblek Renteng Batik

If you put vertical and horizontal lines in the middle of the theme, you will see the basic concept of rotation. In this theme we see POK rotated 180° counterclockwise at O, and the rotation matrix associated with α is $\begin{pmatrix} \cos 180^\circ & -\sin 180^\circ \\ \sin 180^\circ & \cos 180^\circ \end{pmatrix}$. If point P (x, y) is rotated 180° counterclockwise about O, then

$$R(P) = \begin{pmatrix} \cos 180^\circ & -\sin 180^\circ \\ \sin 180^\circ & \cos 180^\circ \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} -x \\ -y \end{pmatrix} \dots \dots \dots (2)$$

Some characteristics of rotation in this theme are the area of POK = P'OK', the shape of the structure remains unchanged, the determinant value of the rotation matrix is 1, and two consecutive rotations have the same value.

D. Dilatation

Dilatation is a change in shape or scaling that involves enlarging or shrinking an object. Unlike rotation, reflection, and translation which only change the position of an object, dilatation performs a geometric transformation by altering the size of the object [37]. Objects can be modified by making them bigger or smaller. This change depends on the scale factor as a multiplier, as depicted in the following Fig. 7.

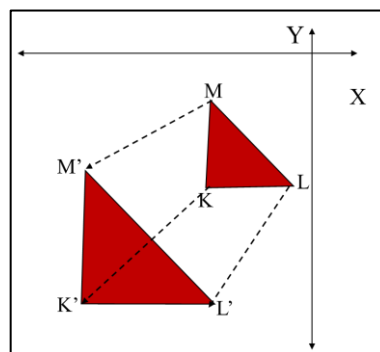


Fig. 7. Dilatation Concept

The concept of dilatation in the Batik GeblekRenteng theme can be seen in Fig. 7. Dilation is known as a change in shape which includes enlarging or shrinking an object. So, the results of these changes will affect the size of an object, depending on the scale used.

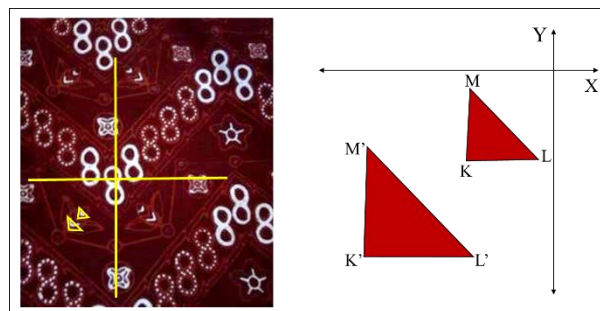


Fig. 8. Dilatation Concept in Geblek Renteng Batik

In the picture above, there are several circles in the Geblek Renteng Batik theme with different sizes and locations, making it possible to observe the concept of dilation. For one of the plane figures whose point $K(x, y)$ is enlarged with the center at $K'(x', y')$ by a scale factor n , the following results are obtained

$$R(K) = \begin{pmatrix} n & 0 \\ 0 & n \end{pmatrix} \begin{pmatrix} x \\ y \end{pmatrix} = \begin{pmatrix} nx \\ ny \end{pmatrix} \dots\dots\dots (3)$$

Some of the characteristics of dilation in the Geblek Renteng batik theme are: it only changes size but does not change shape, the size of the size depends on the scale used, and number dilation is a factor and requires a point as the center.

Discussion

Batik Geblek Renteng from Kulon Progo Regency is a cultural heritage closely related to mathematical concepts, particularly geometric transformations. This theme reflects various mathematical forms, such as figure number eight, symbolizing the number of villages in the area, and the *renteng* pattern, which represents unity. Additionally, the theme incorporates elements of the BINANGUN symbol and mangosteen fruit, symbolizing growth and the region's natural wealth. The patterns in this batik not only possess aesthetic value but can also be explained mathematically through geometric transformation concepts such as translation, reflection, rotation, and dilation.

The concept of translation in geometry is evident in the Geblek Renteng theme, where repetitive patterns are shifted in a specific direction and distance without changing their shape. For instance, the triangular themes in this batik illustrate that if a triangle is moved m units upward and n units sideways, a consistent pattern is formed by the principle of translation. In addition to translation, the concept of reflection is also present in this batik, where specific patterns are reflected along a line, producing an identical but reversed image, similar to a mirror reflection.

Besides translation and reflection, the Geblek Renteng theme also demonstrates the concepts of rotation and dilation in geometric transformations. Rotation is observed when a pattern is rotated 180° around a fixed point, maintaining its shape but altering its position.

Meanwhile, dilation is evident in the variations of theme sizes, where elements retain their shape despite being enlarged or reduced by a specific scaling factor. These characteristics indicate that Batik Geblek Renteng not only holds profound cultural value but can also serve as a contextual and engaging mathematical learning medium for students [38].

In the context of education, learning media play a crucial role in effectively delivering messages and enhancing students' understanding [39]. Teachers utilize instructional media as tools to engage students and facilitate interaction in the learning process [40], [41]. These media help transform abstract concepts into more concrete forms, making them easier for students to comprehend and relate to their daily experiences. The criteria for selecting effective teaching materials include attractiveness, motivation, alignment with student characteristics, as well as factors such as visibility, simplicity, ease of use, and content validity.

The use of culture-based learning media, such as Batik Geblek Renteng, can connect mathematical concepts with students' everyday lives. Through this approach, geometric transformation concepts are not only understood theoretically but also contextualized within local culture. For example, batik patterns can be used to teach translation, rotation, dilation, and reflection key components of advanced mathematics curricula in schools. This approach aligns with the principles of ethnomathematics-based learning, which links mathematical concepts to cultural aspects to enhance student relevance and understanding [42].

Classroom experiments using the Batik Geblek Renteng theme as an ethnomathematics learning medium can provide students with a more contextual learning experience. Students are encouraged to explore geometric transformation concepts through the traditional batik patterns of Kulon Progo, thereby improving their comprehension and interest in learning. This approach helps students recognize that mathematics is not merely an abstract discipline but something deeply embedded in their cultural heritage [43]. However Fatimah et al. [44] and Saurjana et al. [45] highlight challenges in its implementation, particularly the lack of teachers' understanding of ethnomathematics and limited resources for integrating these concepts into the curriculum.

To address these challenges, teacher training programs are necessary to equip educators with the skills to implement ethnomathematics-based learning effectively. Additionally, collaboration between the government, academics, and cultural communities should be strengthened to develop appropriate teaching materials [46]. Another crucial factor is students' acceptance of this teaching method, as there is still a common perception that mathematics is a discipline separate from culture. Therefore, innovative approaches such as research-based projects, student exhibitions, and collaborations with batik artisans can be

effective strategies to reinforce the connection between mathematics and culture while fostering greater appreciation for local heritage.

Conclusion

Based on the results and discussion, the Geblek Renteng batik theme shows the relationship between mathematical and cultural concepts, especially in the context of ethnomathematics. Within this theme, geometric principles such as dilation, rotation, reflection, and translation are identified. This discovery illustrates that mathematical ideas extend beyond formal settings and integrate into various facets of societal and cultural contexts. In the Geblek Renteng batik theme, these geometric elements serve not only as decorative features but also reflect the practical application of mathematics within local cultural heritage. This underscores the significance of ethnomathematics, forging connections between mathematics and cultural traditions in everyday life.

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