PROSIDING DISKUSI PANEL NASIONAL PENDIDIKAN MATEMATIKA

Original Research

Exploring Ethnomathematics: Concepts of Transformational Geometry in the Batik Motifs of the Banten Sultanate (Kepandean, Pamaranggen, and Ki Jimat)

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INFO ARTICLES

Key Words:

Ethnomathematics; Concept of Geometry; Batik Motif; Banten.

Abstract: *This study aims to explore the application of ethnomathematics concepts to the decorative patterns of batik fabric characteristic of the Banten Sultanate, specifically the Kepandean, Pamaranggen, and Ki Jimat motifs. The method used was qualitative research with an ethnographic approach through direct observation at the Old Banten Archaeological Site Museum and a literature review. The results of the study indicate a close integration between the philosophical values of Banten culture and the concepts of formal transformational geometry. The Kepandean motif applies the concept of translation; the Pamaranggen motif demonstrates the application of rotation (fourth-order rotational symmetry) and reflection; while the Ki Jimat motif utilizes multi-directional translation. The conclusion of this study affirms that Banten batik is a medium for culture-based learning with the potential to teach transformational geometry in a contextualized manner at the secondary education level.*

Abstrak: Penelitian ini bertujuan untuk mengeksplorasi penerapan konsep etnomatematika pada pola dekoratif kain batik khas Kesultanan Banten, khususnya motif Kepandean, Pamaranggen, dan Ki Jimat. Metode yang digunakan adalah penelitian kualitatif dengan pendekatan etnografi melalui observasi langsung di Museum Situs Arkeologi Banten Lama dan tinjauan pustaka. Hasil penelitian menunjukkan integrasi yang erat antara nilai-nilai filosofis budaya Banten dan konsep geometri transformasional formal. Motif Kepandean menerapkan konsep translasi; motif Pamaranggen menunjukkan penerapan rotasi (simetri rotasi orde keempat) dan refleksi; sedangkan motif Ki Jimat menggunakan translasi multiarah. Kesimpulan penelitian ini menegaskan bahwa batik Banten merupakan media pembelajaran berbasis budaya dengan potensi untuk mengajarkan geometri transformasional secara kontekstual di tingkat pendidikan menengah.

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INTRODUCTION

For many students, math is often seen as a scary, rigid subject that's far removed from the real world. In fact, when traced back to its roots, mathematics is actually a discipline that grows out of the human capacity for logical thinking in navigating daily life. It is the way we measure, organize, and model the world around us (D'Ambrosio, 1985). Thus, to bridge the gap between this seemingly "cold" mathematics and real-world reality, an approach known as ethnomathematics has emerged. This field invites us to view mathematics not as static formulas, but as an integral part of the culture, language, and even the behavior of the communities that use it (Mahuda, 2020).

Indonesia, with its cultural diversity, is a "goldmine" for ethnomathematics. One fascinating example worth exploring is Banten's culture. Traces of the Islamic Sultanate of Banten are evident not only in its architectural heritage but also in batik art, elegantly reflected. Banten batik has a unique character compared to other Javanese batiks; its colors tend to be soft yet convey a strong, bold impression, much like the nature of its people (Firdaussa et al., 2021). What is even more intriguing is that the motifs of Banten batik are not created haphazardly. Each name holds a story, whether derived from the names of historic places, noble titles, or symbols of heirlooms left behind by the sultanate (Mahuda, 2020).

In classroom instruction, one topic is highly relevant when linked to batik patterns: transformational geometry. This topic explores how an object can change its position or shape through translation, reflection, rotation, and dilation (Firdaussa et al., 2021). Unknowingly, traditional Banten batik artisans had already applied these complex concepts in every stroke of their canting to ensure the resulting motifs remained symmetrical, balanced, and visually pleasing. If this concept is introduced in the classroom, students no longer need to imagine transformations as abstract lines on a Cartesian coordinate plane, because they can see them directly on the batik fabric familiar to them in their daily lives (Astriandini & Kristanto, 2021). However, although Banten batik has been studied quite frequently, discussions focusing on the geometry of transformations in specific motifs such as the Kepandean, Pamaranggen, and Ki Jimat motifs remain relatively scarce. Meanwhile, these three motifs possess a strong philosophical background and a very rich geometric structure. That is why this study was conducted: to examine how cultural values and mathematical concepts particularly geometric transformations are integrated within these three motifs. It is my sincere hope that the findings of this exploration will eventually serve as engaging teaching materials, enabling students not only to gain a deeper understanding of mathematics but also to take pride in the cultural richness of their homeland (Hakim, 2016).

METHOD

This study employs a qualitative, ethnographic approach. This method was chosen to systematically, accurately, and factually describe cultural phenomena, particularly in bridging cultural objects with formal mathematical concepts. The ethnographic approach was deemed highly relevant because the study's focus is on exploring the historical legacy of the Banten Sultanate as embodied in batik motifs, which requires the researcher to be directly immersed in that cultural environment.

In this study, the researcher serves as the primary instrument (human instrument). The data collection procedures were carried out through the following stages:

a. Literature Review: The researcher conducted a literature search on ethnomathematics, the history of the Banten Sultanate, and other relevant studies to establish a theoretical foundation and facilitate comparison of findings.
b. Field Observation: The researcher made a field visit to the Banten Museum to closely observe the Kepandean, Pamaranggen, and Ki Jimat motifs. This visit was crucial for the researcher to obtain primary data regarding the composition, proportions, and authentic details of the decorative patterns on the batik fabric artifacts housed in the museum.

c. Documentation: The researcher documented the motif patterns and explored the philosophical meanings behind each decorative motif.

The data analysis technique applied in this study is the interactive qualitative model developed by Miles and Huberman, which consists of the following three main stages:

1. Data Reduction: In this stage, the researcher carried out the process of selecting, focusing, and simplifying the raw data that had been collected. Visual data, in the form of photographs of batik motifs from the Banten Museum, and literature documentation were carefully sorted to separate motif elements with geometric features from other aesthetic elements. The researcher then classifies the data into relevant geometric transformation categories, such as translation, reflection, rotation, or dilation. This process aims to eliminate irrelevant information, leaving the remaining data to focus more on the mathematical structures to be analyzed further.
2. Data Presentation The reduced data were then organized into a systematic descriptive narrative. The researcher presented an in-depth analysis of the mathematical results for each motif (Kepandean, Pamaranggen, and Ki Jimat), linking each visual element of the batik such as flower petals, tumpal motifs, or line patterns to the principles of geometric transformations. This data presentation is designed to help readers understand how batik artisans intuitively yet accurately apply mathematical concepts in ornamental composition, while also providing a clear visual illustration of the locations of coordinate points, axes of symmetry, or displacement vectors within these motifs. Drawing Conclusions: The final stage involves deriving meaning from the presented data. The researcher conducted an in-depth integration of empirically discovered ethnomathematical facts from the Banten Museum with theories of mathematics education and culture reviewed in the literature. The researcher formulated logical propositions about how philosophical values and geometric transformation concepts interlock in batik design. These conclusions were formulated to address the research questions while also providing scientific justification for the potential of integrating Banten Sultanate batik as a mathematics learning medium rooted in local wisdom.

RESULT

Based on an exploration of three types of batik fabric motifs characteristic of the Banten Sultanate, a very close functional relationship was found between the motif arrangements and geometric mathematical structures. The following is a detailed presentation of the results of the cultural and mathematical analysis for each motif:

A. Motif Kepandean

1. Cultural Context and Philosophical Values

   The name of the Kepandean motif is taken directly from the urban layout of the former Banten Sultanate's administrative center. "Kepandean" is the name of an ancient district or village that served as the residential and working hub for iron smiths (pande) within the Banten Sultanate. These artisans played a vital role in supplying agricultural and carpentry tools, as well as bladed weapons, for both domestic needs and the sultanate's defense. The incorporation of this village's name into a batik motif serves as a tribute to the skill, productivity, and hard work of the blacksmiths in sustaining the sultanate's economy.

2. Ethnomathematics Analysis (Concepts of Plane Figures and Transformational Geometry)
   a. Geometric Concepts

      The ornaments in the Kepandean motif result from the orderly arrangement of basic two-dimensional geometric shapes. Upon visual inspection, the main motif forms a closed curved structure resembling a combination of triangular patterns or modified semicircular shapes. Visually, these semicircular shapes are reminiscent of the arched domes found on historic buildings in the Surosowan Palace complex, combined with simple geometric patterns. This arrangement forms a tightly packed pattern, creating a repetitive and harmonious visual rhythm.

b. Geometric Transformations (Translation)

The most prominent geometric transformation concept explicitly represented in this motif is translation (shifting). The main patterns (both the triangular and semicircular dome shapes) are positioned horizontally with a shift vector $T_1 = \begin{pmatrix} a \\ 0 \end{pmatrix}$, where the distance between motifs is kept constant, this repeated process of horizontal shifting produces a neat, continuous row of motif bands. In addition to horizontal translation, the artisans also arrange these horizontal bands vertically, either upward or downward, using the concept of vertical translation vectors $T_2 = \begin{pmatrix} 0 \\ b \end{pmatrix}$. It is this combination of translations along the axes that produces a repeating, regular pattern (tessellation) that precisely covers the entire surface of the fabric. Mathematically, the position of each point P() in the pattern after undergoing repeated translations can be expressed as:

$$P'(x + m \cdot a, y + n \cdot b)$$

where m and n are integers representing the number of repetitions of the motif on the coordinate plane.

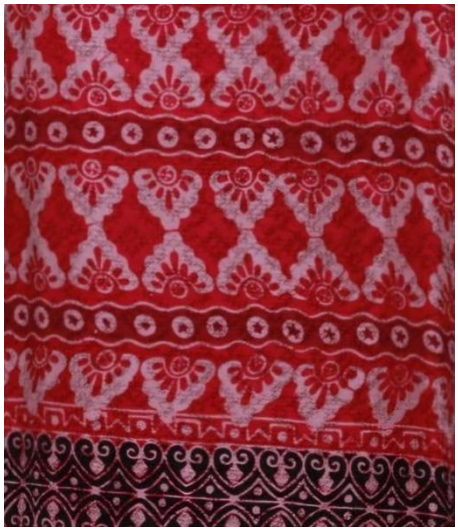

Figure 1. Translation Analysis of the Kepandean Motif

Marked with a red box and horizontal and vertical translation arrows indicating the repetition of the dome and triangle patterns.

B. Motif Pamaranggen

1. Cultural Context and Philosophical Values

Similar to Kepandean, the Pamaranggen motif is derived from a place name in the area outside the Banten Sultanate's fortress. "Pamaranggen" comes from the root word maranggi, which refers to the experts or artisans who craft keris, warangka (keris sheaths), and the accompanying accessories for these heirloom weapons. In the culture of the Banten Sultanate, the keris served not merely as a means of self-defense but as a symbol of social legitimacy, honor, status, and a man's maturity. The Pamaranggen motif symbolizes the high level of

precision, sharpness of thought, and profound artistic value possessed by the master artisans who created the sultanate's weapons.

2. Ethnomathematics Analysis (Concepts of Plane Figures and Transformational Geometry)
   a. Geometric Concepts

      The main decorative elements of the Pamaranggen motif are arranged in a centralized pattern. The primary ornament is positioned exactly at the center of an imaginary square, featuring a flower-like pattern with four petals or wings that bloom and extend symmetrically toward the square's diagonals (its corners).

   b. Geometric Transformations (Rotation and Reflection)
      1) Rotational Symmetry (Rotation)

         The main ornament of this motif exhibits Order-4 Rotational Symmetry. The center of symmetry lies exactly at the center of the flower's coordinate system. If the flower's main pattern is rotated 90, 180, or 270 degrees counterclockwise (or clockwise) around that center point, the positions of the geometric petal objects will return to their original positions within the frame without altering their visual shape. Mathematically, this rotation is expressed by the formula for the center rotation transformation coordinates:

$$R_{(O,90^\circ)}(x,y) = (-y,x)$$
$$R_{(O,180^\circ)}(x,y) = (-x,-y)$$
$$R_{(O,270^\circ)}(x,y) = (y,-x)$$

      2) Fold Symmetry (Reflection)

         This main pattern has several lines of symmetry (reflection axes). The petal ornament can be divided into two identical parts when reflected across a vertical line (axis X), a horizontal line (axis Y), or a diagonal line. These reflections produce precise and balanced mirror images in each Cartesian quadrant.

      3) Translation of the Border Ornament

         Along the border or at the bottom of Pamaranggen-patterned fabric, there is a decorative motif consisting of a continuous wavy line resembling the graph of a trigonometric function (a sine wave). This wavy line employs the concept of unidirectional linear translation, in which a full-wave pattern is repeatedly shifted horizontally to frame the edges of the batik fabric aesthetically.

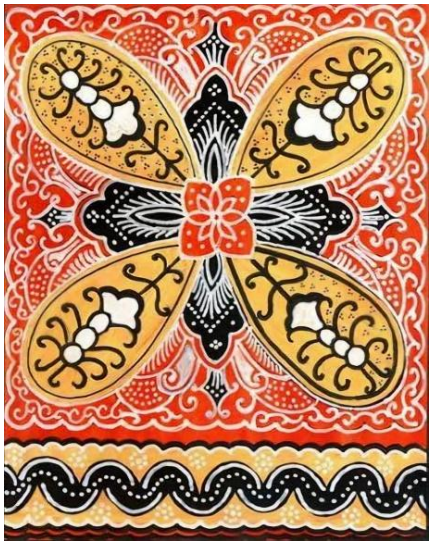

Figure 2. Translation Analysis of the Pamaranggen Motif

Circled in yellow with an axis of symmetry and rotation arrows illustrating rotational symmetry of order 4 and diagonal reflection.

C. Motif Ki Jimat

1. Cultural Context and Philosophical Values

The Ki Jimat motif has a very strong historical and spiritual significance for the people of Banten. This motif is not derived from the name of a place, but rather stems from the grand testament of the Sultan of Banten, which reads amal ma'ruf nahi munkar (encouraging all forms of goodness and preventing all forms of evil). This religious and social philosophical message is permanently inscribed on the body of a legendary giant bronze cannon belonging to the Sultanate of Banten, known as the Ki Amuk Cannon (currently housed at the Old Banten Archaeological Site Museum). The name "Ki Jimat" refers to the status of this testament, which is regarded as a guiding principle for life, a protector, or a true spiritual "talisman" ensuring that the people of Banten always walk within the framework of divine values and morality.

Figure 3. Translation Analysis of the Ki Jimat Motif

2. Ethnomathematics Analysis (Concepts of Plane Figures and Transformational Geometry)
   a. Geometric Concepts

The basic ornamental elements of the Ki Jimat motif have unique geometric characteristics. The decorative patterns are scattered and arranged geometrically to form flat shapes resembling flowers or regular polygonal stars, namely six-pointed or eight-pointed stars (adapted to the aesthetic details of the fabric's decorative motifs). These star-shaped polygons reflect the regularity of their interior angles, which are all equal in measure.

   b. Geometric Transformations (Multi-Directional Translations)

The primary transformation used to spread the Ki Jimat star/flower motif across the entire fabric is Translation (Shift). The basic pattern, or single main motif, is consistently shifted horizontally (left-right) and vertically (up-down) within the two-dimensional plane of the fabric. Mathematically, the shift of the points that make up the star motif satisfies the equation:

$$T = \begin{pmatrix} m \cdot \Delta x \\ n \cdot \Delta y \end{pmatrix}$$

Where (an integer), and and denote the fixed spacing between the centers of the floral ornaments. This repeating pattern covers the entire fabric surface with the motif in a balanced manner (tessellation). In addition, the lower border of the fabric is adorned with a repeating wavy polygonal motif that consistently employs linear translation along the horizontal axis.

marked with a blue triangle and multi-directional translation arrows showing the distribution of the star motif across the entire fabric.

DISCUSSION

Based on the above findings, it is clear that mathematics and Banten culture are closely intertwined. Naturally, Banten batik artisans of the past applied mathematical principles when designing motifs. Although they did not use formal mathematical formulas, the resulting motifs exhibit a high degree of symmetry, balance, and aesthetic proportion. This underscores that mathematics is not merely an abstract concept taught in the classroom, but a living discipline deeply integrated into a community's cultural works.

In the Kepandean motif, the most dominant concept employed is translation or shifting. Its primary forms resembling the arched dome of the Surosowan Palace and triangular patterns are arranged in precise, evenly spaced rows. Artisans shift these patterns horizontally and vertically to form orderly rows. This visual order aligns perfectly with the philosophy of "Kepandean" as the district of blacksmiths during the Banten Sultanate era. These repetitive, consistent patterns reflect the productivity, discipline, and work ethic of the tool and weapon makers of that time.

The Pamaranggen motif exhibits distinct characteristics, emphasizing a central design through the principles of rotation and reflection. The floral motifs in this decorative pattern feature four petals forming a fourth-order rotational symmetry, meaning their positions align perfectly when rotated by 90, 180, or 270 degrees. Furthermore, these motifs will precisely overlap when mirrored from various directions. This level of precision is highly relevant to Pamaranggen's background as a region of maranggi (master keris makers). Just as the creation of these motifs requires precision, the crafting of keris also demands extraordinary meticulousness, high skill, and sharp thinking.

Furthermore, the Ki Jimat motif consists of regular polygons, such as six- or eight-pointed stars. This motif is distributed across the entire surface of the fabric using simultaneous multi-directional translation techniques. This pattern of distribution shares a close symbolic connection with the history

behind the name Ki Jimat, which derives from the message of amal ma'ruf nahi munkar (promoting good and forbidding evil) inscribed on the Ki Amuk Cannon. The repetition of the star pattern in various directions can be interpreted as a reminder or "talisman" of goodness that continuously radiates in all directions, so that the community may always hold fast to moral and spiritual values. The richness of meaning and mathematical concepts behind this Banten batik motif makes it highly suitable for integration as a medium for teaching mathematics. Instead of merely imagining the abstract translation of geometric objects, teachers can demonstrate their direct application on batik fabric. This learning approach, rooted in local wisdom, not only makes mathematics feel more tangible and contextual but also fosters students' pride in Banten's cultural heritage.

CONCLUSION

Based on the results of the ethnomathematical exploration of batik motifs characteristic of the Sultanate of Banten, it can be concluded that the Kepandean, Pamaranggen, and Ki Jimat motifs are cultural artifacts that are not only rich in the history, philosophy, and toponyms of the Sultanate of Banten but also embody the precise and systematic application of transformational geometry concepts. Mathematically, the findings of this study show that:

1. The Kepandean motif applies the concept of tessellation through translation, in which the basic dome or triangle-shaped pattern is shifted horizontally (x) and vertically (y) by a constant vector.
2. The Pamaranggen motif represents a centralized geometric concept by implementing 4th-Order Rotational Symmetry (Rotation) and Folding Symmetry (Reflection) along vertical, horizontal, and diagonal axes, resulting in perfect visual balance.
3. The Ki Jimat motif utilizes regular polygonal star shapes distributed across the entire fabric surface through a combination of Multi-Directional Translation, which technically satisfies the point-shift matrix equation.

These findings demonstrate that artisans of the past in the Banten Sultanate intuitively applied the principles of transformational geometry in their design compositions. From a pedagogical perspective, the results of this ethnomathematics research have great potential for integration into the Merdeka Curriculum's mathematics curriculum materials at the secondary school level (junior and senior high schools). Through a culture-based learning approach, Banten batik can serve as a learning medium that bridges the abstract concept of geometric transformations with contextual cultural realities, thereby enhancing students' mathematical understanding while fostering a sense of pride in their regional cultural heritage.

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