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# Ethnomathematics exploration of Al-Barkah Great Mosque, Bekasi City, through geometry and transformational geometry learning

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# ABSTRACT

Article history:	Ethnomathematics integrates cultural elements into mathematics
Submitted: January 15, 2023 Accepted: June 10, 2023 Published: July 20, 2023	preserving cultural heritage. Ethnomathematics in religious architecture offers a unique perspective on the relationship between mathematical concepts and cultural values. This study aims to explore the ethnomathematical aspects of the Al-Barkah
Keywords:	Great Mosque in Bekasi by analyzing its symbolic and geometric
ethnomathematics, geometry, the Al-Barkah Great Mosque, transformational geometry	elements. A qualitative research approach with a realist ethnographic method was employed, incorporating interviews, observations, documentation, and literature reviews to examine the mathematical structures embedded in the mosque's architectural design. The findings reveal that the Al-Barkah Great Mosque exhibits various geometric shapes and transformation elements, including reflection, rotation, and translation, which hold both cultural and spiritual significance. These mathematical features serve as concrete representations that enhance students' comprehension of geometric concepts. The study concludes that integrating ethnomathematics into geometry learning provides an engaging and meaningful context for students, connecting mathematical theories with real-world cultural artifacts. The implications of this study include enriching geometry instruction through cultural perspectives and providing educators with culturally relevant resources to enhance student learning and appreciation of mathematical concepts.

# Eksplorasi etnomatematika pada Masjid Agung Al-Barkah, Kota Bekasi, melalui pembelajaran geometri dan geometri transformasi

Kata Kunci:	Etnomatematika mengintegrasikan unsur budaya ke dalam
etnomatematika, geometri, Masjid Agung Al-Barkah, transformasi geometri	pembelajaran matematika, sehingga memperkuat pemahaman konsep matematis sekaligus melestarikan warisan budaya. Studi etnomatematika dalam arsitektur religius menawarkan perspektif unik tentang hubungan antara konsep matematika dan nilai-nilai budaya. Penelitian ini bertujuan untuk mengeksplorasi aspek etnomatematika pada Masjid Agung Al-Barkah di Bekasi dengan menganalisis elemen simbolik dan geometrisnya. Pendekatan penelitian kualitatif dengan metode etnografi realis digunakan dalam penelitian ini, melibatkan wawancara, observasi, dokumentasi, serta telaah literatur untuk mengkaji struktur matematika yang terkandung dalam desain arsitektur masjid. Hasil penelitian menunjukkan bahwa Masjid Agung Al-Barkah mengandung berbagai bentuk geometri dan elemen transformasi, seperti refleksi rotasi dan translasi yang memiliki makna

budaya dan spiritual. Unsur-unsur matematis ini berfungsi sebagai representasi konkret yang dapat meningkatkan pemahaman siswa terhadap konsep geometri. Penelitian ini menyimpulkan bahwa integrasi etnomatematika dalam pembelajaran geometri memberikan konteks yang menarik dan bermakna bagi siswa, menghubungkan teori matematika dengan artefak budaya di dunia nyata. Implikasi dari penelitian ini mencakup pengayaan pembelajaran geometri melalui perspektif budaya serta penyediaan sumber daya yang relevan secara budaya bagi pendidik untuk meningkatkan pemahaman dan apresiasi siswa terhadap konsep matematika.

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## **Contribution to the literature**

This research contributes to:

- Exploring the ethnomathematics aspects of Al-Barkah Great Mosque, Bekasi City, through geometry and transformational geometry.
- Emphasizes the uniqueness of integrating cultural heritage with mathematics education, offering a model that aids students in grasping abstract geometric concepts while appreciating local cultural heritage.
- This paper extends previous research by providing practical applications for geometry education across educational levels and encouraging a cultural perspective in mathematical learning.

#### 1. INTRODUCTION

Many geometric shapes are around us [1]–[3], like the geometry and value of the batik pattern of Yogyakarta [4], making geometry an essential area of mathematics in everyday life. Additionally, previous research has shown the presence of geometric shapes and transformations in cultural sites, such as the Great Mosque of Demak [5] and the batik patterns of Yogyakarta, which involve concepts of transformational geometry [4]. Learning geometry is vital as it helps students comprehend other mathematical concepts, improves problem-solving skills, and fosters effective communication through inquiry, discussion, and research activities [6]. Despite its importance, students' geometric problem-solving skills remain underdeveloped, often due to challenges in understanding abstract concepts [7]. Ideally, geometry learning should involve familiar shapes from students' surroundings, making these abstract shapes more accessible as learning media. Therefore, approaches that can assist students in enhancing their geometry understanding are needed [8]–[11].

In 1976, D'Ambrosio introduced ethnomathematics at the International Congress on Mathematical Education (ICME3) in Germany [12]. D'Ambrosio introduced ethnomathematics as an understanding that makes culture an actual form of constructing mathematical concepts [13], [14]. Ethnomathematics allows educators to teach mathematical ideas that are culturally relevant, making abstract concepts more approachable for students through familiar cultural elements [15]. For instance, introducing Indonesian cultural elements in mathematics education can facilitate a better understanding of these concepts [16]–[18].

Several studies have explored ethnomathematics in the context of West Javanese cultural heritage, particularly regarding geometry. Examples include studies on the Great Mosque of Cimahi, which incorporates geometry and algebraic concepts [19], the ornamentation of the Bandung Great Mosque [20], and the ethnomathematics of the

Jami' Mosque Sungai Jingah [21], the historical aspects of the Al-Barkah Mosque in Bekasi [22], and the role of ethnomathematics in West Java [23]. These studies illustrate the potential of ethnomathematics as an effective medium for contextualizing mathematical learning within Indonesian cultural heritage.

A few researchers have focused on the ethnomathematics of West Javanese cultural artifacts, particularly in examining the elements of mosques and temples. However, limited studies have concerned the specific ethnomathematical elements of the Al-Barkah Great Mosque in Bekasi City. Therefore, this research was intended to investigate the ethnomathematical aspects of Al-Barkah Great Mosque, focusing on its geometric shapes and transformational geometry elements. This study aimed to enrich students' cultural understanding and mathematical knowledge, improve their problem-solving skills, and increase their motivation to learn mathematics through culturally relevant examples.

# 2. METHOD

This research employed a qualitative research design with a realist ethnographic approach, allowing direct observation of cultural elements associated with the Al-Barkah Great Mosque [24]. Located at Jl. Veteran No.46 Bekasi, this mosque serves as a focal point for studying ethnomathematics through its architecture and symbolism. This research involved an ethnographic approach, analyzing cultural and mathematical aspects through observation, interviews, and documentation [25].

Data collection involved both primary and secondary sources [26]–[28]. The primary data-collecting techniques included in-depth interviews, observations, and documentation [29], [30]. After receiving consent, the interviews were conducted with the mosque's secretary and *Ri'ayah* (physical maintenance) staff, who provided insights into the cultural and historical significance of the mosque's architecture. Observations involved detailed visual assessments and measurements of specific geometric features within the mosque, focusing on elements related to ethnomathematics. Documentation included photographing and creating sketches of architectural elements relevant to transformational geometry concepts. Figure 1 provides a flowchart outlining the stages of the ethnomathematics exploration at the mosque, presenting a structured data gathering and analysis process.



Figure 1. Flowchart of Ethnomathematics Exploration Research at the Al-Barkah Great Mosque

A triangulation method was employed to validate the collected data, ensuring reliability by comparing information from various sources and applying multiple data collection techniques [31]–[33]. Data analysis was conducted using Wolcott's ethnographic approach, encompassing description, analysis, and interpretation [34]–[37]. The triangulation approach reinforced the psychometric properties of validity and

reliability, promoting consistency across data sources. Given the qualitative nature of this study, statistical tests were not applied. Instead, interpretive analysis was employed to identify significant geometric and cultural patterns within the mosque's architecture.

This research followed a thoughtful approach to explore how cultural heritage and mathematical concepts beautifully intersect. It focused on how the Al-Barkah Great Mosque reflects geometric and transformational geometry elements. This research sought to uncover a richer understanding of ethnomathematics, showing how culture and mathematics can come together in meaningful and inspiring ways.

# 3. **RESULTS AND DISCUSSION**

Mosques are one of the protected and preserved Indonesian cultures. They function as places of worship for Muslims. Furthermore, they also function as cultural objects that can be used as the theme for developing the 2013 curriculum [22]. One area that still maintains its culture is Bekasi City. Bekasi City is one of the areas in West Java and is one of the busiest cities in West Java [38]. Even so, people's lives are closely related to culture. One of the cultures that has become the icon of Bekasi City is the Al-Barkah Great Mosque. The Al-Barkah Great Mosque is the oldest in Bekasi City, located on Jalan Veteran, right next to the Bekasi City square. The Al-Barkah Great Mosque, founded in 1890 on *waqf* land, played a role in the independence movement as a political headquarters. Renovated in 1969, 1985, and 2004–2008, it has evolved into the mosque known today.



Figure 2. The Mosque Before Renovation

Figure 3. The Current Mosque

There are geometric shapes and geometric transformations at the Al-Barkah Great Mosque. The concept of geometric shapes in the Al-Barkah Great Mosque is the cuboid minarets and the rhombus mosque ornaments. Furthermore, the concept of transformation geometry is prominently reflected in the design elements of the Al-Barkah Great Mosque. The transformational geometry can be seen in the main door of the mosque, which incorporates the element of reflection; the ornamentation, which features the element of rotation; and the mosque's railing, which demonstrates the element of translation.

The Al-Barkah Great Mosque, the oldest mosque in Bekasi City, stands out for its unique characteristics. One notable feature is its courtyard, which is adorned with date palms. Given Indonesia's climate, which is generally unsuitable for cultivating date palms, the presence of these trees indicates the exceptional care they receive. According to interviews with informants, the mosque holds significant historical value, not only as a place of worship but also as a site associated with the struggle for independence movements. This dual role as a spiritual and historical landmark adds to the mosque's cultural and historical importance.

# 3.1 The Value of the Minaret

Al-Barkah Great Mosque has four minarets on the mosque's roof. They are located on the sides of the mosque's roof, surrounding the mosque's dome. The four minarets represent the four pillars of knowledge: sharia, Arabic, history, and philosophy. The following are the four minarets of Al-Barkah Great Mosque, which are right behind the *saung* (gazebo):



Figure 4. The Cuboid Minaret of the Mosque

The minaret of Al-Barkah Great Mosque, displayed in Figure 4, has a square base with dimensions of  $3,5 \ m \times 3,5 \ m$  and a height of  $15 \ m$ . After studying its geometry, the researchers found that the minaret of the mosque is cuboid-shaped. A cuboid is a geometric shape with six sides with congruent, opposite sides, and square and rectangular [39], [40].

Research showed that students' mistakes in solving problems regarding twodimensional shapes are caused by students' difficulties in determining formulas and making models [41]. Difficulties arise because students are unable to distinguish the surface area of the cuboid from its volume. Figure 5 can be used as an example to help students improve their understanding of geometric material on two-dimensional side shapes. Based on geometric modeling, the following shape is obtained:



Figure 5. Geometry Modelling of Cuboid

Figure 5 shows that the cuboid nets contain congruent planes. Congruence in these planes will produce a surface area so that the volume of the cuboid will be obtained later. This congruence ensures that the faces align perfectly when folded into a three-dimensional shape. The following are congruent fields:

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Field ABCD  $\cong$  Field EFGH produces  $p \times l$ Field AEFB  $\cong$  Field DHGC produces  $l \times t$ Field ADHE  $\cong$  Field BCGF produces  $p \times t$ 

Equation (1) can be made from the equation of the cuboid, which is the formula for the surface area of the cuboid. The following is the form of the equation:

Surface area = 
$$2(pl + lt + pt)$$
 (1)

From the modeling results, the cuboid consists of length, width, and height. The results of this modeling can be made into equation (2) of the formula for a cuboid's volume. The following is the equation:

$$Volume = p \times l \times t \tag{2}$$

#### 3.2 The Number of Mosque Doors

The construction of the structure of Al-Barkah Great Mosque was made not only to show beauty and comfort while getting closer to Allah but also to consider the messages to be conveyed. Based on interviews with informants conducted on October 25, 2022, eight doors are on each side of Al-Barkah Great Mosque. The installation of these doors is one of the messages to convey that there are many ways to enter His heaven. Therefore, never stop getting His grace. After observing through the cartesian plane, at the main door of Al-Barkah Great Mosque, there is a reflection element that intersects on the y-axis. The following is a model of the transformation geometry on the cartesian plane.



Figure 6. The Reflection Shape Intersects on the y-axis at the Main Door

Figure 6 displays that the main door of Al-Barkah Great Mosque has an intersection on the y-axis. Based on the data analysis, the intersection of the main door of the mosque in the y-axis makes (1) each side of the door facing each other, (2) the width of each side of the door is 1.5 m, and (3) the carving and shape of each side of the door have similarities. Therefore, the results of the data analysis show that the intersection of the mosque's main door concerning the y-axis produces a reflection geometric transformation element [42]. The reflection of the mosque's door on the y-axis can be made as a matrix. Equation (3) is the matrix obtained from the reflection of the y-axis.

The results of testing ethnomathematics-based transformation geometry on 35 eleventh-grade students found that 86% of students could increase their mathematics scores above the minimum achievement criteria [43]. Furthermore, the analysis also shows that the eleventh-grade students at SMA Negri 1 Purwoharjo can observe, classify, and conclude transformation geometric forms at Pura Luhur Giri Salaka [44]. Based on the results of this study, ethnomathematics-based learning can also be an actual form of applying transformation geometry to students.

#### 3.3 Ornaments on the Railing

The Al-Barkah Great Mosque has beautiful ornaments in its interior. These ornaments can be found on stairs,  $2^{nd}$ -floor railings, and fences, as shown in Figure 6. Various shapes are displayed on these ornaments, such as isosceles, triangles, squares, stars, and hexagons.



Figure 7. Railing

The geometric analysis of the railings reveals a rhombus shape. A rhombus is a two-dimensional shape with perpendicular diagonals and four sides of the same length [45]. By dividing a rhombus into two triangles, the formula for the area of a rhombus can be found as follows:



Figure 8. Rhombus Shape on the Railing

The part of the railing in Figure 8 marked in red can be illustrated as a rhombus and then transformed into two congruent triangles. The triangle formed can be used to determine the area of a rhombus. Equation (4) is how to determine the area of a rhombus using the formula for two equal triangles.

$$L.ABCD = L.ADC + L.ABC$$
  
=  $\frac{1}{2} \times AC \times OD + \frac{1}{2} \times AC \times OB$   
=  $\frac{1}{2} \times AC \times (OD + OB)$ 

$$L.ABCD = \frac{1}{2} \times AC \times BD \tag{4}$$

The perimeter can be found using the sum of the lengths of the sides of a rhombus. Equation (5) is the formula for the circumference of a rhombus by adding up each side.

$$K.ABCD = AD + DC + CB + AB \tag{5}$$

The increased student learning outcomes aligned with the teacher's delivery (information phase) to students [46]. Making ornaments at the Al-Barkah Great Mosque as learning media can help fourth-grade students learn rhombus. Ethnomathematics-based learning in *ma'belle*, *ma'ggurecceng*, and *ma'cciccu* games could help students learn mathematics more quickly [47].

The ornament on the railing in Figure 9, visualized using a Cartesian diagram, shows a two-dimensional geometric shape with the rotation geometric transformation element. Rotation is moving points by rotating these points as far as  $\alpha$  to a certain point [48]. From Figure 9, it is observed that the railing ornament rotates three times, with the initial turning point at A (5, 20) and the center point at O (0, 0). When a point (x, y) is rotated by an angle  $\alpha$  about the center point (0, 0), it produces a corresponding image point.



Figure 9. Rotation on the Railings Ornament

$$\begin{pmatrix} x'\\ y' \end{pmatrix} = \begin{pmatrix} \cos \alpha & -\sin \alpha\\ \sin \alpha & \cos \alpha \end{pmatrix} \begin{pmatrix} x\\ y \end{pmatrix}$$
(6)

Equation (6) is a matrix form with a center point (0,0). Regarding equation (6), the results of the data analysis presented in Figure 8 have been rotated three times. The initial rotation point is set at A (5.20), and the center of rotation is at point O (0.0). This process will yield the following outcomes:

$$A(5,20)^{R_{[o(0,0),90^{\circ})}}A'(-20,5) \text{ so, it can be written } A(x,y)^{R_{[o(0,0),90^{\circ})}}A'(-y,x)$$
  

$$A(5,20)^{R_{[o(0,0),180^{\circ})}}A''(-5,-20) \text{ so, it can be written } A(x,y)^{R_{[o(0,0),180^{\circ})}}A'(-x,-y)$$
  

$$A(5,20)^{R_{[o(0,0),270^{\circ})}}A'(20,-5) \text{ so, it can be written } A(x,y)^{R_{[o(0,0),270^{\circ})}}A'(y,-x)$$

Analysis shows that ninth-grade students at State Vocational Schools in Cimahi City committed mistakes in solving transformation geometry problems, mainly calculating shadows after being rotated [49]. Ethnomathematics studies can be used as

learning media to increase students' understanding of transformation geometry learning [50], [51]. The data analysis results on the Al-Barkah Great Mosque ornaments can be used as learning media for students to understand the concept of rotation.

As seen through the Cartesian plane, the railing on the second floor of Al-Barkah Great Mosque has moved twice on the x-axis. The following is the result of shifting the railing on the Cartesian plane.



Figure 10. Railing Shift

Figure 10 shows that the railing has shifted twice on the x-axis as far as 236 cm. Translation is a change in the position of each point or plane with the same distance and direction [52]. Based on the analysis's results, in addition to the discovery of two-dimensional geometric shapes, the railing also contains elements of transformation geometry, namely translation.

The Lampung Tapis cloth with the *rebung* (bamboo shoots) motif can be used as a learning medium on the topic of translation transformation geometry. Also, the bamboo shoots design can be used to ask ninth-grade junior high school students questions about transformation geometry material [53]. Research on the development of Jepara woodcarving ethnomathematics-based mathematics teaching materials on geometry transformation material for ninth-grade junior high school students obtained a feasibility test result of 94.16%, a readability test result of 92%, and a student response test of 86.67%. These results indicate that the ethnomathematics teaching materials for Jepara woodcarving are feasible and easy to understand in transformation geometry learning [54]. In addition to helping students overcome their problems, ethnomathematics can also increase student motivation in learning geometry material and introduce the diversity of Indonesian culture [55].

The findings of this study highlight the potential of ethnomathematics as an effective tool in mathematics education, particularly in culturally rich contexts like Indonesia. Lubis *et al.* [56] support the results of this study, who state that ethnomathematics-based mathematics learning can improve students' understanding and motivation. By integrating geometric concepts found in significant cultural sites, such as the Al-Barkah Great Mosque, educators can make mathematics more relatable and accessible to students. This approach enhances students' understanding of abstract mathematical concepts and fosters cultural appreciation and pride, aligning with national efforts to preserve cultural heritage. Moreover, using cultural objects in the mathematics curriculum, as suggested by the 2013 curriculum guidelines, can motivate students to engage more actively in learning. The geometric elements identified in this study, such as reflection, rotation, and translation, provide concrete examples that can be incorporated into teaching materials, potentially improving students' understanding of transformational

geometry. These findings suggest that further development of ethnomathematics-based educational resources could benefit mathematics curricula in Indonesia, promoting a culturally responsive teaching approach that aligns with the local context.

Despite the valuable insights provided, this study has several limitations. Firstly, the research is limited to a single cultural site, the Al-Barkah Great Mosque, which restricts the generalizability of the findings to other cultural settings or architectural styles in Indonesia. Future research could extend this approach to various mosques or other cultural sites across different regions to create a more comprehensive ethnomathematics resource. Secondly, the qualitative ethnographic approach focuses on interpretive analysis, which, while rich in cultural detail, lacks quantitative assessment. Future studies might benefit from incorporating quantitative measures to assess the educational impact of ethnomathematics-based learning materials on student outcomes. Lastly, the study's reliance on observational and interview data presents limitations regarding the subjective interpretation of cultural symbolism and mathematical concepts. Expanding data sources, such as involving additional cultural experts or using comparative studies, could enhance the validity of future research findings.

#### 4. CONCLUSION

This study reveals that the architecture of the Al-Barkah Grand Mosque in Bekasi City contains various geometric forms and transformation elements, such as reflection, rotation, and translation, which can be used as concrete learning media in mathematics education. By utilizing cultural elements in geometry teaching, students not only find it easier to understand abstract concepts but can also increase their appreciation of local heritage. findings support the importance developing cultural These of ethnomathematics-based teaching materials that integrate mathematical concepts with cultural elements so that mathematics learning becomes more contextual and relevant for students while contributing to the preservation of local culture in the educational environment.

# AUTHOR CONTRIBUTION STATEMENT

JS contributed to research conceptualization, literature review, and methodology design. FIL contributed to data collection, analysis, manuscript writing, and editing. Both authors reviewed and approved the final manuscript before submission.

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