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THE MATHEMATICS BEHIND GEDUNG KEMBAR OF PURWAKARTA: TRACING GEOMETRIC TRANFORMATION

Artini Bastianti[1], Indrie Noor Aini[2]
Universitas Singaperbangsa Karawang, Indonesia
e-mail: 2410632050003@student.unsika.ac.id, indrie.nooraini@staff.unsika.ac.id

Abstract

The exploration of geometric transformations in Gedung Kembar of Purwakarta aims to explore the relationship between mathematical concepts and the architectural form of cultural heritage buildings in Purwakarta Regency. Qualitative methods were used to investigate the architectural elements of the building through direct observation. The focus of the study was on four main geometric transformations, namely translation, reflection, rotation and dilation, which were discussed in the context of building design and ornamentation. The results of the study show that the Purwakarta Twin Towers depict four types of geometric transformations (translation, reflection, rotation and dilation). The principle of translation can be seen in the repetition of neatly arranged pillar ornaments, while reflection can be seen in the identical and opposing shapes of the building ornaments, creating a symmetrical impression. The principle of rotation is found in the twin building ornaments, which depict the congruence of an object, but with a change in orientation. Dilation is seen in the difference in the size of the ornaments, one of which is found in the window ventilation, which emphasizes the artistic side. In general, this study shows that geometric transformations are not only abstract ideas in mathematics, but can also be applied in real life in architectural design. The Purwakarta Twin Buildings are a concrete example of how mathematical principles can be applied to physically beautiful forms. Thus, this exploration not only enriches our understanding of the relationship between mathematics and architecture, but also opens up learning opportunities relevant to the surrounding environment, which can be used in mathematics education in a local context.

Keywords: Exploration, Gedung Kembar, Geometric Transformation

Abstrak

Eksplorasi transformasi geometri pada Gedung Kembar Purwakarta bertujuan mengeksplorasi hubungan antara konsep matematika dengan wujud arsitektur cagar budaya di Kabupaten Purwakarta. Metode kualitatif digunakan untuk menyelidiki elemen arsitektural bangunan melalui observasi langsung . Fokus penelitian adalah empat transformasi geometri utama yaitu translasi, refleksi, rotasi dan dilatasi yang dibahas dalam konteks desain dan ornamen bangunan. Hasil penelitian menunjukkan bahwa pada Gedung Kembar Purwakarta menggambarkan 4 macam transformasi geometri (translasi, refleksi, rotasi dan dilatasi. Prinsip translasi terlihat pada pengulangan ornamen pilar yang tersusun rapi, refleksi terlihat dari bentuk ornamen bangunan yang identik dan saling berhadapan sehingga menciptakan kesan simetris. Prinsip rotasi terdapat pada ornamen gedung kembar yang menggambarkan kongruensi dari sebuah objek, tetapi orientasi berubah. Dilatasi terlihat pada perbedaan ukuran ornamen, yang salah satunya terdapat pada ventilasi jendela yang menonjolkan sisi artistik. Secara garis besar, penelitian ini menunjukkan bahwa transformasi geometri tidak hanya ide abstrak dalam matematika, tetapi juga bisa diterapkan secara nyata dalam desain arsitektur. Gedung Kembar Purwakarta menjadi contoh nyata bagaimana prinsip-prinsip matematis bisa diterapkan pada bentuk fisik yang tampak indah. Jadi, eksplorasi ini tidak hanya memperkaya pemahaman tentang hubungan matematika dan arsitektur, tetapi juga membuka peluang belajar yang relevan dengan lingkungan sekitar, yang bisa dipakai dalam pembelajaran matematika di konteks lokal.
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Kata kunci: eksplorasi, Gedung kembar, transformasi geometri

INTRODUCTION

Mathematics and culture are often seen as two separate things. According to Firdaus & Hodiyanto (2019) Education and culture are two interconnected components that can

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influence each other, and cultural development is certainly also influenced by education. Mathematics has become part of the culture in every aspect of human life ife (Wardani & Budiarto, 2022).

One way to connect culture and education, especially in mathematics learning, is ethnomathematics (Kudus, 2015). Ethnomathematics is mathematics practised among identifiable cultural groups, such as national tribes, labour groups, children of a certain age group, professional classes, and so on. Its identity is highly dependent on the focus of interest, motivation, and on certain codes and jargon that are not included in the realm of academic mathematics (D'Ambrosio, 1985).

Ethnomathematics can be implemented in schools as a contextual learning approach, making mathematics more accessible and relevant to students (Kou et al., 2021). Ethnomathematics can integrate several aspects of Indonesian cultural heritage into mathematics education. One study on ethnomathematics was conducted by Manapa (2021) in his research, he identified ethnomathematical elements in traditional clothing, dowries, pottery, musical instruments, fishing tools, and games. Another cultural heritage that can be integrated into ethnomathematics is historical buildings.

Ethnomathematics in historical buildings provides a contextual approach to teaching mathematical concepts. Since many students consider mathematics an abstract subject far removed from everyday life, using real buildings that students are familiar with as a learning context makes learning more realistic and interesting, especially for geometry material.

Research exploring historic buildings has been conducted in various places, and several studies have been carried out, including those conducted by Safitri (2023) towards traditional Joglo houses, which display geometric concepts such as triangles, trapezoids, and symmetry. The research was also conducted by Lisnani et al (2020) at the Balaputera Dewa South Sumatra Provincial Museum in Palembang, these buildings feature various geometric shapes, such as squares, triangles, polygons, cylinders, and prisms, which can teach concepts such as flat shapes and spatial geometry.

One of the historic buildings that has become a cultural heritage site is in Purwakarta Regency. Two buildings on Kornel Singawinata Street, Nagri Kidul Village, Purwakarta District, known as the Twin Buildings, are historical relics of Purwakarta (A. S. Widodo, 2022). These buildings are called 'Gedung Kembar' because they stand side by side and have the same

shape, like a gate with a unique architectural design. The structure of these buildings is in the Art Deco architectural style (Lubis, 2022). One of the distinctive features of Art Deco architecture is the arrangement of geometric patterns deliberately designed to give an impression of order and strong structure, through a combination of horizontal and vertical elements, which create repeating patterns (Anzila & Ramadhan, 2024).

Photo Source: Personal Documentation

Figure 1. Gedung kembar 1

Figure 2. Gedung kembar 2

Gedung Kembar 1 is a Regional Museum Balai Panyawangan Diorama Purwakarta, and Gedung Kembar II is the Regional Government Office, Jl. Kol. Kornel Singawinata No. 23. Gedung Kembar in Purwakarta. They are captivating symbols of colonial history and architecture and possess unique shapes and patterns that are interesting to study in depth, especially from a mathematical perspective. While historic buildings have often been discussed in terms of their aesthetics or historical value, this study attempts to look at them from another angle: how geometric concepts, particularly geometric transformations, are contained within historic buildings.

Gedung Kembar Purwakarta are a historical building with distinctive architectural value and reflect cultural acculturation during the colonial period (A. S. Widodo, 2022). So far, research on integrating local culture in mathematics learning has mostly utilised batik motifs, traditional houses, or traditional arts. However, studies relating historical buildings such as the Twin Towers to mathematical concepts are still very limited.

Previous studies on geometric transformations in traditional buildings have included analysing geometric concepts in Mekongga motifs in traditional Tolaki houses (Hidayati et al., 2025). and geometric explorations in the design of the Grand Mosque of Surakarta (Wahyuni

et al., 2024). These studies consistently identify geometric transformations in traditional architectural elements, including reflection, translation, rotation, and dilation.

The novelty of this research lies in the fact that there has not been much research exploring iconic buildings in Purwakarta as a medium or context for mathematics learning, compared to other regions. Previous studies have also been very few in addressing the concept of geometric transformation in the context of historic buildings. Although both studies address the concept of geometric transformation, this study explores the Purwakarta Twin Buildings Cultural Heritage Site, which has never been explored in this context before.

This study aims to use the context of the Gedung Kembar in Purwakarta Regency to explore and analyse the concept of geometric transformation, which can then be used as a source of learning and knowledge related to real-world objects in mathematics education.

METHODS

This study employs descriptive qualitative research. Bogdan and Taylor (1982), in their book(Abdussamad, 2021) Qualitative research is a research procedure that produces descriptive data in the form of written or spoken words from people and observable behaviour.. The data collection techniques used included library data and field data, thus forming a comprehensive approach. Library data provided an understanding of the theoretical framework and historical context of ethnomathematics, while field data enabled direct observation and documentation of the building and its ornaments (Tuhfatul Janan et al., 2023).

In this study, researchers directly participated in the field to seek information and collect data through observation, interviews, and field documentation at Gedung Kembar Purwakarta. Data analysis in this study was conducted using triangulation techniques, which included data reduction, data presentation, and conclusion drawing. In the data reduction stage, the results of observations, visual documentation, interviews, and field notes were converted into written form and selected so that only relevant information about the mathematical elements in the architecture and ornamentation of the Twin Towers was retained. The reduced data was then presented by grouping and linking it to the concept of geometric transformation. The final stage was concluding, namely formulating the results of the ethnomathematical

exploration of which ornaments and architectural elements could be linked to the concept of geometric transformation. In this study, researchers directly participated in the field to seek information and collect data through observation, interviews, and field documentation at Gedung Kembar Purwakarta.

RESULTS AND DISCUSSION

Based on the observations and direct interviews with the managers of the twin buildings in Purwakarta Regency, with permission from the relevant agencies, researchers obtained information that the twin buildings are one of the cultural heritage sites in West Java Province. After conducting exploration, observation, and documentation directly, in addition to the two buildings that have twin structures representing the concept of reflection in geometric transformation, the researcher also found several objects that have flat shapes in accordance with the concept of Geometric Transformation, as follows:

1. Translation

   Translation is also called displacement. This transformation does not alter the orientation and congruence of geometric shapes; it merely shifts them from one position to another (Masta et al, 2022).

Photo Source: Personal Documentation

Figure 3. Ornamen Gedung Kembar 1

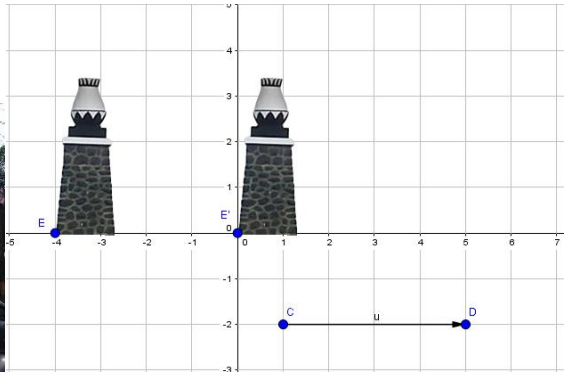

Figure 4. Simulasi Transalsi di Koordinat Kartesius

The concept of translation in transformational geometry can be found in several ornaments on the twin buildings. As seen in image 3, there are two pillars with congruent shapes. This shows the application of the concept of translation or displacement.

In the Cartesian plane, we can define translation as follows: Given any point P(x,y). Translation related to vectors $\binom{a}{b}$ for the point P(x,y), written as $\tau_{(a,b)}$ (x,y), defined as $\tau_{(a,b)}$(x,y)=(x+a,y+b) (Masta, dkk. 2022).

Image 4 illustrates that one of the poles is translated against vector u, which is parallel to the x-axis, showing the horizontal shift from one pole to another position. Pay attention to the point E(-4,0) translated with respect to the vector $\vec{u} = \binom{4}{0}$, then the point E′(0,0).

$$E(-4,0) \xrightarrow{T_{(4,0)}} E'(-4+4\ ,\ 0+0) = E'(0,0)$$

2. Reflection

Reflection, also known as mirroring, is a transformation in which an object is reflected against a line called the line of reflection (Masta & dkk, 2022).

Photo Source: Personal Documentation

Figure 5. Ornaments of the Gedung Kembar 2

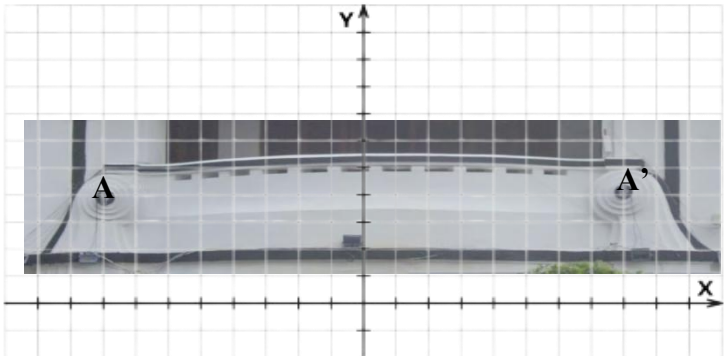

Figure 6. Reflection Simulation in Cartesian Coordinates

From the twin building ornaments marked with red circles in Image 5, it can be seen that the two ornaments reflect each other across an imaginary line parallel to the y-axis.

When analysed in a Cartesian coordinate system, this shape can result from reflection on the line x = 0 (y-axis), producing the image shown in Figure 6. For example, point A(-8,4) will be reflected on the Y-axis, producing the reflection A'(8,4).

In accordance with the concept of reflection across the Y-axis, the image of point A (x, y) reflected across the Y-axis is A' (–x, y).

$$A(-8,4) \xrightarrow{M_y} A'(-(-8),4) = A'(8,4)$$

3. Rotation

This transformation preserves an object's congruence, but its orientation may change. It is important to note that if the angle is positive, the rotation is counterclockwise; if the angle is negative, it is clockwise (Masta & dkk, 2022).

Photo Source: Personal Documentation

Figure 7. Ornaments of the Gedung Kembar 1

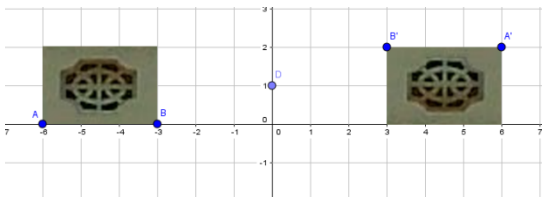

Figure 8. Simulation in Cartesian Coordinates

the ornament marked with a red circle on the right results from rotating the ornament marked with a red circle on the left. For further clarification, see Image 8, where the shape on the left is rotated by 180^o with the centre D(0,1), The result is the building on the right. On the left side of the building there is a point A(-6,0) and point B(-3,0). Points A and B will be rotated by 180^0 with the centre point D(0,1) which will produce a shadow A'(6,2) dan B$'$(3,2).

When applied to matrix operations related to rotation around an arbitrary point, the matrix associated with a rotation of θ radians around the point (a,b) is

$$\begin{bmatrix}\cos(\theta) & -\sin(\theta)\\ \sin(\theta) & \cos(\theta)\end{bmatrix}\begin{bmatrix}x-a\\ y-b\end{bmatrix}+\begin{bmatrix}a\\ b\end{bmatrix}$$

For point A(-6,0) rotated by 180^0 relative to point D(0,1), the matrix operation is as follows:

$$=\begin{bmatrix}\cos(180^0) & -\sin(180^0)\\ \sin(180^0) & \cos(180^0)\end{bmatrix}\begin{bmatrix}-6-0\\ 0-1\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}$$

$$=\begin{bmatrix}-1 & 0\\ 0 & -1\end{bmatrix}\begin{bmatrix}-6\\ -1\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}$$

$$=\begin{bmatrix}6\\ 1\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}$$

$$=\begin{bmatrix}6\\ 2\end{bmatrix}$$

For point B(-3,0) rotated by 180^0 relative to point D(0,1) the matrix operation is as follows:

$$=\begin{bmatrix}\cos(180^0) & -\sin(180^0)\\ \sin(180^0) & \cos(180^0)\end{bmatrix}\begin{bmatrix}-3-0\\ 0-1\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}$$

$$=\begin{bmatrix}-1 & 0\\ 0 & -1\end{bmatrix}\begin{bmatrix}-3\\ -1\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}$$

$$=\begin{bmatrix}3\\ 1\end{bmatrix}+\begin{bmatrix}0\\ 1\end{bmatrix}$$

$$=\begin{bmatrix}3\\ 2\end{bmatrix}$$

4. Dilatation

Dilation is a geometric transformation that involves changing the size of a shape by a certain scale factor while maintaining its shape and proportional relationships. Dilation can be understood as enlargement or reduction (Masta & dkk, 2022).

Figure 9. Gedung Kembar 1

Figure 10. Ornaments of the Gedung Kembar

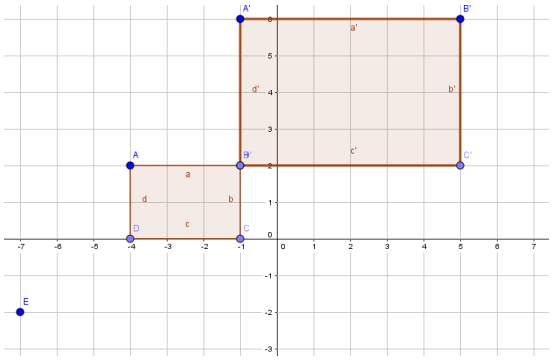

Figure 11. Ventilationof the Gedug Kembar Figure 12. Simulation in Cartesian Coordinates
Photo Source: Personal Documentation

The window panes of Gedung Kembar circled in red in Picture 9, with details in Picture 10 and 11, show two squares, one small and one large. The two squares are congruent, so the large square results from dilation (enlargement) and the small square results from contraction. Figure 12 illustrates dilating a point relative to a centre point on the Cartesian coordinate system.

If point A(-4,2) is dilated with respect to point E(-7,-2) by a factor of 2, then the map of that point is

$$\overrightarrow{FA'} = \overrightarrow{2FA} = 2\begin{bmatrix}x\\y\end{bmatrix} - \begin{bmatrix}-7\\-2\end{bmatrix} = 2\begin{bmatrix}-4\\2\end{bmatrix} - \begin{bmatrix}-7\\-2\end{bmatrix} = \begin{bmatrix}-8\\4\end{bmatrix} - \begin{bmatrix}-7\\-2\end{bmatrix} = \begin{bmatrix}-1\\6\end{bmatrix}$$

So the map from point A is (-1,6)

A study of Indonesian cultural heritage shows that broad geometric transformation concepts are embedded in traditional architecture and art forms. A study of Joglo houses shows geometric concepts such as lines, angles, flat shapes, Pythagoras' theorem, spatial shapes, similarity, and geometric transformations such as translation, reflection, and rotation(Mahiro, 2021). In addition to traditional Joglo houses, mosque architecture displays comprehensive geometric concepts, including angles, flat shapes, spatial shapes, and transformations (Wahyuni et al., 2024), In mosque architecture, geometric transformation concepts: reflection, translation, dilation, and rotation, are present.

Similar research uncovering concepts such as translation, reflection, rotation, and dilation was conducted on the decorative cultural heritage of Yogyakarta (Abdullah, 2020), and the Tikus

Temple in Mojokerto (Rifqy et al., 2025). In addition, geometric transformations were also studied in the Melati batik motif in Kebon Village (Fachrunnisa & Sari, 2023) These studies emphasise the potential of ethnomathematics to improve mathematical understanding by linking cultural elements with geometric transformation concepts, thereby making learning more contextual and meaningful for students.

The results of exploratory research on historical buildings, including cultural heritage sites, traditional houses, and mosques, can be developed into teaching materials, including the Student Worksheet (LKPD). Learning with a contextual approach based on ethnomathematics using LKPD that takes the context of historical buildings is expected to make learning more meaningful for students.

CONCLUSION

Based on the study's results, the concepts of geometric transformation, namely translation, reflection, rotation, and dilation, are applied to several elements of the twin building's ornamentation. This study shows that combining geometric transformation concepts in twin building design can be an effective contextual learning medium in mathematics education, particularly in demonstrating the real-world application of abstract concepts. The researcher conducted this study because exploring historic buildings in Purwakarta Regency is rarely done. Apart from being an icon of regional architecture, the application of this concept also proves that geometric transformation is not just an abstract theory, but has a real role in creating architectural works that are functional, beautiful, and have educational value for the community.

Future research is expected to expand the scope of mathematical research conducted at the Twin Towers and explore other historical sites in Purwakarta Regency. Such exploration could enable the development of learning materials integrated with local cultural values, enriching students' understanding of the relationship between mathematics and historical heritage.

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