Representation of the Architectural Geometry Concept of the Yogyakarta Palace on the Structure of the *Mandalasana* Ward: An Ethnomathematical Study

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Abstract. This research aims to identify cultural values and geometric concepts in traditional architecture in the *Mandalasana* Ward Building in the Yogyakarta Palace with an ethnomathematical approach. The building not only represents the value of cultural philosophy and aesthetic value, but it is also a geometric structure that can be used in mathematics learning. The research was conducted using a descriptive qualitative approach with a case study method on the cultural objects of the *Mandalasana* Ward in the Yogyakarta Palace. Data collection techniques were done through field observation, visual documentation, and semi-structured interviews. The results of the study show that (main findings). These findings identify that (conclusions/implications).

Keywords: Ethnomathematics, Geometry, Culture, *Mandalasana* Ward, Mathematics Learning.

1 Introduction

In the context of Javanese culture, the Yogyakarta Palace is a cultural symbol rich in philosophical, aesthetic, and mathematical values implied in its architecture. The *Mandalasana* Ward is a building that functions as a place for music performances, with the characteristic of a regular octagonal floor, an octagonal pentagram-shaped roof, and an octagonal prism. The mathematical concepts in the building reflect geometric shapes that are pretty deep, so they can be used as styling materials in learning [1]. The formation of music functions as music to welcome important guests to the palace, and as entertainment played in the *Mandolosono* Ward. The *Mandalasana* ward has a different roof shape from other traditional buildings, with four sides of the building, while the *Mandalasana* ward has eight sides [2].

Mathematics learning is designed to create an environment for students to carry out mathematics learning activities [3]. In mathematics learning, integrating local wisdom can facilitate students' understanding of mathematical concepts through a cultural context close to their lives [3]. Integrating ethnomathematics based on local traditions, such as Gumbrengan in

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Gunungkidul, can be an effective strategy to increase students' involvement and understanding in learning the concept of building space in mathematics [4].

Mathematics learning, especially in geometry, is closely related to ethnomathematical culture and concepts. A learning approach that integrates cultural elements is proven in understanding mathematics [5]. However, the reality in the field shows that mathematics learning in schools is often presented abstractly and is not relevant to the context of students' daily lives. This condition has an impact on the low interest and understanding of students, especially in learning geometry topics.

Geometry is one of the branches of mathematics that studies points, lines, planes, and spaces, as well as their properties, sizes, and relationships [1]. The integrity of ethnomathematics in education is important to strengthen the values of local wisdom, which are increasingly eroded by globalization. In learning activities, ethnomathematics can be used as a bridge to relate formal mathematics concepts with contexts that often have a different philosophical basis from formal mathematics, which can also be raised as meaningful and contextual teaching materials.

2 Method

This study uses a descriptive qualitative approach with a case study method on the cultural objects of the *Mandalasana* Ward of the Yogyakarta Palace. The data collection technique was carried out through direct observation at the location of the Yogyakarta Palace to identify relevant geometric shapes and ornaments on the building structure. In addition, visual documentation in the form of photographs and sketches is used to analyze architectural elements from a geometric point of view. Literature studies on ethnographic sources, Javanese cultural history, and ethnomathematical theories are also carried out to strengthen the cultural and academic context. Semi-structured interviews were also conducted with courtiers and *guides* in the Yogyakarta Palace who understood the philosophy and structure of the buildings in the Yogyakarta Palace. Data analysis is carried out by categorizing geometric elements such as symmetry, transformation, and pattern, and interpreting the meaning of the accompanying cultural philosophy.

3 Result and Discussion

3.1 Result

The discussion focused on the mathematical concept of geometry of ethnomathematical objects in the Yogyakarta place, namely the *Mandalasana* ward, and its integration in mathematics learning. This study's discussion is divided into identifying geometric concepts and cultural values (see Fig. 1).

Fig. 1. *Mandalasana* ward and its integration in mathematics learning

Identification of Geometric Concepts

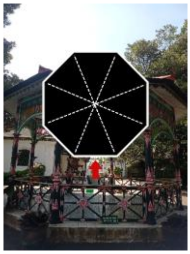
The *Mandalasana* Ward is part of the Yogyakarta Palace complex, which has a distinctive structure with high philosophical and aesthetic values. Visually, this building contains many geometric elements that can be identified and associated with mathematical concepts taught at the junior and senior high school levels, especially in geometry materials.

Geometry of the field.

Ethnomathematics in the *Mandalasana* Ward, located in the Yogyakarta Palace complex, is a Javanese architectural building with many cultural values, storing various geometric concepts of the field that can be applied in the mathematics learning process in schools. The following is an identification of the concepts of field geometry found in the *Mandalasana* Ward, namely, there are building forms related to the matter of folding symmetry, circumference, various types of flat buildings, flat building areas, reflection, congruence, cohesion, and circular elements.

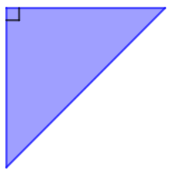
First, the material of folding symmetry is present in the carving patterns that decorate the ward, especially in the fence and the octagonal floor shape with eight folding symmetries.

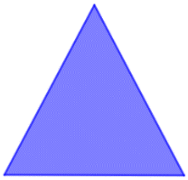
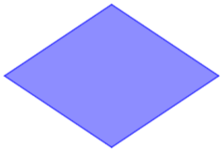
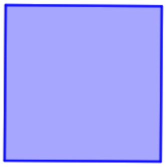
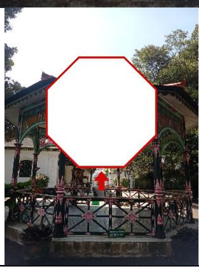
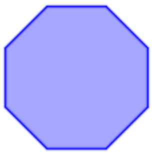
Table 1. Folding symmetry in the *Mandala Sana* Ward

Symmetry lipate	Picture	Concept
Square	Square shape around the lower fence 	
Rectangle	Rectangular shape around the lower fence 	
Octopus	Octagonal shape on the floor of the *Mandalasana* Ward 	

Second, the material about the types of flat buildings on ornaments in the *Mandalasana* Ward is very diverse. In the parts of the ward there are several flat buildings, namely the elbow triangle is in the lower fence, the isosceles triangle is in the lower fence, the rhombus is in the decorative part of the pillar, the square is on the floor and the upper fence, the rectangle is in the lower part of the fence, the circle, the octagon, and the hexagon are on the inside of the floor.

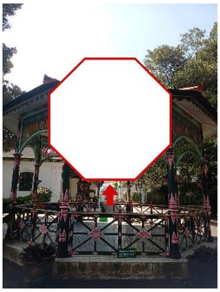
Table 2. Types of flat buildings in *Mandalasana* Ward

Types of flat buildings	Picture	Concept
Right triangle		

Rectangle		
Octopus	 	
Square		
Rectangle		
Octopus		

Third, the diversity of flat buildings in the *Mandalasana* Ward is calculated in the circumference of the building. As stated in the various flat buildings above, it can be calculated to find its circumference as follows:

Table 3. Around the flat building of the *Mandalasana* Ward

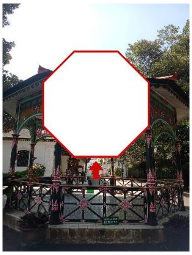
Circumference of a flat building	Picture	Concept
Rectangle		Find the circumference of a rectangle by summing up all sides that face each other and have different lengths.
Square		Find the circumference of a rectangle by adding up all sides of equal length on all four sides.
Right triangle		Find the circumference of a right triangle by adding up the three sides, consisting of two perpendicular sides and
Octopus		Find the circumference of an octagon by adding up the number of sides of the same length and forming regular angles.
Circle		Searching for the circumference of a

		circle of a circular length of a perfectly rounded shape that has no angle

Fourth, after observing the structure and ornaments of the *Mandalasana* Ward directly, I noticed there is material about the area of the circle on the building. From the various flat buildings above, the concepts of calculating the area of flat buildings can be explained as follows:

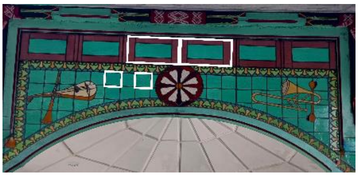
Table 4. Area on the flat building of *Mandalasana* Ward

Width on flat build	Picture	Concept
Rectangle		Find the area of a rectangle by looking at the relationship between the long and short sides that are perpendicular to each other to form a plane.
Square		Find a square area by multiplying two sides of equal length to form a flat plane.
Right triangle		Look for a triangle of elbows – the part of the plane bounded by two perpendicular sides.
Octopus		Find the area of an octagon by dividing the building into parts of a triangle

		or square, then adding them up.
		
Circle		Find the area of the circle by determining how much area is covered in a circular shape centered on a point.

Fifth, in addition to the various forms of flat buildings, the concept of congruence and harmony can be seen in the carving patterns and ornamental shapes that decorate the ward. As in the square shape of the upper fence, the identical and regularly repeated triangle shape on the fence shows confluence. Meanwhile, the patterns on the outer rectangle of brown color are the same as the inner rectangle of green. Circles of the same size but with different sizes, but the same shape, reflect the concept of togetherness.

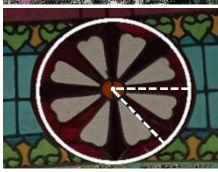
Table 5. Congruence and Harmony in the *Mandalasana* Ward

	Picture	Concept
Squares and rectangles		The visible shapes are precisely the same size and shape, arranged repeatedly, and overlapping without different parts.
Triangle		Patterns formed from triangles with identical sizes and shapes and

		arranged in regularity show the exact similarity of shape and size.
Rectangle		Patterns that are similar in shape but different sizes show the same proportions on each side, even though the scale is different.
Circle		Circles – circles of the same shape and different sizes, arranged regularly at the top and bottom of the fence. Although they are not the same size, they remain similar and proportional, reflecting the concept of togetherness.

Finally, certain parts of the ward, especially the carved ornaments, are in the shape of a circle. The elements of the circle are the center point, radius, diameter, arc, and sector.

Table 6. Elements – Circle elements

Elements – Elements Circle	Picture	Concept
Central point		
Radius		
Diameter		
Bow		 
Sector		

Geometry ruang.

The *Mandalasana* Ward is one of the important buildings in the Yogyakarta Kraton complex, which is used as a place for music performances or performances to welcome important guests of the Palace. It has a philosophical meaning in Javanese cosmology [1] . The structure of the *Mandalasana* Ward building reflects the local wisdom of traditional aesthetics, and also stores mathematical values, especially in terms of spatial geometry.

The basic form of the main room of the *Mandalasana* Ward building is an octagonal prism room. In each frame of the building, which is connected by support columns in the form of an upright hexagonal prism, there is also a spherical decoration in the middle of the roof of the *Mandalasana* Ward.

Table 7. Volume of building space in *Mandalasana* Ward

Build Space	Picture	Concept
Prism		Prism Volume (V) $V = \frac{1}{3} \times L_a \times t$ Information: $V = Volume\ bola L_a$ $= Luas\ alas$ $t = tinggi\ limas$
Ball		Volume Ball $V = \frac{4}{3}\pi r^3$ Information: $V = Volume\ bola \pi$ $= phi\ (3{,}14\ atau\ \frac{22}{7})$ $r = jari - jari$

Geometry transformation.

Transformation is the transfer of moving an object from the initial position to a new one [6]. *Mandalasana* Ward is one of the traditional buildings in the Yogyakarta Palace complex. The building has an orderly, symmetrical structure and visually and structurally ornate features. $(x, y)(x', y')$

After observing the structure and ornaments of the *Mandalasana* Ward directly, there are several reflections, namely the reflection of the building framework of the *Mandalasana* Ward space, which is separated by roof support pillars, and the reflection on the decorative motifs of the roof support pillars.

Table 8. Reflection/Reflection of the *Mandalasana* Ward

Building structure	Picture	Concept
Build a hexagonal prism space.		
Roof Rack Decoration		
Fence decoration/pattern		
		
		

Ceramic patterns		

3.2 Discussion

Cultural Values

The *Mandalasana* Ward, which stands majestically in the courtyard of the Yogyakarta Palace, is one of the historical buildings with high cultural and aesthetic value. Unlike typical Javanese rectangular buildings, this building is octagonal, reflecting the mandala symbol as a symbol of cosmic harmony and order. The two-story roof decorated with stained glass patterned with Western musical instruments combined with typical Javanese ornaments, such as the motifs of Wajibkan, Tlacapan, Saton, and Tegel Kunci, makes this ward not only a place for music performances and events to welcome guests of honor, but also an architectural work that can be studied from an ethnomathematical perspective. Even the Candra Sangkala that adorns this building provides symbolic and numerical meaning related to the year of its construction, namely 1727 Java (1794 AD), making Bangsal *Mandalasana* a real example of how the value of art, music, and mathematics can be integrated in a work.

According to Mr. Misran, a courtier who understands the palace's values and rules, no one can use this building, and its sacred value is always maintained. "When entering, everything must be neat and directed; you cannot just go in and out," he said. The value of familiarity and loyalty can also be seen from how applicants or students who have served can be asked to return at any time if their energy is needed, following the words of the queen's sabdo, which means that what has been said must be done. This also emphasizes the importance of maintaining and developing ancestral heritage values so that they are not lost from generation to generation, making Bangsal *Mandalasana* not only a building, but also a symbol of values, harmony, and wisdom that continues to be inherited from time to time.

The results focused on the mathematical concept of geometry of ethnomathematical objects in the Yogyakarta Palace, namely the *Mandalasana* Ward, and its integration in mathematics learning. The *Mandalasana* Ward, as a traditional architectural heritage, not only reflects Javanese cultural values and philosophy and stores mathematical structures that can be explored in geometry learning in schools.

Integration in Learning

Integrating ethnomathematics-based mathematics learning, such as in the *Mandalasana* Ward's structure, can contextually improve students' understanding of geometric concepts. Students can not only solve problems, but also construct their understanding through cultural exploration. This encourages creativity, culture, and a deeper understanding of mathematics.

Geometry of the Plane

The learning began with a visual observation of the image of the lower fence of the *Mandalasana* Ward at the Yogyakarta Palace. This fence has a geometric structure consisting of rectangular, triangular, and symmetrical arrangements. The integration of local cultures is used in mathematics learning to facilitate understanding the concept of building a flat through contextual and visual approaches (see Fig. 2).

Fig. 2. The image of the lower fence of the *Mandalasana* Ward at the Yogyakarta Palace

Students are invited to observe the overall shape of the fence, which resembles a rectangle. To reinforce this concept, the teacher presented an illustration of a rectangle with a length of 12 cm and a width of 6 cm.

Initial Stage: Understanding Rectangles

The teacher showed me a large rectangle.

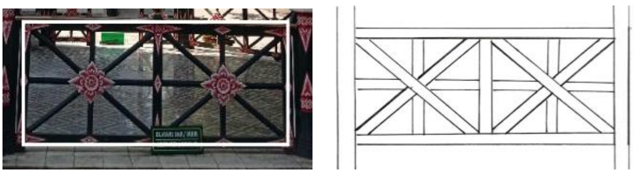


Fig. 3. The image of the lower fence of the *Mandalasana* Ward at the Yogyakarta Palace

Exploration questions:
Area = length × width
Area= (12) × (6) = (72)cm^2

Then the teacher gave a lighter question: "Can you guys divide this rectangle into two squares?" This question encourages students to think creatively and outline the basic form of fence construction.

Stage Two: Finding the Squares in the Rectangle

The learner divides the rectangle into two rectangles measuring 6 × 6, and one small rectangle remains (sizes 6 × 6), which visually has no area and is considered irrelevant. There is an understanding that a square is a special case of a rectangle, where length = width. Then square area = (side) × (side)
What is the area of the square? Square Area = (6) ×(6) =(36)cm^2

This step reinforces the relationship between a square and a rectangle. It instills a visual awareness that many shapes in everyday life are combinations of geometric basic shapes (see Fig. 4).

Fig. 4. The image of the *Mandalasana* rectangle at the Yogyakarta Palace

Third Stage: Finding the Triangle in a Rectangle

The teacher directs the students to do diagonal folds against a 12 x 6 rectangle, forming two congruent elbow triangles. This teaches learners that triangles can be produced from the folding of a rectangle.
Triangle area = ()$\frac{1}{2} \times alas \times tinggi = \frac{1}{2} \times 12 \times 6 = 36\ cm^2$

This fold shows that the two triangles formed have the same area, i.e. each , and if folded back to form the original rectangle.36 cm^2

Visual Conclusion: Students are asked to conclude from the exploration activities. (see Fig. 5)

Fig. 5. The image of the *Mandalasana* Triangle in a Rectangle at the Yogyakarta Palace

Geometry Ruang

Analysis of the structure of the *Mandalasana* Ward in ethnomathematical activities. The main structure of the Mandalasan Ward in the Yogyakarta Palace is a cultural object that is not only aesthetically and historically valuable but also stores spatial shapes that can be analyzed through a geometric approach. Mathematics learning activities can be designed to encourage students to observe the structure visually and relate it to the concept of building space and calculating its volume (see Fig. 6).

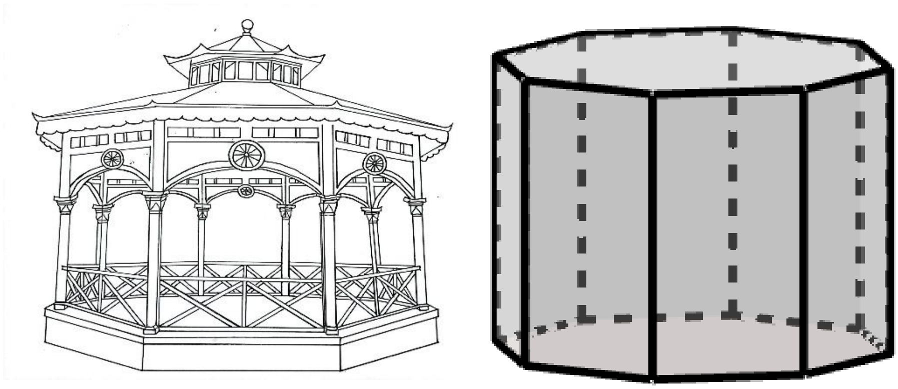


Fig. 6. Image of spatial volume and geometric concepts in the structure of the *Mandalasana*

In ethnomathematics-based learning and the Discovery Learning model, students can be directed to explore the geometric shapes seen on the building. Some exploratory questions that can be developed to support this activity include: From the results of the observation of the images of the structure of the *Mandalasana* Ward, what building space seems to dominate the most? Explain based on the visual shape of the building. If students are asked to make a miniature *Mandalasana* Ward, what data needs to be measured to calculate the volume of the upper space of the roof or the space in the building? Based on the size data obtained through observation in the picture, students were asked to calculate the volume of the building space using the appropriate formula.

This exploration activity can encourage students to think critically and creatively and directly engage in a meaningful learning process by connecting geometry, mathematics, and local culture concepts. Thus, students understand mathematical concepts in the abstract and see their application in real-life and cultural contexts.

Transformation Geometry.

The geometric transformation in the form of reflection (reflection) can be recognized through observation of the ornamental shapes and symmetrical structures found in the *Mandalasana* Ward. The structure of the front of this building shows an arrangement of pillars, ornaments, ceramic patterns, and fences arranged mathematically against the Y-axis line.

To facilitate contextual learning, students can be directed to identify these symmetrical patterns through exploration and observation activities through drawings of the *Mandalasana* Ward building located in the Yogyakarta Palace. Some of the activities that can be done in learning include: 1) Observe the front ornaments of the building and determine symmetrical shapes. 2) Identify the observed shape's mirror line (axis of symmetry). 3) Redepict the shape and reflect it against a predetermined mirror line. 4) Analyze whether the shape of the reflection result has a size, shape, and orientation consistent with the principle of reflection in geometry.

As part of integrating cultural values, students are invited to explore the meaning of symmetrical patterns used in traditional Javanese architecture, such as the values of harmony, balance, and proportion that are the basis of the building's philosophy.

4 Conclusion

This research succeeded in identifying and presenting various geometric concepts contained in the architecture of the *Mandalasana* Ward in the Yogyakarta Palace through an ethnomathematical approach. Bangsal *Mandalasana* not only presents Javanese cultural, aesthetic, and philosophical values, but also stores a wealth of mathematical concepts that are very relevant to be used as a medium for learning mathematics, especially in the geometry of fields, spaces, and transformations. In the geometry aspect of the field, there are various forms of flat buildings such as squares, rectangles, triangles, circles, and octagons depicted on the ornaments and structures of the building, as well as the application of the concepts of folding symmetry, confluence, cohesion, circumference, and breadth. For spatial geometry, the structure of the roof and pillars of buildings show the shape of an octagonal prism, as well as spherical ornaments that can be analyzed through the concept of the building volume of the space, while in geometric transformation, visual reflection is found through symmetrical patterns found in the decoration of pillars, fences, and building floors, which can be explained through the concept of geometric reflection. Integrating these geometric elements into culture-based mathematics learning can provide students a more contextual and meaningful learning experience. By observing directly through the visualization of the *Mandalasana* Ward building, students not only learn to solve mathematical problems in the abstract, but can also understand by constructing mathematical concepts in real life based on cultural values. This approach also encourages creativity, curiosity, and active involvement of students in mathematics learning, while strengthening the understanding of local wisdom as part of the nation's cultural heritage.

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