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GEOMETRIC AND MATHEMATICAL PATTERNS IN THE ARCHITECTURE OF THE GRAND MOSQUE OF SYEKH YUSUF GOWA: AN EXPLORATION

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ABSTRACT

Ethnomathematics studies the relationship between mathematics and culture, including its application in everyday life. One of the relevant cultural objects is the mosque, which can be an interesting approach in learning mathematics. This study aims to explore the application of geometric concepts and mathematical patterns in the architectural design of the Grand Mosque of Syekh Yusuf Gowa. Using a qualitative approach with ethnographic methods, data were collected through observation, documentation, and literature review. The results of the study show that the structure and ornaments of the mosque reflect various geometric elements, such as two-dimensional shapes (square, circle, triangle, rhombus, octagon, and trapezoid) and three-dimensional shapes (cylinder and quadrilateral pyramid). In addition, geometric transformations such as reflection, translation, and dilation are also found in the design. There are also mathematical patterns that enrich the aesthetics of the architecture. These findings underline the importance of the integration of mathematics and culture in education, and provide new insights into the application of mathematical concepts in traditional architecture. This study confirms that the architecture of the Grand Mosque of Syekh Yusuf is not only a place of worship, but also a source of inspiration in learning mathematics.

Keywords: Mathematics Pattern, Exploration, Ethnomathematics, Qualitative research

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INTRODUCTION

Mathematics, Mathematics, although often regarded as abstract subjects in schools, has a very important role in understanding and developing science and technology. Without the contribution of mathematics, progress in various fields of science and technology is not possible (Noprianilubis et al., 2017; Tuhfatul Janan, 2024).

In the context of daily life, mathematics does not only function as an abstract science, but also becomes a tool to understand and apply concepts in the culture of society (Chaudhary et al., 2023; Noto et al., 2018). One approach that connects mathematics with social and cultural reality is ethnomathematics, which is the study of the relationship between mathematics and culture, as well as how mathematics is applied in everyday life (L Wakhidah, 2022). This approach supports mathematics learning that is relevant to real life while fostering love for culture through the integration of local wisdom or local culture into the learning process (Chaudhary et al., 2023; Noto et al., 2018).

Ethnomathematics was first introduced in 1977 by Brazilian mathematicians, D'Brosio, which explains that this term consists of three components: "Ethno" which refers to the socio - cultural context, including language, symbols, and traditions; "mathema" which includes the activities of understanding, measuring, classifying, and modeling; and "tics," which comes from the word "techne" which means technical (D. S. Ayu, 2020). Etnomatematics also has a close relationship with geometry (Izah & Malasari, 2021), especially in the context of exploration of geometric forms and mathematical patterns that are often found in everyday life, such as flat shapes and building space. Flat shapes include shapes such as squares, rectangles, triangles, circles, kite, trapezoid, parallelogram, and rhombus that do not have dimensions of space but only in the form of flat planes that have length and width, while building space includes cubes, beams, tubes, cones, balls, and pyramids that have length, width, and high. Thus, mathematics has a variety of forms in everyday life. So that ethnomathematics can be interpreted as a tool to act in the world because it advances in a closer way with real life (Yuniarti, 2021).

One of the cultural objects that is close to the daily life of students is the mosque. The selection of mosques as a cultural object in learning mathematics is an interesting approach and has Grand potential. A number of studies have been conducted to explore ethnomathematics related to the mosque. Some examples include ethnomathematics exploration at the Grand Mosque of Probolinggo City (Rofiq et al., 2022), Ethnomathematics research at the Grand Mosque of Tasikmalaya City (Saviraningrum & Wahidin, 2023), and more deep ethnomathematics research at the Al-Akbar Mosque in Surabaya (Tuhfatul Janan et al., 2023). In addition, there are ethnomathematics exploration research at the Al-Alam Marunda Mosque (Faturrahman & Soro, 2021), and Jami 'Al-Baitul Amien Jember (Yudianto et al., 2021). The study shows how important it is to understand the relationship between cultural elements in mosque architecture and mathematical concepts contained therein, thus providing broader insights about the application of mathematics in the context of culture and religion (Tuhfatul Janan, 2024).

Most mosque architectural research in Indonesia is more focused on historical, arts, and cultural aspects, while studies that specifically explore geometry and mathematical modeling in mosque design are still limited. Many studies focus more on the aesthetics and symbolic meaning without analyzing the geometric shape and mathematical order that underlies the structure of the building. In fact, the architecture of the mosque is rich in geometry concepts such as symmetry, transformation, fractal, and tessellation that can be analyzed mathematically to understand the pattern of design and optimization of space. Lack of research that builds mathematical models of mosque architectural elements shows the gap in Islamic architectural literature, especially in the context of structural modeling. Therefore, this study aims to fill the gap, in this case, the Grand Mosque of Sheikh Yusuf Gowa was chosen as the main research object, with a focus on geometric concepts applied in mosque architecture and ornaments. Such as square, rectangle, trapezoid, rhombus, circle, and triangle. Build space such as pyramid and tube, as well as geometry transformation such as reflection, translation, and rotation contained in it. This research will explore more deeply how these geometric elements become part of the beauty of architecture. In addition, this research will explore the relationship between geometric forms and mathematical concepts that may not have been widely disclosed and explore mathematical modeling in the design of the Grand Mosque of Sheikh Yusuf Gowa. Through an ethnomathematics approach, it is hoped that this study can provide new insights on how traditional architecture such as the Grand Mosque of Sheikh Yusuf Gowa can be a source of inspiration in mathematics learning, as well as enriching understanding of the role of culture in the development of science (Tuhfatul Janan, 2024).

METHOD

This research uses ethnographic research with a qualitative approach to explore the application of mathematical concepts and geometric principles in the architecture of the Grand mosque of syekh yusuf gowa. The ethnographic approach is applied by studying how cultural values and mathematical concepts combined in the design and structure of the mosque, both in the main building and ornaments. Data collection is carried out through observation, documentation, and literature study. Direct observations at the location, which was carried out in November 2024 at the Grand mosque of syekh yusuf gowa, Jalan Sungguminasa Masjid, Somba Opu, Gowa Regency, South Sulawesi, aimed to identify the forms of geometry in the structure of building and mathematical patterns in ornaments. Documentation is carried out through photography and recording design elements to support visual analysis.

In this research, literature study is used to compare the findings with relevant theoretical references related to geometry in Islamic architecture. Data collected were analyzed using thematic analysis, where geometric patterns were identified and categorized based on mathematical concepts such as symmetry, geometric transformation, fractal, and tesselation. This analysis aims to reveal the relationship between geometric forms, aesthetic values, and structural functions in mosque architecture. Through this approach, research can provide in-depth insights on how mathematical principles are applied in the design of the Grand mosque of syekh yusuf gowa, as well as how these elements reflect the cultural values and traditions of Islam in local architecture.

RESULT

The Grand Mosque of Syekh Yusuf is one of the mosque buildings that is an icon and a source of pride for the people of Gowa Regency, South Sulawesi Province, located in Sungguminasa Village, Somba Opu District. Initially, the idea to establish this mosque came from the community's need for a place of worship that could accommodate a large number of worshipers as well as a center for the development of Islamic civilization in Gowa Regency. After being used for 16 years, a total renovation was carried out on the physical form of the mosque building as well as changing the name which was originally known as the Somba Opu Grand Mosque, then changed to the Gowa Grand Mosque and finally became the Grand Mosque of Syekh Yusuf (Syukur et al., 2024).

The naming of one of the best sons of Gowa Regency as well as a cleric who is a symbol of culture in a local identity that has an emotional connection with the Gowa community which has been documented in many research results. Such as the results of research conducted by Syamsu Alam which states that the figure of Sheikh Yusuf is a local figure in South Sulawesi Province who is a national hero. His figure is not only in the local or national scope, but has gone global and he has even been made a National Hero of the Republic of South (Alam, 2021). Then in other literature, it is stated that the location of Sheikh Yusuf's figure in practicing Islam is the values of faith that are instilled and taught to the community such as Sheikh Yusuf's teachings regarding the process of inner purification (Musa, 2021; Syukur *et al.*, 2024). From this explanation, it can be understood that Sheikh Yusuf is a very influential figure in Gowa Regency so that the community chooses to immortalize his name as the name of one of the mosques in Gowa Regency.

Figure 1. Sheikh Yusuf Gowa Grand Mosque (Source: https://it.pinterest.com/pin/2040762320847868/)

1. The Concept of Geometry of Flat Buildings

a. Triangle 2D Shape

Figure 2. The Tower of the Grand Mosque of Sheikh Yusuf Gowa

Figure 3. Ceiling of the SheikhYusuf Gowa Grand Mosque

Observations of the tower and ceiling of the Grand Mosque of Syekh Yusuf Gowa revealed the application of geometric concepts, especially in triangular plane shapes. A triangle is a plane shape that has three sides and three angles, with the total number of angles always reaching 180°. If classified based on the length of its sides, triangles are divided into three types, namely equilateral triangles, isosceles triangles, and arbitrary triangles. Meanwhile, based on the size of the angles, triangles are grouped into acute triangles, right triangles, and obtuse triangles (Mardatih & Sintawati, 2019). The following is the formula used to calculate the area and circumference of a triangle:

Area: $L = \pi \times r^2$
Perimeter: $K = 2 \times \pi \times r$

b. Square and Rectangle Plane Structures

Figure 4. Courtyard of the Sheikh Yusuf Gowa Grand Mosque

Figure 5. Floor of the Grand Mosque of Sheikh Yusuf Gowa

Observation results, on the floor of the mosque both inside and outside (courtyard) of the mosque are square and rectangular. On the floor of the courtyard of the mosque, there is an interesting mathematical pattern in the form of ceramic arrangements with two types of geometry, namely square and rectangle. Each square consists of 16 cream ceramics arranged in a 4x4 formation, while each rectangle consists of 20 cream ceramics in a 5x4 formation. Both of these geometric shapes are surrounded by black ceramics, which function as a divider or frame to highlight the geometric pattern. In addition, square and rectangular shapes are also found on the main door of the mosque and the walls of the mosque.

Figure 6. Main Door of the Sheikh Yusuf Gowa Grand Mosque

Figure 7. Wall of the Sheikh Yusuf Gowa Grand Mosque

A square is a two-dimensional flat shape that has four sides of the same length and four corners that form right angles (90°). On the other hand, a rectangle is also a two-dimensional flat shape that has four right angles, with opposite sides having the same length (Fajar et al., 2019). The following are the formulas used to calculate the area and perimeter of a square and rectangle:

Square	**Rectangle**
Area: $L = sisi \times sisi$	Area: $L = p \times l$
Perimeter: $K = 4 \times sisi$	Perimeter: $K = 2(p + l)$

c. Rhombus Plane

Figure 8. Ornaments of the Grand Mosque of Sheikh Yusuf Gowa

Figure 9. Calligraphy Ornaments of the Grand Mosque of Sheikh Yusuf Gowa

Figure 10. Ventilation of the Grand Mosque of Sheikh Yusuf Gowa

The rhombus shape can be found in the ornaments and ventilation of the Grand Mosque of Syekh Yusuf Gowa. A rhombus is a quadrilateral with all sides of equal length. A rhombus fulfills all the properties of a parallelogram, thus a rhombus is a parallelogram with all four sides of equal length, so it has the following properties: each angle is divided into two equal parts by its diagonals and its diagonals intersect at right angles (Fajar et al., 2019). The formula used in calculating the area and perimeter of a rhombus can be expressed as follows:

Area: $L = \frac{1}{2} \times d_1 \times d_2$

Perimeter: $K = 4 \times s$

d. Octagonal Plane

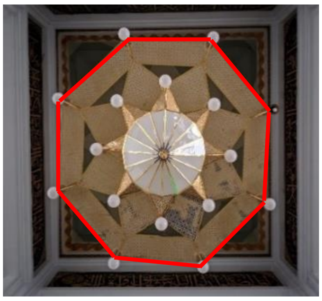

Figure 11. Decorative Lights of the Sheikh Yusuf Gowa Grand Mosque

Figure 12. Place of Ablution at the Grand Mosque of Sheikh Yusuf Gowa

An octagon is a two-dimensional flat shape that has 8 sides and 8 angles. If analyzed more deeply, an octagon consists of a combination of two quadrilaterals, and it can also be separated into several symmetrical triangular shapes (Kurniawan & Rahmawan, 2021). The octagonal shape can be found on the decorative lamps of the Grand Mosque of Syekh Yusuf Gowa and the ablution area for both male and female worshipers. The results of the observation show that each ablution area has 45 taps for use by worshipers, which are designed to meet the needs when the number of worshipers increases, especially during congregational prayer times or on religious holidays. This tap facility helps reduce long queues and makes it easier for worshipers to access ablution water, so that they can perform ablution comfortably and efficiently. The formula for determining the area and perimeter of an octagon:

Area: $L = 2 \times r^2 \times \sqrt{2}$

Perimeter: $K = 8 \times sisi$

e. Trapezoid Plane

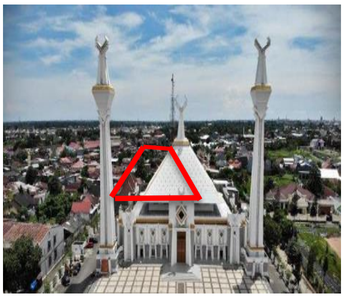

Figure 13. Kubah Masjid Agung Syekh Gowa

A trapezoid is a two-dimensional flat shape that has a pair of parallel sides but not the same length, has four sides and four corner points, has an angle between the parallel sides of 180°. In general, trapezoids can be divided into 3 types, namely isosceles trapezoids, right trapezoids, and arbitrary trapezoids (M. S. Ayu, 2020). An isosceles trapezoid can be seen on the dome of the Grand Mosque of Syekh Yusuf Gowa. An isosceles trapezoid is a trapezoid that has a pair of parallel sides and two hypotenuses of the same length. This trapezoid has one line of symmetry and one rotational symmetry (M. S. Ayu, 2020). The formula used to calculate the area and circumference of a trapezoid can be expressed as follows:

Area: $\frac{1}{2} \times t(AB + CD)$

Perimeter: $K = AB + B + D + AD$

2. Geometry Concept of Spatial Buildings

a. Spatial Building of Quadrilateral Pyramids

Figure 14. Dome of the Grand Mosque of Sheikh Yusuf Gowa

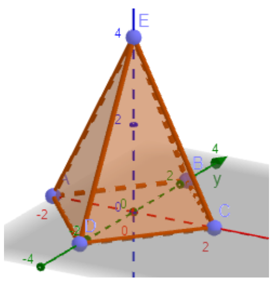

Figure 15. Quadrilateral Pyramid in Cartesian Plane

Observation results, on the dome of the mosque there is a geometric concept of a rectangular prism-shaped space if we extend the basic lines. A rectangular pyramid is a three-dimensional space that has 4 triangular surfaces and one square surface at the base, has 8 edges, and there are 5 corners, one of which is the peak of the pyramid (Sari et al., 2022). The formula for determining the area and volume of a rectangular pyramid:

Area: $LP = Area\ of\ base + (4 \times area\ of\ triangle)$

Perimeter: $v = \frac{1}{3} \times s^2 \times t$

b. Build a Cylinder Space

Figure 16. Pillars of the Grand Mosque of Sheikh Gowa

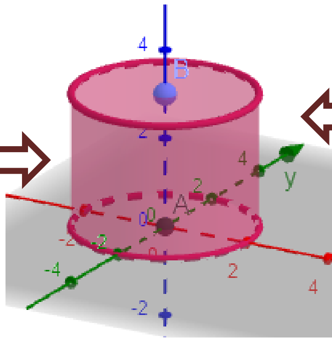

Figure 17. Cylinder In Cartesian Plane

Figure 18. Water Tower of the Grand Mosque of Sheikh Yusuf Gowa

Observation results, on the pillars of the mosque and water towers (water reservoirs) there is a geometric concept of a cylindrical shape. A cylinder is a three-dimensional geometric shape that has two sides in the form of circles that are parallel and congruent (the same size), and a curved side that connects the two circles (Ermayanti, 2023). Cylinders are often also referred to as cylinders. Formulas for determining area and volume:

Area: $LP = 2\pi r(r + t)$

Volume: $v = \pi \times r^2 \times t$

3. Concept of Transformation Geometry

a. Reflection

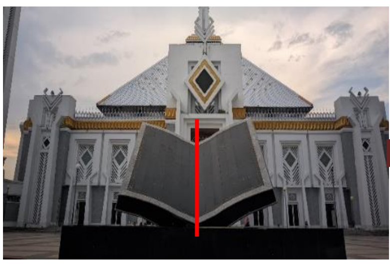

Figure 19. Monument to the Grand Mosque of Sheikh Yusuf Gowa

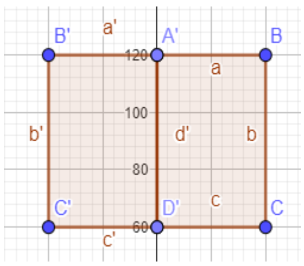

Figure 20. Rectangular Reflection On Cartesian Plane

Based on the results of observations that have been made, the form of the monument of the Grand Mosque of Syekh Yusuf Gowa has a concept of transformation, namely reflection on the y-axis. In addition, the rhombus shape on the roof of the Grand Mosque of Syekh Yusuf Gowa also has a concept of transformation, namely reflection on the y-axis and x-axis.

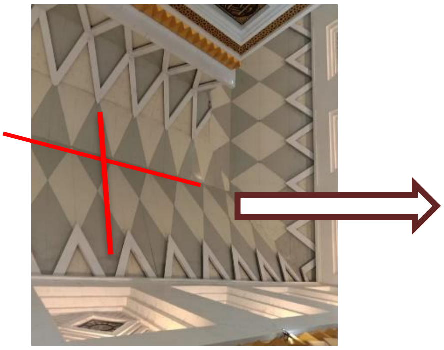

Figure 21. Roof of the Interior of the Grand Mosque of Sheikh Gowa

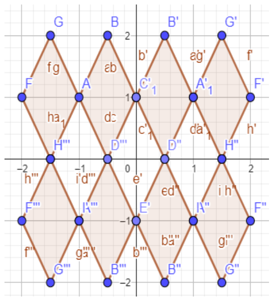

Figure 22. Translation of Rhombus on Cartesian Plane

b. Translation

Figure 23. Elements of the Roof of the Sheikh Gowa Grand Mosque

Based on the observation results, there is a geometric concept of transformation in the architectural elements of the mosque roof, namely translation. Researchers found the concept of translation, namely the movement or shift of hexagonal ornaments in one direction with the same distance.

c. Dilation

Figure 24. Ornamen Masjid Agung Syekh Gowa

Based on the observation results on the exterior ornaments of the Grand Mosque of Syekh Yusuf Gowa, these ornaments not only contain the concept of translation but also contain the concept of dilation. If we look at the rhombus shape, there are changes in size that are getting bigger or smaller but these changes do not change the shape of the rhombus shape itself.

4. Mathematical Modeling

Figure 25. Water taps in the ablution area

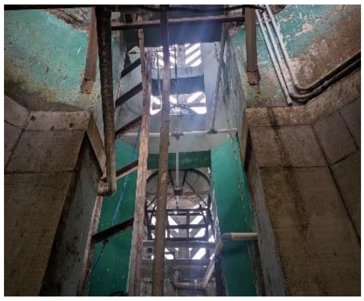

Figure 26. Water tower in the ablution area

In the Grand Mosque of Sheikh Yusuf, there are two areas for ablution for male and female worshipers. Each area has 45 taps, and each area is supported by 4 water towers, where each tower has a capacity of 1000 liters. So, each area (male and female) has a total water capacity of 4000 liters. During prayer time, there are 300 male worshipers and 250 female worshipers performing ablution. Each worshiper uses an average of 3 liters of water for one ablution. Assume that all taps in both areas can flow water simultaneously at a rate of 0.2 liters/second per tap.

a. Is the total water capacity sufficient to meet the needs of all worshipers who will perform ablution once?
b. How long will it take for the water in the tower to run out if all the taps in both areas are used non-stop?
c. How many times can all the male and female worshippers perform ablution until the water in the tower runs out?

Solution:

a. Total water capacity sufficient to meet the needs of all worshipers who will perform ablution once.
   Step 1: Total Water Capacity in Each Area

   Each area (both male and female) has 4 towers with a capacity of 1000 liters per tower.

$$Total\ capacity\ per\ area = 4 \times 1000\ liters = 4000\ liters$$

   Since there are two areas (men and women), the total water capacity throughout the mosque is:

$$Total\ capacity\ of\ all\ towers = 2 \times 4000\ liters = 8000\ liters$$

   Step 2: Total Water Needs for Ablution

   - Water needs for male pilgrims
     $Number\ of\ male\ pilgrims = 300$
     Water needs per pilgrim $= 3\ liters$

$$Total\ water\ requirements\ for\ male\ pilgrims = 300 \times 3\ liters$$
$$= 900\ liters$$

   - Water requirements for female pilgrims

Number of female pilgrims $= 250$
Water requirements per pilgrim $= 3 liters$

$$Total\ water\ requirements\ for\ female\ pilgrims = 250 \times 3\ liters$$
$$= 750\ liters$$

- Total Water Needs for all pilgrims
  $Total\ water\ needs = 900\ liters + 750\ liters = 1650\ liters$

Because the total capacity of the tower is Grander than the total water needs of all pilgrims ($8000\ liters > 1650\ liters$), the water capacity is sufficient for all pilgrims to perform ablution once.

b. Water Runs Out Time in Tower if All Taps are On

If all taps in both areas are used non-stop, we calculate the time it takes for the water to run out.

Total number of taps in both ablution areas:
$$Total\ taps = 45 + 45 = 90\ taps$$

- Water flow rate per tap: 0,2 liters/second.
- Total water flow rate from all taps:
  $$Total\ flow\ rate = 90 \times 0{,}2 = 18\ liters/second.$$
- Time until the water in all the towers runs out:

With a total water capacity of 8000 liters, the time required for all the water to run out is:

$$Water\ running\ out\ time = \frac{Total\ capacity\ of\ all\ towers}{Total\ flow\ rate}$$

$$= \frac{8000\ liters}{18\ liters/second} \approx 444{,}44\ second$$

Convert time to minutes:

$$444{,}44\ seconds \approx 7{,}4\ minutes$$

So, if all the taps in both areas flow water simultaneously without stopping, the water in the tower will run out in about 7,4 minutes.

c. All female and male worshipers can perform ablution until the water in the tower runs out

- Total Water Required for One Ablution by:
  Male worshipers$= 300 \times 3\ liters = 900\ liters$

  Female worshipers $= 250 \times 3\ liters = 750\ liters$

- The amount of ablution that can be done:

$$Male\ worshipers = \frac{4000\ liters}{900\ liters} \approx 4{,}444$$

$$Female\ worshipers = \frac{4000\ liters}{750\ liters} \approx 5{,}333$$

So, all male worshippers can perform ablution 4 times before the water in the tower runs out, with a little water left for some worshippers in the 5th ablution, and all female worshippers can perform ablution 5 times before the water in the tower runs out, with a little water left for some worshippers in the 6th ablution.

DISCUSSION

Based on the research results, it can be concluded that the building of the Grand Mosque of Syekh Yusuf Gowa contains geometric concepts and structured mathematical patterns that can be analyzed in depth. The mosque's architectural elements show mathematical order which not only plays a role in aesthetics, but also in building structures. This is relevant to the previous research conducted by Dina Sulistyowati & Rita Pramujiyanti Khotimah (2022), which found that mathematical elements in building form include flat shapes, geometric transformations, and certain patterns of order that support architectural functions and designs.

In addition, research conducted by Lela Nur Safrida, Susanto, Toto Bara Setiawan, & Erfan Yudianto (2022) revealed that several historical buildings in Alas Purwo National Park, including Pura Luhur Giri Salaka, also reflected the concept of ethnomathematics in the form and pattern of geometrics. The results of their research found that the gate at the location contains various forms and geometric spaces such as triangles, rectangles, prisms, and pyramids, and display geometry transformation such as translation, reflection, and dilatation. The same thing was found in the Grand Mosque of Syekh Yusuf Gowa, where the architectural element contains typical geometric shapes, such as trapezoidal domes, doors and window shapes, and mathematical patterns in ornaments that show mathematical regularity. In addition, the principle of geometric transformation such as translation and reflection appears in the arrangement of ornaments, while fractal concepts are seen in repeated decoration patterns on a smaller scale. Thus, this study not only confirmed the previous findings, but also expanded the understanding of the application of geometry in Islamic architecture through a deeper study of the structural and decorative elements of the mosque. This finding indicates that the mosque environment can be used as an effective and contextual source of learning mathematics.

A similar view was expressed by Noto (2018), who emphasized that mathematics is a basic science that has a crucial role in supporting various scientific disciplines, both in terms of logic and its application in everyday life. In addition, mathematics also contributes significantly to the development of science, technology, and the preservation of cultural values. Therefore, mathematics learning for students needs to be designed with a more creative, interactive, and meaningful approach, so that they can understand concepts more comprehensively and are able to apply them in various real situations.

CONCLUSION AND SUGGESTIONS

In this study the assessment of geometric concepts was carried out on historic buildings namely the Grand mosque of syekh yusuf gowa. The explored mathematical concepts include: the concept of a flat -building geometry and building space, the concept of geometry of transformation and mathematical modeling contained in the building of the Grand mosque of syekh yusuf gowa. The concept of building space such as rectangular pyramids and tubes found in mosque tower, mosque domes, mosque pillars, and water reservoirs. The concept of flat shapes found in buildings, namely, rhombus, triangle, square, rectangles, circles, segments, and trapezoids. The mathematical modeling made based on observations in the mosque building in the form of modeling about the water capacity in the Grand mosque of syekh yusuf gowa. This research can also provide insight into how local culture can be integrated into mathematics learning. The mosque as a symbol of culture and religion has Grand potential to become an interesting and relevant learning medium. By linking mathematical concepts with cultural elements, students not only learn about theory but also understand their application in everyday life.

This research is still limited to qualitative analysis without precise geometric measurements and has not compared directly with other mosques to see broader design patterns. In addition, the use of digital technology in modeling and structural analysis is still limited. Therefore, further research is advised to apply a more precise mathematical measurement method, comparing with other mosque architecture, and utilizing technology such as 3D modeling and artificial intelligence -based analysis. The interdisciplinary approach that connects geometry with cultural values and building functionality can also deepen understanding of the role of mathematics in Islamic architecture.

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