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A culture-based development of mathematics learning: A case on the Muhammad Cheng Hoo Mosque Surabaya

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ABSTRACT
Learning mathematics in schools aim to make students able to make mathematics as a solution or approach in simplifying or solving daily problems. To achieve this goal, it is necessary to have a culture-based mathematics learning which expected to be able to help students understand and master mathematics better. The purpose of this study is to identify the mathematical elements contained in the ornament and architecture of the Muhammad Cheng Hoo Mosque in Surabaya. This research is qualitative research with an ethnographic approach. Data collected by using a literature study, observation, documentation, and interviews. Data analysis is classified into several stages, namely domain and taxonomic analysis, componential analysis, and cultural theme analysis. The results showed that there are mathematical elements in the ornament and architecture of the Muhammad Cheng Hoo Mosque in Surabaya included the concepts of plane geometry, solid geometry, and transformational geometry. Mathematical elements in this mosque may be used as material for the development of culture-based mathematics learning at the primary and secondary school levels.

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1. INTRODUCTION

The aim of learning mathematics in schools is students can solve the problems of human life by implementing appropriate mathematical concepts or approaches (Acharya, 2017; Căprioară, 2015; Gravemeijer et al., 2017; Saragih et al., 2017; Saragih & Napitupulu, 2015). However, in the perception of the majority of students, mathematics is an abstract object, and students need a lot of effort to understand it well (House, 2006; Markovits & Forgasz, 2017). The students' average ability in solving types of reasoning questions is still low until now. This problem indicates that these students are not yet able to bring mathematics into a solution to simplify or solve problems in their daily lives (Ilmiyah, Rofiqoh, et al., 2020). One reason is mathematics learning in schools tends to be rigid and conventional (Mazana et al., 2018). Learning mathematics is only a transmission of knowledge, and students only accept it without any critical reflection on it (Risdiyanti & Prahmana, 2020). Students have not been allowed to carry out meaningful learning activities, such as exploring mathematical concepts, finding principles, and applying them to real problems (Kristanti et al., 2018).

Mathematics considered frightening for students can create anxiety when students learn it, and this anxiety thought to affect the learning process and mastery of mathematics (Anita, 2014; Maloney & Beilock, 2012; Rubinsten & Tannock, 2010; Young et al., 2012). Efforts to bring the abstract mathematical concepts into the real world are expected to be able to minimize students' mathematical anxiety (Abi, 2016; Klee et al., 2021). Teachers must use appropriate learning methods that able to provide a stimulus to students, so they can define, connect, and transform mathematical concepts with the environment around them. Contextual teaching and learning is one method that can answer this challenge (Tsai et al., 2008). To achieve the goal of efficient and optimal contextual learning, teachers must know and understand the environmental factors that affect student learning.

The way a student understands something is determined by the culture and environment around him (Ilmiyah, Rofiqoh, et al., 2020; Simamora et al., 2018). Various objects that are known by students in their daily lives can be used and contribute to building an understanding of mathematical facts, principles, and concepts (Anggo, 2011). There is a lot of mathematical thinking behind the actions and products created by humans (d'Entremont, 2015; Palhares, 2012). Therefore, the mathematics learning process requires an approach that can integrate concepts in mathematics with the culture that develops in the surrounding community. This approach needs to be applied to help students understand abstract mathematical language. Because every student is directly involved and has a role in culture, they will be helped by the use of culture-based learning media (Ilmiyah, Annisa, et al., 2020). D'Ambrosio initiated Ethnomathematics to encourage the creation of new mathematical knowledge (Risdiyanti & Prahmana, 2020).

The application of ethnomathematics in schools can increase student involvement and creativity in mathematics (D'Ambrosio & D'Ambrosio, 2013). Ethnomathematics is proven to be able to strengthen the relationship between mathematics and the conditions of social reality which are considered to be unrelated because mathematics in schools is often taught rigidly and does not pertain to community conditions (Alangui, 2010). Teaching mathematics through a cultural approach will help students to know more about their own culture and environment so that it is hoped that they can understand and master mathematics better (T. Purniati et al., 2020). Ethnomathematics can help teachers in the humanization of mathematics (Agustin et al., 2018; Palhares, 2012). Ethnomathematics allows learning mathematics in schools to be seen as a process of training students to be able to explore aspects of their culture (Rosa & Gavarrete, 2017). Through ethnomathematics, students can also explore moral values in culture by using various methods in exploring mathematical ideas, practices, and problem solving carried out by society in that culture (Rosa et al., 2016).

The development of language and culture has an impact on the creation of mathematical thinking that is closely related to human life (Palhares, 2012). One of the manifestations that emerged as a result of culture, especially the culture of the Islamic community, is the existence of mosques as the center of worship (Muchlis, 2009). The physical shape of the mosque depended on the socio-cultural conditions of the community, is one of the causes for the emergence of various mosque shapes (Endrayadi, 2019). To preserve civilization, Muslims enlivened the mosque with various things. They built a unique and attractive mosque architecture. The architecture and ornaments in these mosques are not only interesting to study in terms of their aesthetics. More than that, there are a lot of mathematical concepts that can be adapted as a medium for learning mathematics based on culture.

Many researchers have conducted studies on mathematical elements in mosques, such as ethnomathematical research at the Great Mosque of Demak (Radiusman et al., 2021), the Great

Mosque of Pondok Tinggi in Sungai Penuh City (Patri & Heswari, 2021), the Great Jami' Mosque of Malang (Asnawi et al., 2022), Soko Tunggal Mosque in Yogyakarta (Putra et al., 2020), the Old Mosque of Tosora (Kastolani, 2021), the Great Mosque of Bandung (Purniati et al., 2021), the Great Mosque of Kediri (Susanti et al., 2022), the Jami' Mosque of Jingah River (Fajriah & Suryaningsih, 2021), the Raudhatus Sa'adah Mosque in Bengkulu (Friansah & Yanto, 2020), Al-Khalid Mosque of Kediri (Ilmiyah, Rofiqoh, et al., 2020), and the Great Mosque of Cimahi (Purniati et al., 2020). We can find mathematical concepts in these mosques' architecture and ornaments like the concept of plane geometry, solid geometry, transformational geometry, graph theory, and others. Most of these studies only examine the mathematical elements, with a short discussion of the symbols and their philosophy (explaining activities) in the mosque's design.

One of the mosques in Indonesia that has a beautiful architectural design is the Muhammad Cheng Hoo Mosque in Surabaya. It is the first mosque in Indonesia built-in 2002 with the theme of Chinese architecture. The mosque design which is identical to Chinese culture makes so many questions and curiosity to know more about this mosque. It is not only has a unique architecture but also has an interesting philosophy. The idea discussed in this article is an attempt to elaborate ethnomathematics in the architecture and ornament of the Muhammad Cheng Hoo Mosque in Surabaya as culture-based mathematics learning medium. The results of this study expected to provide benefits for educators and educational institutions to develop teaching and learning tools.

2. METHOD

The type of research in this article is qualitative research with an ethnographic approach. Ethnographic research involves learning activities about elements of a culture that speak, hear, think, see, and act in different ways (Spradley, 1997). Researchers use qualitative research to represent reality, find patterns, and gain a deep understanding of architecture and ornamental of the Muhammad Cheng Hoo Mosque in Surabaya as the research object. Primary data collected through triangulation techniques by combining observation, documentation, and interview techniques. The type of observation is an unstructured observation by making direct observations on the architecture and ornamental of the Muhammad Cheng Hoo Mosque Surabaya. From these observations, the researcher chose the architectural and ornamental parts of the mosque that contained mathematical elements. The results of the observation were documented in photos and videos. The interview technique was implemented to obtain data regarding the history of the mosque construction, building area, and building sketches, with the takmir of Muhammad Cheng Hoo Mosque as a resource. Researchers obtain the secondary data includes studies of geometry using literature studies. Researchers as human instruments have a function to determine the focus of research, select data sources, collect data, check data quality, review data, interpret data, and provide conclusions. Data analysis was classified into several parts, namely domain and taxonomy analysis, componential analysis, and cultural theme analysis.

3. RESULTS AND DISCUSSION

3.1. Domain and Taxonomy Analysis

Domain analysis was implemented to determine the presence or absence of mathematical elements in the architecture and ornamental of Muhammad Cheng Hoo Mosque Surabaya. The results of domain analysis show that there are mathematical elements in the architecture and ornamental of the mosque. The domain focus in this study is restricted to activities of measuring, designing, and explaining. Researchers analyze these domains in more depth through the following descriptions:

3.1.1. Measuring Activities

Measuring is an activity to find out the comparison of location using the unit of measure. All parts of the Muhammad Cheng Hoo Surabaya Mosque were built through a measurement process, like measuring the land, the area of the building, and others. As shown in Figure 1, Figure 2, and Figure 3, Muhammad Cheng Hoo Mosque Surabaya has a size of 21 × 11 meters and has an area of 231 m^2 (Endrayadi, 2019). The main building of this mosque has a measurement of 11 × 9 meters. The stairs in the mosque have six steps, while the stairs in the foyer have five steps.

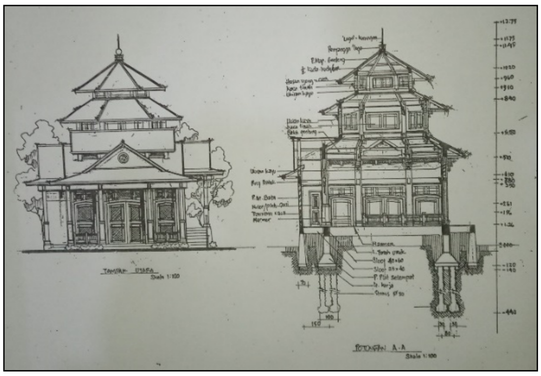

Figure 1. Muhammad Cheng Hoo Mosque Surabaya Sketch 1

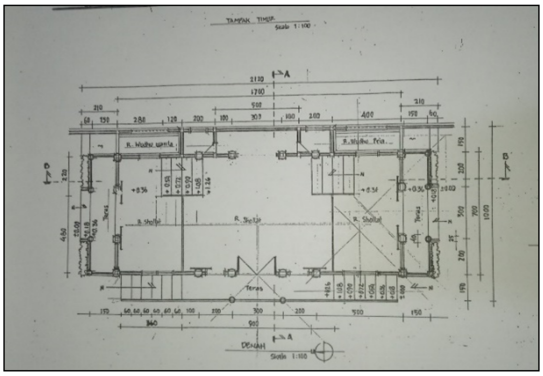

Figure 2. Muhammad Cheng Hoo Mosque Surabaya Sketch 2

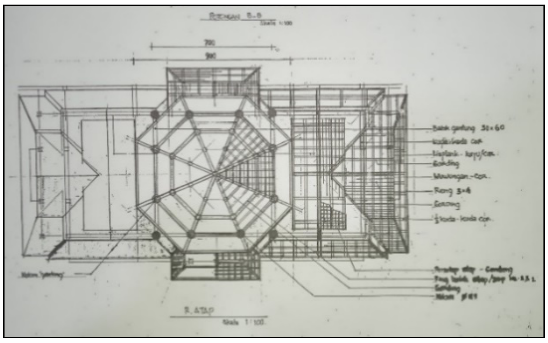

Figure 3. Muhammad Cheng Hoo Mosque Surabaya Sketch 3

3.1.2. Designing Activities

The activity of designing in the Muhammad Cheng Ho Mosque Surabaya can be seen in its unique architecture resembling a temple model, as shown in Figure 4. The concept of cultural acculturation in the design of the Muhammad Cheng Hoo Mosque Surabaya is well planned to form a beautiful harmony of buildings.

Figure 4. The front section of Muhammad Cheng Hoo Mosque Surabaya

One of the differences between Muhammad Cheng Hoo Mosque and other mosques is that the mosque's dome is pagoda-shaped. The pagoda is arranged in layers by the size getting smaller and smaller. The ceiling in front of the main hall is decorated with square panels that are painted on each corner with a circular design of red, yellow, and bright green (Endrayadi, 2019).

The Muhammad Cheng Hoo Surabaya Mosque roof is full of symmetrical ornaments as shown in Figure 5. The right and left sides of the mosque are also symmetric. The pillars of the mosque are tubular. In mathematics, the ideal pillar design is tubular.

Figure 5. The ornamental of Muhammad Cheng Hoo Mosque Surabaya

3.1.3. Explaining Activities

The initial design of the Muhammad Cheng Hoo Mosque was inspired by the shape of the Niu Jie Mosque in Beijing which was built in 996 M (Tanaja & Tulistyantoro, 2017). Bambang Suyatno is a Chinese Muslim who initiates this mosque. The name 'Muhammad Cheng Hoo' is taken from the name of a Chinese merchant who traded and spread Islam in Indonesia (Titisari & Salamun, 2015).

Based on the results of observations from various literary sources and direct interviews, the researcher obtained some information related to explaining activities contained in the architecture of the Muhammad Cheng Hoo Mosque Surabaya. The explaining activities of Muhammad Cheng Hoo Mosque Surabaya is on the roof of the main building, the pillars, the number of steps, the place for the *imam* to pray, and others. Each shape and number of parts of the mosque symbolizes religious meaning and contains mathematical elements.

This mosque was built to resemble the shape of a temple to honor the ancestors of Chinese citizens who are predominantly Buddhist. The main building of this mosque has a measure of 11 × 9 meters. Number 11 refers to the length and width of Ka'bah. Number 9 refers to the number of Walisongo (Endrayadi, 2019). Figure 6 shows the stairs inside the Muhammad Cheng Ho Mosque Surabaya. The number of 6 steps in the mosque shows the number of Rukun Iman. The number of 5 steps on the mosque terrace shows the number of Rukun Islam.

Figure 6. The stairs of Muhammad Cheng Hoo Mosque Surabaya

This mosque was built to support Chinese Muslims so that they do not feel inferior in showing their identity as Muslims and carrying out worship. In the mosque ornament, there is a Joglo collaboration which means the unity of the people (Endrayadi, 2019). In the main building of the mosque, there is a place for the *imam* to lead prayers whose ornaments resemble the shape of a church door as shown in Figure 7. That is a symbol and shows that Islam recognizes the existence of Prophet Isa (AS) as the messenger of Allah. It is also a symbol that Islam loves a peaceful life, respects each other, and does not interfere with other people's beliefs.

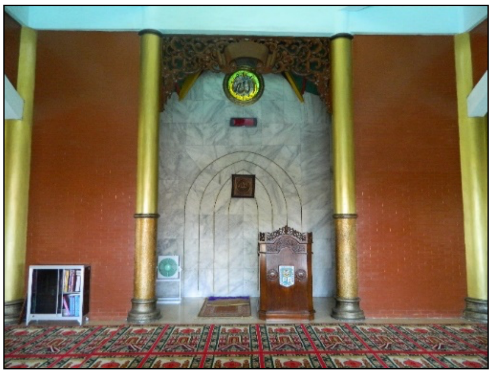

Figure 7. The place for *imam*

At the top of the main building, there is an octagonal shape (pat kwa) as shown in Figure 8. In Chinese, the number eight is called Fat, and it means victory and luck (Endrayadi, 2019). Above the main building are a regular octagonal prism and a regular octagonal pyramid resembling a spider web. This spider web is formed by the 45° rotation of a triangle seven times. This spider web has a philosophy that Islam is a religion that loves peace. It is based on the story of Prophet Muhammad and Abu Bakr who hide in Tsur Cave. Allah saved both of them from the pursuit of Quraish by ordering a spider to build a web at the mouth of Tsur Cave.

Figure 8. Octagonal shape of roof

3.2. Componential Analysis

From the results of the domain analysis and taxonomic analysis, there are mathematical elements contained in the architecture and ornaments of the Muhammad Cheng Hoo Mosque Surabaya. The math elements contained in the architecture and ornamental of this mosque are: (1) the concept of plane geometry includes a square, rectangle, circle, trapezoid, and triangle; (2) the concept of solid geometry includes tubes, octagonal prism, and octagonal pyramid; and (3) the concept of transformational geometry includes reflection, translation, dilation, rotation, and tessellation.

The concept of plane geometry is also found in the Great Mosque of Demak (Radiusman et al., 2021), the Great Mosque of Pondok Tinggi (Patri & Heswari, 2021), the Great Jami' Mosque of Malang (Asnawi et al., 2022), Soko Tunggal Mosque in Yogyakarta (Putra et al., 2020), the Old Mosque of Tosora (Kastolani, 2021), the Jami' Mosque of Jingah River (Fajriah & Suryaningsih, 2021), the Raudhatus Sa'adah Mosque in Bengkulu (Friansah & Yanto, 2020), and the Great Mosque of Cimahi (Purniati et al., 2020). The concept of solid geometry is also found in the Great Mosque of Demak (Radiusman et al., 2021), the Great Mosque of Pondok Tinggi (Patri & Heswari, 2021), the Great Jami' Mosque of Malang (Asnawi et al., 2022), the Old Mosque of Tosora (Kastolani, 2021), and the Great Mosque of Cimahi (Purniati et al., 2020). The concept of transformational geometry is also found in the Great Mosque of Demak (Radiusman et al., 2021), the Great Mosque of Bandung (Purniati et al., 2021), and the Great Mosque of Cimahi (Purniati et al., 2020).

3.3. Cultural Theme Analysis

From the results of the componential analysis, the researcher conducted a more in-depth study by analyzing cultural themes as follows:

3.3.1. The Concept of Plane Geometry

The plane geometry elements that can be found on the image of the front of the Muhammad Cheng Hoo Mosque, as shown in Figure 9, include squares, rectangles, triangles, circles, and trapezoid. The concepts of plane geometry that can be learned from the image of the front of the Muhammad Cheng Hoo Mosque includes: (1) determining the properties and characteristics of a square, rectangle, triangle, circle, and trapezoid; (2) calculating the area of a square, rectangle, triangle, circle, and trapezoid using units of the area; (3) calculating the perimeter of a square, rectangle, triangle, circle, and trapezoid; and (4) solving problems related to the area and perimeter of a square, rectangle, triangle, circle, and trapezoid.

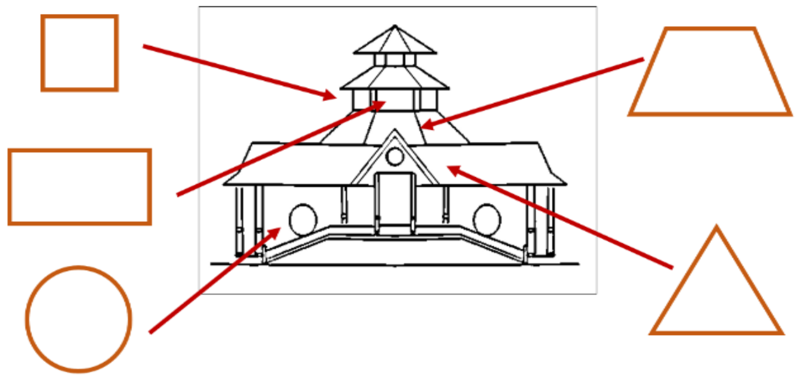

Figure 9. Plane geometry elements on sketch of front section of Muhammad Cheng Hoo Mosque Surabaya

Researchers find the plane geometry elements on the roof of the Muhammad Cheng Hoo Mosque's main building, as shown in Figure 10, include triangles and octagon. The concepts of plane geometry that can be learned from the roof of the Muhammad Cheng Hoo Mosque's main building: (1) determine the properties and characteristics of triangles and octagon; (2) calculate the area of triangles and octagon using units of area; (3) calculate the perimeter of triangles and octagon; and (4) solve problems related to the area and perimeter of triangles and octagon.

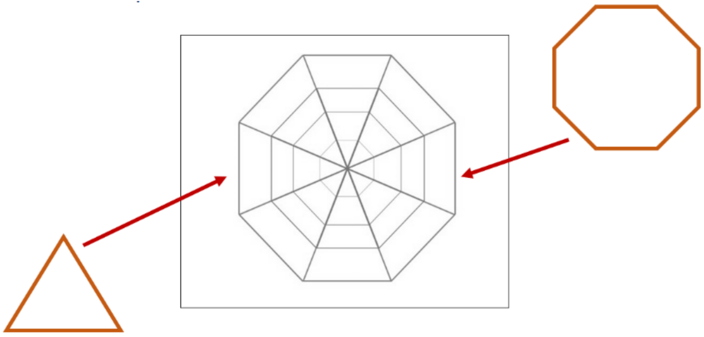

Figure 10. Plane geometry elements on sketch of roof of Muhammad Cheng Hoo Mosque Surabaya

As a comparison, at the Great Mosque of Demak, researchers found the concept of triangles with the same shape but different sizes, which is related to the congruence of the triangles. In addition, they also found the construction of angles in the four main pillars that support the Great Mosque of Demak (Radiusman et al., 2021). At the building structure and ornaments of the Pondok Tinggi Grand Mosque, researchers found elements of square, kite, parallelogram, rhombus, rectangle, and trapezoid (Patri & Heswari, 2021). At the Soko Tunggal Mosque, researchers found triangle elements on *Mustoko Gapura* and carvings, square construction on the main room of the mosque, rectangular elements on windows and doors, rhombus elements on carvings, trapezoidal elements on the roof, and circle elements on air vents (Putra et al., 2020).

At the basic plan of Jingah River Jami' Mosque, researchers found elements of rectangle, square, trapezoid, rhombus, circle, symmetry, ellipse, parallelism, congruence, and hexagon (Fajriah & Suryaningsih, 2021). At the Raudhatus Sa'adah Mosque, researchers found a circle element on the bedug, which is related to the concept of the tangent to a circle. In addition, they also found inspiration from the mosque's mihrab in learning the curve area by integrating the integral concept (Friansah & Yanto, 2020). The roof shape on the Great Mosque of Cimahi tower is associated with the construct of plane geometry, namely triangles and trapezoids. The ornaments in this mosque are related to the construction of a square and a rhombus (Purniati et al., 2020).

3.3.2. The Concept of Solid Geometry

Most of the roofs in Indonesia's mosques have a modified hemisphere or rectangular pyramid shape. For example, the Great Mosque of Bandung's roof has a modified hemisphere shape (Purniati et al., 2021). Meanwhile, the Great Mosque of Demak's roof, the Great Mosque of Pondok Tinggi, the Soko Tunggal Mosque, the Raudhatus Sa'adah Mosque, and the Great Mosque of Cimahi have a modified rectangular pyramid shape (Friansah & Yanto, 2020; Patri & Heswari, 2021; Purniati et al., 2020; Putra et al., 2020; Radiusman et al., 2021). The Al-Khalid Mosque roof adopts the Joglo House roof, which is in the form of a rectangular pyramid. The rectangular pyramid structure on the Al-Khalid Mosque roof has been modified so that the ends of the roof are not pointed. The rectangular pyramid tip has a shape that resembles a trapezoidal prism (Ilmiyah, Rofiqoh, et al., 2020).

The Muhammad Cheng Ho Mosque roof is synonymous with Chinese culture. The ceiling in the main building (skydome) is designed with terraces that get smaller and smaller with an octagonal shape. As shown in Figure 11, this is one of the different findings between solid geometry elements in Muhammad Cheng Ho Mosque and other mosques.

Figure 11. Solid geometry elements on the main building roof

The solid geometry elements that can be found on the main building roof of the Muhammad Cheng Hoo Mosque, include the octagonal prism and octagonal pyramid. The concepts of solid geometry that can be learned from the main building roof includes: (1) determining the characteristics of octagonal prisms and octagonal pyramids; (2) calculating the volume of octagonal prisms and octagonal pyramids using the unit volume; (3) calculating the surface area of octagonal prisms and octagonal pyramids with units of the area; (4) drawing a net of octagonal prisms and octagonal pyramids; and (5) solving problems related to the volume and surface area of octagonal prisms and octagonal pyramids.

Researchers find cylinders as the solid geometry element on the pillars of Muhammad Cheng Hoo Mosque as shown in Figure 12. The concepts of solid geometry that can be learned from the Muhammad Cheng Hoo Mosque pillars are: (1) determining the characteristics of cylinders; (2) calculating the volume of cylinders using the unit volume; (3) calculating the surface area of cylinders with units of area; (4) drawing a net of cylinders; and (5) solving problems related to the volume and surface area of cylinders.

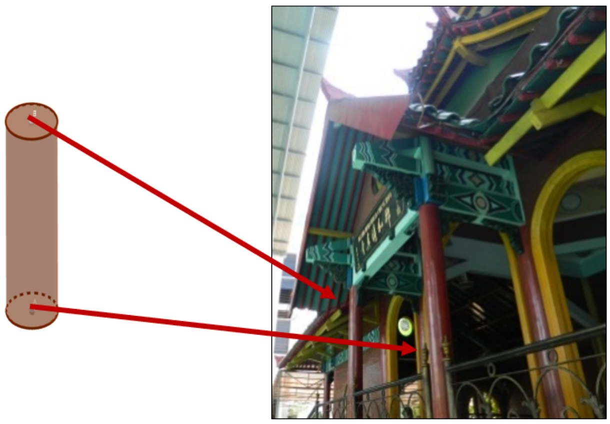

Figure 12. Solid geometry elements on the mosque pillars

3.3.3. The Concept of Transformational Geometry

The transformational geometry elements that can be found on Muhammad Cheng Hoo Mosque fence, as shown in Figure 13, include reflection and translation. The concepts of transformational geometry that can be learned from Muhammad Cheng Hoo Mosque fence are: (1) determining the properties of reflection and translation; and (2) solving problems using the concept of reflection and translation.

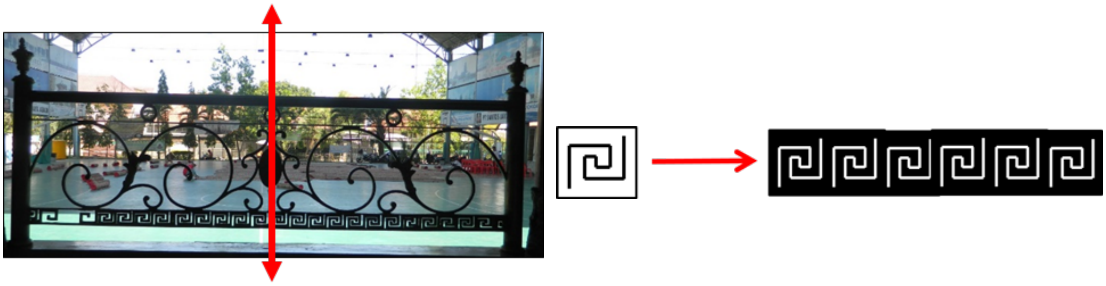

Figure 13. Reflection and translation on the mosque fence

From the mosque fence ornaments, researchers also found the concept of Frieze Group. The Frieze Group that corresponds to the pattern on the mosque fence ornament is Pattern 12. Number 1 indicates no vertical reflection, while number 2 indicates half-turn. This pattern is evident in Figure 14. From the results of ethnomathematical research at the Great Mosque of Cimahi, there are also Frieze Group patterns on its ornaments (Purniati et al., 2020).

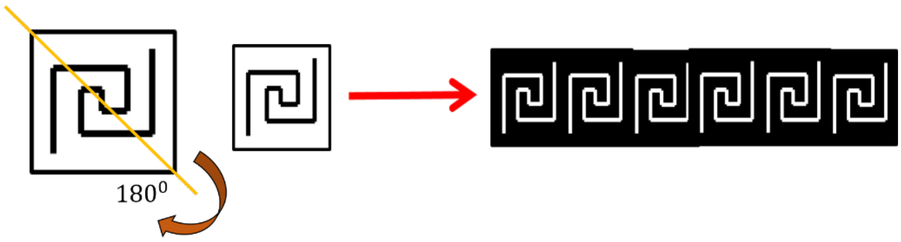

Figure 14. Frieze group pattern of the mosque fence ornament

The transformational geometry elements that can be found on Muhammad Cheng Hoo Mosque ornaments include reflection, translation, and dilation, as shown in Figure 15. The concept of reflection and dilation is also found in the carvings of the Great Mosque of Demak's main pillars (Radiusman et al., 2021). The transformational geometry concepts that can be learned from Muhammad Cheng Hoo Mosque ornaments are: (1) determining the properties of reflection, translation, and dilation; and (2) solving problems using the concept of reflection, translation, and dilation.

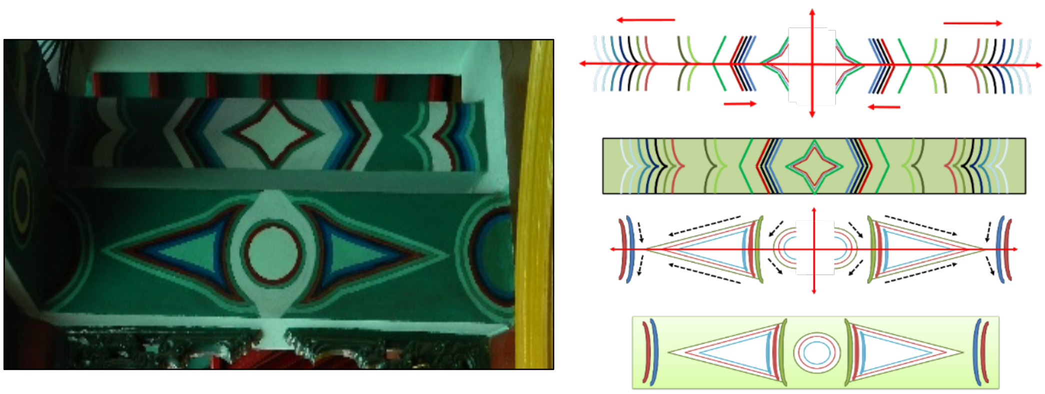

Figure 15. Translation, reflection and dilation on the mosque ornaments

The transformational geometry element that can be found on Muhammad Cheng Hoo Mosque door is reflection, as shown in Figure 16. The transformational geometry concepts that can be learned from Muhammad Cheng Hoo Mosque door are: (1) determining the properties of reflection, and (2) solving problems using the concept of reflection.

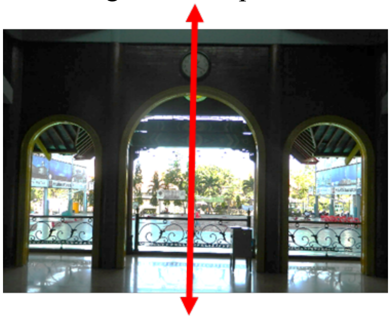

Figure 16. Reflection on the mosque door

The transformational geometry element that can be found on the roof ornament of Muhammad Cheng Hoo Mosque is reflection, as shown in Figure 17. The transformational geometry concepts that can be learned from the roof ornament of Muhammad Cheng Hoo Mosque are: (1) determining the properties of reflection; and (2) solving problems using the concept of reflection.

Figure 17. Reflection on the roof ornament

The transformational geometry elements that can be found on Muhammad Cheng Hoo Mosque wall are translation and tessellation, as shown in Figure 18. The transformational geometry concepts that can be learned from Muhammad Cheng Hoo Mosque wall are: (1) determining the properties of translation and tessellation; and (2) solving problems using the concept of translation and tessellation.

Figure 18. Translation and tessellation on the mosque wall

Through the presentation of the data analysis, the ornamental and architecture of Muhammad Cheng Hoo Mosque can be used as materials for compiling culture-based mathematics learning tools and media, especially in the field of geometry studies. The mathematical elements in the mosque that can be used to achieve the basic competency standards of mathematics at the primary and secondary school levels include: (1) The front section of the mosque can be used as learning material related to analysis, identification, calculating the area, and calculating the perimeter of the polygon, which learned in grade 4, semester 2 of elementary school. Also, the octagonal and circle elements in the front section of the mosque can be used as learning materials related to calculating the area and circumference of the octagonal and circle, which studied in grade 6, semester 1 of elementary school; (2) The pillars of the mosque and the main building roof of the mosque can be used as learning materials regarding the surface area and volume of cylinders, octagonal prisms, and octagonal pyramids, which are studied in junior high school grades 8 and 9; and (3) Wall ornaments, roof ornaments, fence ornaments, and mosque doors can be used as learning materials regarding types of transformation, which are studied in senior high school grade 11 semester 1.

4. CONCLUSION

We conclude that there are math elements in the architecture and ornamental of the Muhammad Cheng Hoo Mosque Surabaya included the concept of planes, solids, and transformations. We can find it in the wall, roof, main building, pillars, doors, stairs, fence, ornamentals, and others. These math elements can be used as a material for developing cultural-based mathematics learning at the primary and secondary school levels.

This study has the following limitations: (1) the study results only focused on the concept of geometry in the design and ornaments of the Muhammad Cheng Hoo Mosque Surabaya. Topics other than geometry needs to be researched. Many mathematical concepts can be explored and developed from the mosque design and ornaments. (2) This research only focuses on extracting mathematical elements in Muhammad Cheng Hoo Mosque Surabaya. Researchers have not followed up by developing ethnomathematical-based learning tools. The researcher provides suggestions for further researchers to develop it.

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