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When math meet culture: Exploring ethnomathematics in red mosque's design

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Abstract

Mathematics can be found in cultural aspects. Moreover, Indonesia has a variety of cultures that can be explored and used as mathematics learning resources. Existing mathematics learning has yet to integrate cultural elements that are close to students. The aim of this study is to examine the findings of geometric objects and mathematics activities in the Moekhlas Sidik Red Mosque. The research method used was an ethnographic study and data collection techniques in the form of observations, documentation, and interviews. The obtained data were analyzed using an interactive model: data reduction, data presentation, data interpretation, and conclusion. This study found that the geometric objects include 2D shapes, 3D shapes, and geometric transformations. The 2D shapes observed are triangles, trapeziums, squares, rectangles, rhombuses, and semicircles. The 3D shapes that can be observed are rectangular prisms. Geometric transformation is the use of the principles of translation, reflection, and rotation. The mathematical activities that can be explored include creating tile patterns, finding the purpose of tile patterns, and drawing 2D shapes using geometric transformation principles. In addition, the existence of the Moekhlas Sidik Mosque provides socioeconomic value that has an impact on the surrounding community.

Keywords: ethnomathematics; geometry; mosque

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Introduction

The existence of mathematics will always be present in life, even if we don't realize it. Mathematics itself consists of 4 important areas such as numbers, measurement, geometry and logic (Bishop, 1988). Humans will always come into contact with these 4 fields every day. However, there are still many people who think that mathematics is a science that is far from reality and culture (Prahmana & D'Ambrosio, 2020). Teachers often teach mathematics without integrating it with local cultural elements that are close to students. Students are not invited to explore how mathematics develops as a universal and applicable science that influences existing socio-cultural life. This can unknowingly cause problems. Students will lose their motivation in learning mathematics because it is difficult to see the direct benefits of learning mathematics, and students are unable to appreciate the value of mathematics in the context of their own culture.

In real life, culture elements is one of the elements that is influenced by mathematics. Culture is a form of implementing rules and entertainment for society which also has value (Prahmana & Istiandaru, 2021). Even though culture moves dynamically following the times, but in that culture there will be mathematics in it. So, the relationship between them cannot be separated. The appropriate term for the relationship between these two things can be called ethnomathematics. Ethnomathematics is a way of thinking like a bridge that connects culture with mathematics (Ambrosio, 1985). The presence of ethnomathematics in learning can be a solution to existing problems. Students can be invited to explore a culture and then study the mathematical elements in it. Ethnomathematics can open students' insights that mathematics and culture are two things that influence each other and cannot be separated.

It is important to study culture because Indonesia has many cultures that are worth exploring and introducing to students. So bringing culture into mathematics learning will be very beneficial, because students will not only learn about mathematics but also about their culture. In addition, this integration can motivate students by showing that mathematics is not just a series of numbers and formulas, but also a tool that humans have used for centuries to understand the world and create culture. In line with the opinion of Prahmana et al. (2021) that mathematics is an idea that humans develop in response to the environment. So it is very possible that mathematics will come along with changes in the environment. In this way, students are more inspired to learn and see mathematics as an important part of their own lives.

There are still many teachers who do not realize that the richness of Indonesian culture can be integrated into learning (Pathuddin et al., 2021). Some examples of culture in Indonesia that can be linked to learning mathematics include dances, buildings, community traditions, and so on. These cultures should be introduced to students in order to foster a sense of pride and understanding of local culture. Developing feelings, creativity and initiative with Pancasila characteristics in line with the objectives of the Independent Curriculum currently being implemented in Indonesia (Aditomo, 2024). Moreover, the implementation of the Independent Curriculum can be applied flexibly to suit student needs and conditions in each school. So it is very possible to integrate the local culture of the local community into learning, for example in mathematics learning.

One of the cultures that is close to students is the mosque. The majority of the population in Indonesia adheres to Islam, so mosques can often be found in students' living areas. Several studies that examined ethnomathematics in mosque buildings, for example, were carried out by Lisnani and Gustira (2023) with research results that found a 2D shape in the Sultan Mahmud Badaruddin Jayowikramo Grand Mosque building in Palembang. Similar research was conducted by Fajriah and Suryaningsih (2021) who found geometric concepts such as lines, corner points, perimeter properties, and area of 2D shapes in the Sungai Jingah Jami Mosque building. Then another research on mosque buildings was also carried out by Zaenuri et al., (2019) who found that there was a 2D and 3D shapes concept in the Kudus Tower Mosque. Research that has been carried out previously has results focus that are dominated by findings on 2D shapes and 3D shapes. Meanwhile, this research will examine the findings of geometric objects and mathematical activities that have the potential to be applied in elementary school mathematics learning. Another difference is in the mosque buildings that will be explored.

This research carried out at one of the mosques which is now becoming famous in Pasuruan, East Java. The name of the mosque is Moekhlas Sidik. This mosque is considered unique when compared to other mosques. Its uniqueness can be seen clearly from the red color that dominates the mosque. If mosques are generally dominated by white, this mosque is not. So it is not uncommon for local people to call it the red mosque. The attractiveness of this mosque has continued to increase since it was inaugurated in 2019, and is now become a religious tourism that is busy with visitors from various regions.

Methods

This research is a type of qualitative research with an ethnographic study. Ethnography was chosen because it is relevant with the aim of ethnomathematics to describing a culture from the native point of view (Spradley, 1979). The aim of this research is to examine the findings of geometric objects and mathematical activities. The research was conducted at the Moekhlas Sidik Mosque, Durensewu Village, Pandaan District, Pasuruan Regency, East Java. Data collection techniques are divided into two, namely to collect primary data and secondary data. Primary data was collected using observation and documentation techniques. Observation were carried out in the Moekhlas Sidik Mosque area to explore findings of geometric objects in the mosque building, and documentation was carried out to support the completeness of the data obtained. Secondary data was collected using interview techniques. Interviews were conducted with the community members around the Moekhlas Sidik Mosque as expert cultural figures. A cultural figure was chosen based on his deep understanding of philosophy of the Moekhlas Sidik Mosque. After the data was collected, the data obtained was then analyzed by an interactive model which consists of data reduction, data presentation, data interpretation, and conclusion based on Sari et al. (2022). The ethnographic research design is adopted from Prahmana D'Ambrosio (2020) in Table 1 below.

Table 1. Ethnographic research design

General Questions	Initial Answer	Starting Point	Specific Activity
Where to start looking?	In the architecture of the Moekhlas Sidik Mosque in Pasuruan where there are mathematical practices in it.	Culture	Conducting interviews with one of the community members around Moekhlas Sidik Mosque in Pasuruan who cultural figure.
How to look?	Investigating the QRS (Quantitative, Relational, Spatial) aspects of the architecture of the Moekhlas Sidik Mosque in Pasuruan related to mathematics practice.	Alternative thinking and knowledge system	Determine what QRS ideas are contained in Moekhlas Sidik Mosque in Pasuruan related to mathematics practice.
What it is?	Evidence (Results of alternative thinking in the previous process)	Philosophy of mathematics	Identifying QRS characteristics in the architecture Moekhlas Sidik Mosque in Pasuruan related to mathematics practice. It shows that the shape of the Moekhlas Sidik Mosque in Pasuruan does have a mathematical character seen from the elements of knowledge and art systems used in everyday life .
What it means?	Valued important for culture and important value patterns for mathematics	Antropologist	Describe the relationship between the two systems of mathematical knowledge and culture. Describe geometric objects and mathematical activities that exis in architecture of Moekhlas Sidik Mosque in Pasuruan.

Results

Moekhlas Sidik Mosque is a mosque located in Pasuruan Regency, East Java with an area of 4 hectares. As the name suggests, the Moekhlas Sidik Mosque was built by a retired officer named Moekhlas Sidik who now serves as the Protective Council on the Moekhlas Sidik Mosque Prosperity Council. Since it was inaugurated on September 2019, this mosque has been busy with visitors who are curious about the architecture and uniqueness of this mosque, which is nicknamed the Red Mosque. It is often nicknamed that because the color of this mosque is dominated by red. Researchers conducted research on several parts of the Moekhlas Sidik Mosque, such as the outside of the Moekhlas Sidik Mosque and the inside of the Moekhlas Sidik Mosque and the results of the interview were taken from the informants of the local community who has known the Moekhlas Sidik Mosque for a long time, namely Mr. Basori as a cultural figures.

Geometric objects

This mosque is divided into inner and outer parts. The interior includes the prayer room, priest's place, ceiling and supporting pillars. Then the outside includes the outer walls, ventilation and mosque dome. On the dome of the mosque there were no 2D structures found. The exterior of the Moekhlas Sidik Mosque is very open because it does not have doors or glass windows that can be opened and closed as seen in Figure 1 below. The purpose of not having a main door in this mosque is so that visitors can enter the mosque from any side. This is like in Islamic teachings that the door to sustenance will come from anywhere unexpectedly. The color of this mosque can be seen from afar, which is bright red. The value contained in this color is that as Muslims we must dare to defend the truth and dare to fight oppression that is not in accordance with religious teachings.

This mosque does not have a tower but has 1 dome consisting of an isosceles triangle. This dome consists of 8 curved isosceles triangles. The choice of a mosque dome consisting of a triangle signifies that humans will return to 1 goal, namely to the one God as seen in Figure 1. The concept of transformation geometry was found, namely the translation or shift in the shape of the mosque ornament as seen in Figure 2.

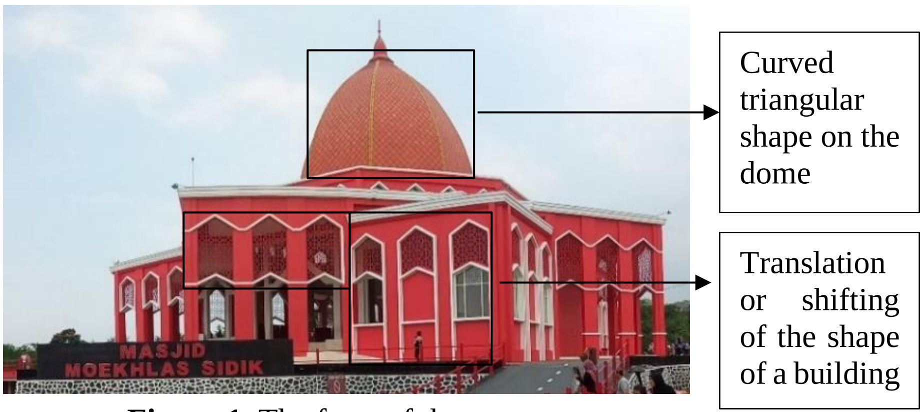

Figure 1. The front of the mosque

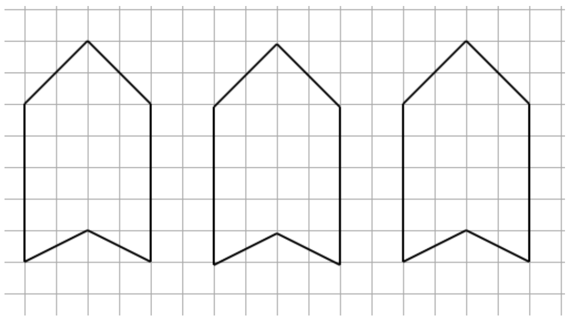

Figure 2. Translation of mosque ornaments

Meanwhile, there is a rectangular prism supporting pillars on the outside of the mosque. The outer pillars of the mosque are amount to 5, arranged in a triangle shape when viewed from above. The number of triangles in this mosque amount to 8, so the total number of pillars is 40. The pillar has a rectangular cross-section and has line ornaments as in Figure 3.

The distance between pillars is regulated proportionally through ornaments in the form of lines that connect the walls. This proportional distance arrangement is in accordance with the concept of translational geometry. There are 6 pillar connecting ornaments for every 5 supporting pillars. So the total number of pillar connecting ornaments is 48. The line ornament is a combination of 2D rectangular and triangular shapes containing a vent as in Figure 4.

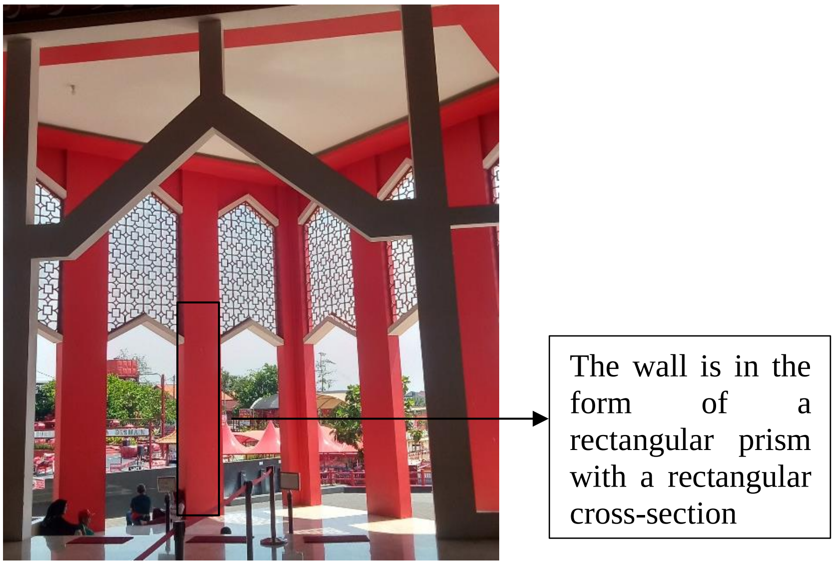

Figure 3. The outer supporting pillars of the mosque

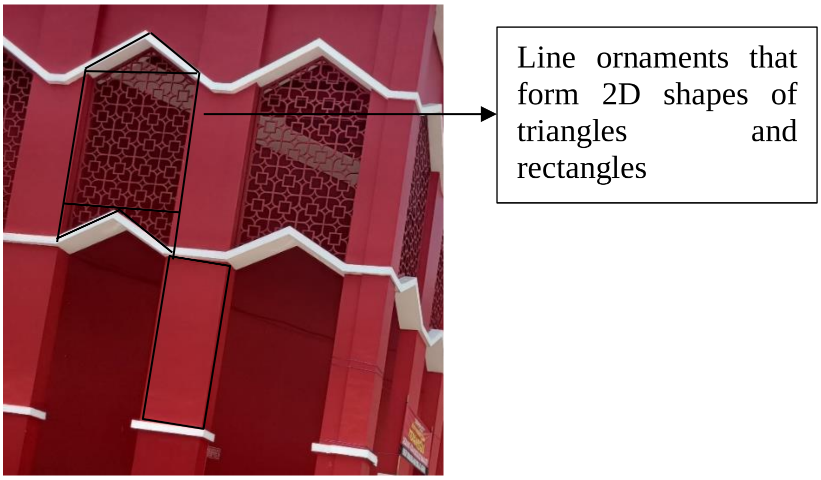

Figure 4. The distance between pillars

In more detail, in the vent section, there are 2D square and rhombus shapes. And there is also glass that is separated by lines to form triangular, rectangular and trapezoidal 2D shapes as seen in Figure 5. The 2D shape that appears in the vent section has a design that is in accordance with the geometric concept of reflection or mirroring and rotation or rotation as illustrated in Figure 6.

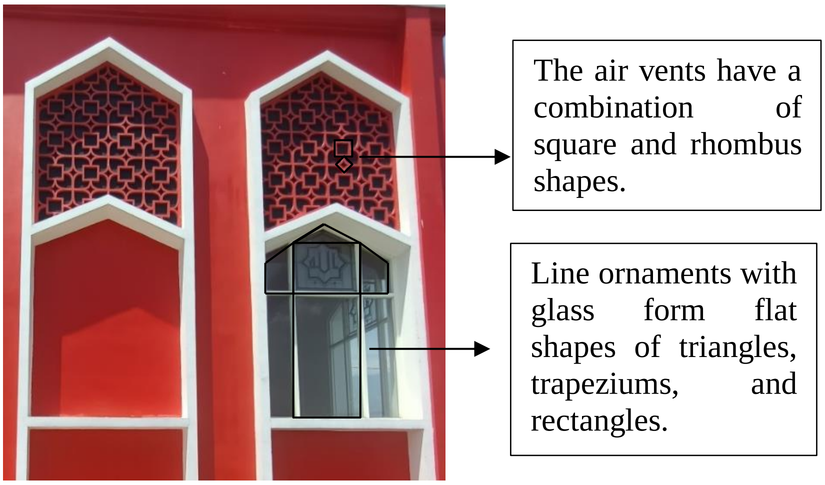

Figure 5. Detail of the vents and lines on the glass

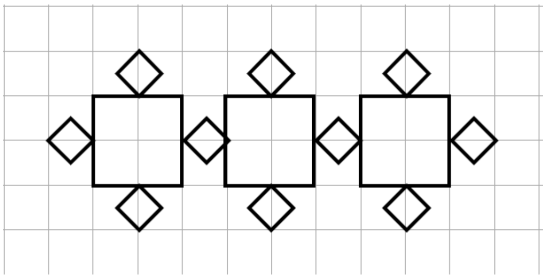

Figure 6. Reflection and rotation in the vent

The interior of the Moekhlas Sidik Mosque consists of 2 parts, namely the prayer area and the imam's area. When entering the mosque towards the prayer place, you will pass a white frame without glass. The frame represents the entrance to the inside of the mosque which can be accessed from 3 parts of the mosque, namely the front, right and left. This frame has a 3-part design, namely the top ventilation frame, the right and left to resemble a window, and the middle for exit and entry access. The top frame is a trapezoid combined with a rectangle, while the right and left frames that resemble a window are rectangular. Then the middle frame which serves as the entrance and exit has a combined shape between a triangle and a rectangle.

Then at the top of the frame, it is also surrounded by ornaments in the form of a 2D shape. The 2D shapes that can be found is combination of triangles and rectangles, as seen in Figure 7. The presence of ornaments that surround the upper walls of the mosque adds to the aesthetic value inside. Inside the mosque, the ceiling is octagonal, with four ornaments on each side surrounding the triangular and rectangular peak of the mosque. So that the total ornaments are 32. The ornament that surrounds the top of the mosque is also an application of the geometric concept of transformation, namely translation or shift, as in Figure 8.

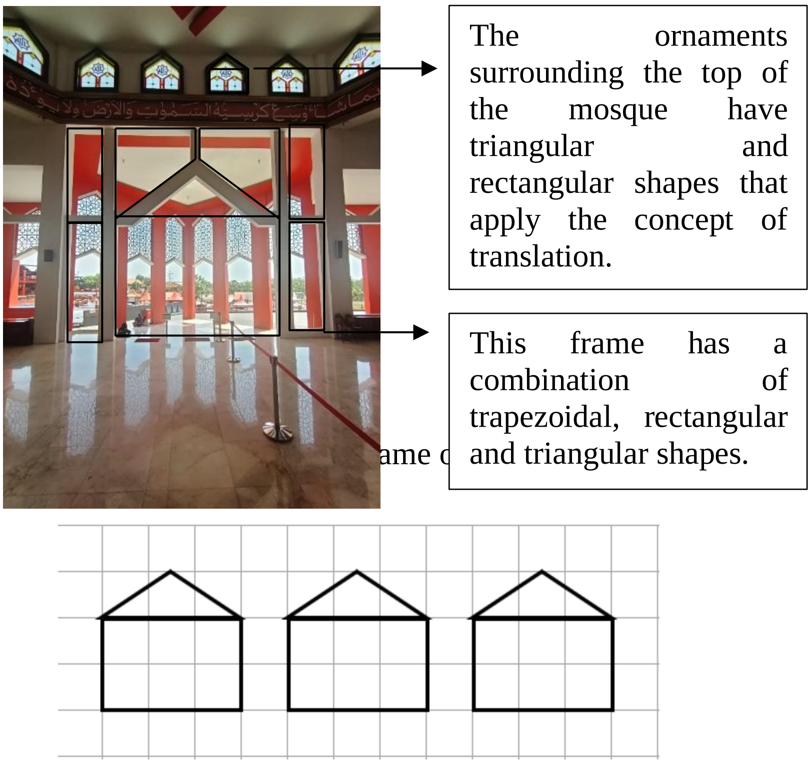

Figure 8. Translation of the top ornament of the mosque

In the prayer area, there are rectangular ceramic floor tiles with 2 different sizes as shown in Figure 9 as a pattern. This tiling is also an application of mathematical concepts where each ceramic is installed in a certain pattern over an area without any gaps. The tiling pattern is depicted in Figure 10. The purpose of installing tiles with this design is related to religious values with the aim of prayer, namely to provide a place for worship so that it is aligned and provides distance between the rows.

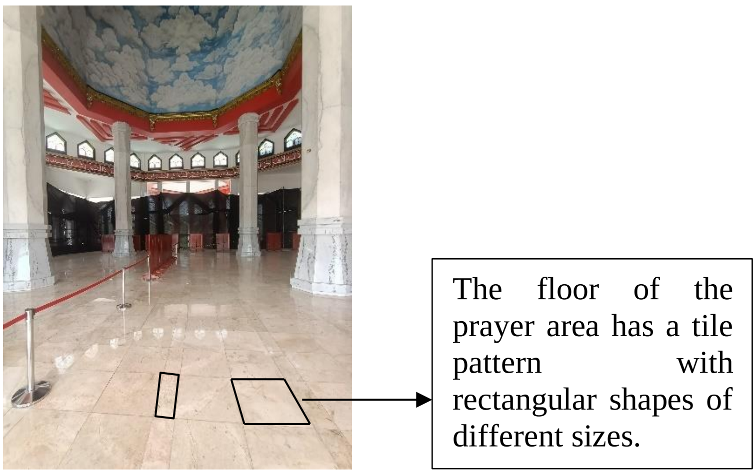

Figure 9. Prayer place

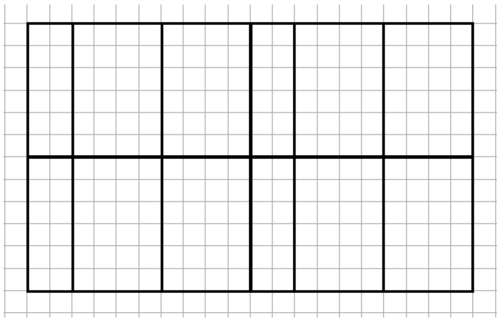

Figure 10. Tiling pattern

This part of the prayer area has 4 pillars supporting the mosque surrounding it inside. The men's and women's prayer areas are separated by red wooden partitions. The lower part of the supporting pillars has a rectangular and trapezoidal shape as in Figure 11. The ceiling of the Moekhlas Sidik Mosque or the inside of the dome has blue and white colors that represented pattern resemble clouds with and is surrounded by a red triangular shape as seen in Figure 12.

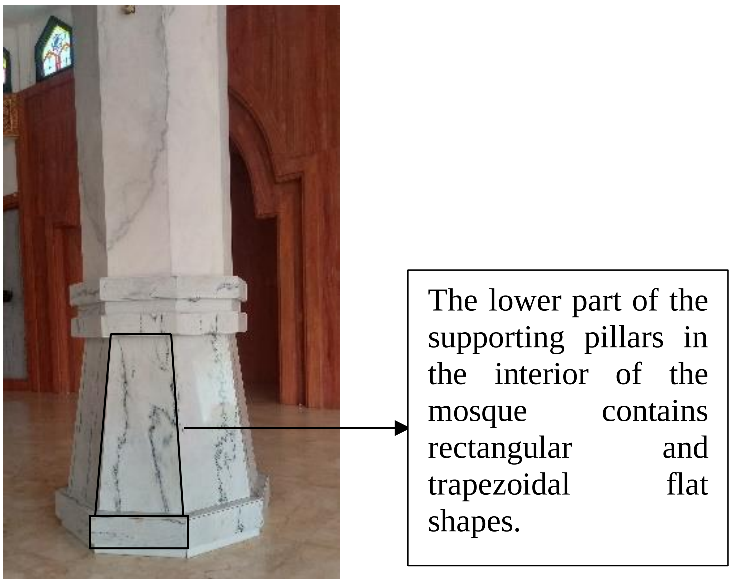

Figure 11. Support pillar

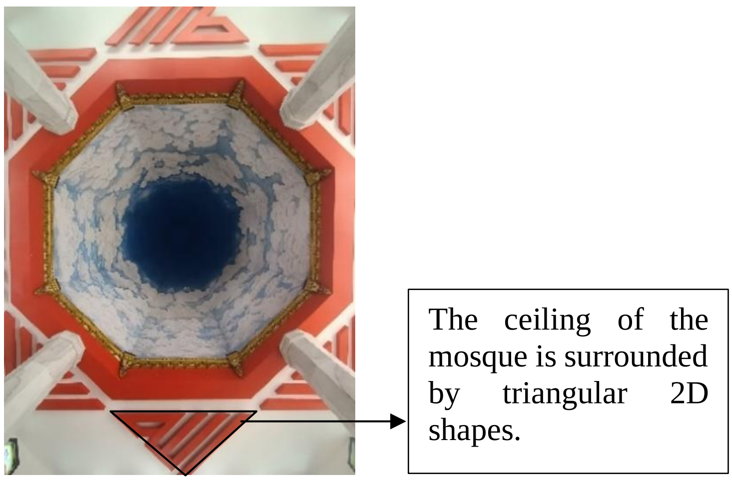

Figure 12. Mosque ceiling

Apart from the prayer area, inside the mosque there is also a place for the imam. This place is at the front and has its own ornament when compared to other congregational prayer places. The ornament that marks this area is called the mihrab. The mihrab at the Moekhlas Sidik Mosque is decorated with brown wooden ornaments which form a 2D rectangular and semi-circular shape as in Figure 12.

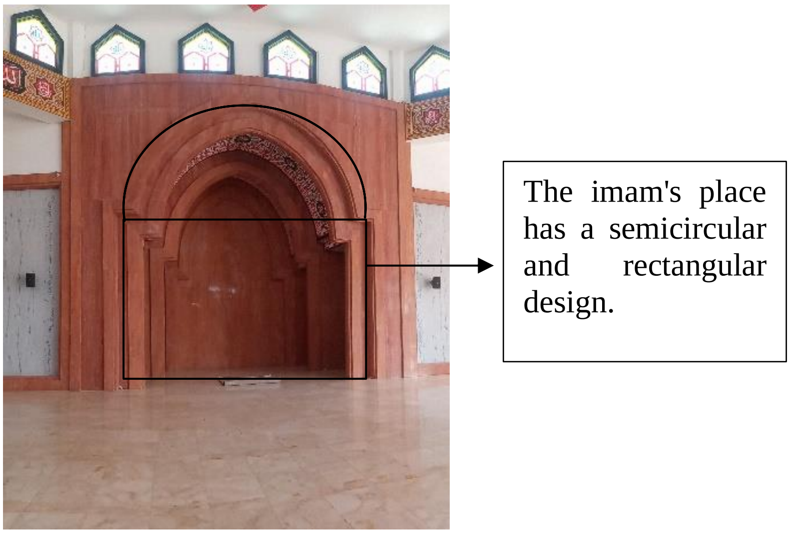

Figure 12. Imam's place

Mathematical activities

The reason why many researchers use ethnomathematics for mathematics learning is because they want to make students understand how to implement mathematical knowledge to solve problems in everyday life (Hendriyanto et al., 2023). Mathematical activities that students can do when they encounter the application of the translation concept in mosque architecture is drawing translations of the mosque ornamental objects found as in checkered paper. Teacher can aask students to draw the shapes of the buildings found. Students will think about making the same shape but in different positions given the distance between the shapes they will draw. This can develop spatial abilities regarding understanding the movement of objects without changing their shape or size. Activities carried out by students to draw translations also train them in logic to arrange logical steps to determine the distance and direction of translation which can increase students' accuracy when the object is moved to the correct position without changing its shape.

A possible mathematical activity related to the concept of reflection is to do direct reflection practice using a mirror. Students can hold a mirror along the line of symmetry of a mosque element such as the vent. However, if this is not possible, students can draw the shape of the vent on checkered paper. Then students will see the complete reflection in the mirror. This activity can make it easier for students to understand the concept of reflection because they carry out the reflection results directly. Meanwhile, an activity that might be carried out related to the concept of rotation is to invite students to create a rotation pattern from the shapes they are exploring, then rotate it several times to get a repeating pattern. After that, students can compare the patterns made with the patterns on the mosque ornaments.

Through this tiling pattern, students can be given stimulating questions to make them reason about why the shape of the tiling pattern on the floor must be consistent and repetitive, as well as what the impact is if the pattern is not consistent. The teacher can also ask questions about what is the purpose installation of tiles made as seen in Figure 10. In figure 10, the tiles are installed with 2 rectangular ceramics then given a border in the form of ceramics with the same shape but different sizes. Students can think about why the tiles are installed in this way. The answers given can vary, but are still associated with the function of the mosque as a place of worship. The design of the tile installation is installed like that to provide space and distance for prayer.

Discussion

Cultures that contain ethnomathematics elements are still very diverse and can be explored (Kusuma et al., 2024). One of the cultures whose existence is often found is the mosque. Mosques are an example of a culture whose ornaments are dominated by geometric motifs (Purniati et al., 2022). In line with this, based on data analysis on the Moekhlas Sidik Mosque building, it was found that there are geometric objects of 2D shapes, 3D shapes and application of geometric transformations. In addition, from the results of the research that has been done, many mathematical activities can be presented to students during learning. These mathematical activities can stimulate students' critical thinking skills and their problem solving towards everything they observe in the architecture of the mosque. The existing types of 2D shapes are triangle, trapezium, square, rectangle, rhombus and circle. Students can learn about the shape and the properties of mosque architecture (Purniati et al., 2022). Build a 2D circle found in a semicircle. Meanwhile, the 3D shapes found were rectangular prisms. Then the geometric transformations found are the implementation of translation, reflection, and rotation.

The results showed that the exploration of geometry object of the Moekhlas Sidik Mosque had enriched knowledge learning mathematics application related to cultural contexts. The ornaments of the Moekhlas Sidik Mosque have a relationship between mathematics and culture. In addition, the mosque ornaments have spiritual values. Ethnomathematics will bring unique cultures to help students in the development of social, emotional, and intellectual knowledge while learning (Zuliana, 2017). These findings can be used as an alternative source of mathematics learning in elementary schools.

Learning in schools currently running uses an independent curriculum. This curriculum has learning outcomes in each phase. Phase A is for grades 1-2, phase B is for grades 3-4, and phase C is for grades 5-6. The achievement of learning geometry in phases A to C as written in the Badan Standar Kurikulum dan Asesmen Pendidikan (2022) is that at the end of phase A students can recognize various shapes of 2D shapes and 3D shapes, and can arrange and decompose 2D shapes, they can determine the position objects against other objects. Then at the end of phase B, students can describe the characteristics of various 2D shapes and can arrange (composition) and decompose (decompose) various 2D shapes in one or more ways if possible. And at the end of phase C, students can determine the perimeter and area of several 2D shapes and their combinations, they can construct and describe several 3D shapes and their combinations, and recognize spatial visualization, they can compare the characteristics between 2D shapes and between 3D shapes, they can determine location on a map that uses a grid system.

Building knowledge and understanding of concepts regarding geometry in everyday life is very important (Sunzuma & Maharaj, 2022). In Phase A, the teacher can introduce the 2D shapes and spatial shapes of the Moekhlas Sidik Mosque building. Teachers can emphasize that mathematical concepts will always be found in everyday life, including cultural elements such as the mosque building which has architecture from various shapes. Of course, this can help students understand that mathematics develops not only from textbooks but also develops from the needs and activities of society, one of which is through cultural elements. So that through ethnomathematics it can be used as a means of introducing culture to the nation's future generations, which it is hoped will ensure its sustainability (Noerhasmalina & Khasanah, 2023). Mathematical activities that students can carry out in phase A include drawing 2D shapes and breaking down 2D shapes from mosque buildings and then grouping them.

In Phase B, it is explained that students can describe the characteristics of 2D shapes, as well as arrange and decompose 2D shapes. This is in accordance with the findings in this research because the 2D shapes found in mosque buildings are dominated by a combination of several shapes. Mathematics learning in schools often involves 2D shapes such as triangles, quadrilaterals and circles (Yudianto et al., 2020). This results in the finding that mosque buildings can be used as a source of learning mathematics and geometric concepts. Moreover, each culture has its uniqueness and diversity which can be studied as a learning resource in mathematics (Fauzi et al., 2023). Apart from that, teachers can also build students' reasoning abilities regarding the characteristics of 2D shapes related to geometric transformations in accordance with the aim of this research, namely by introducing fold symmetry and rotational symmetry of 2D shapes found in mosque buildings. The types of 2D shapes found in mosque buildings along with their folding symmetry and rotational symmetry can be seen in the table. 1 below.

Mathematical activities that students can carry out in phase B apart from breaking down and combining various 2D shapes to then describe their characteristics are by practicing fold symmetry and rotational symmetry. Students can create 2D figures and then find out how many fold and rotation symmetries they have. Students are also expected to be able to think critically about why not all plane figures have line symmetry or rotational symmetry.

In phase C, students can be given mathematical activities related to finding the perimeter and area of 2D shapes from the tiling patterns found on the mosque floor. Students can also do other activities to recognize spatial visualization by trying to draw 2D shapes on checkered paper repeatedly at certain distances. This is an example of the application of the concept of translation or shift. Meanwhile, for the concept of reflection or mirroring, students can draw a shape and then direct the mirror at that shape. Apart from the concepts of translation and reflection, the concept of rotation was also found in mosque buildings. Students can try to make a 2D shape and then rotate it several times. These concepts are real examples of the application of mathematics in culture which are found in the Moekhlas Sidik Mosque building. Considering the importance of passing on cultural knowledge to them, through ethnomathematics the next generation will feel connected and responsible for maintaining and preserving that culture. So that local culture will continue to survive and develop amidst the times. In an effort to bring mathematics closer to reality, culture can be used to learn mathematical concepts, because culture can function as a basis for learning mathematics in schools (Sutarto et al., 2021).

The ethnomathematics approach can be integrated into the school curriculum. Through this ethnomathematics approach, mathematics lessons can be made more relevant and meaningful for students and improve the overall quality of their education (Rosa & Orey, 2011). Ethnomathematics in the Moekhlas Sidik Mosque building can be used as an alternative source of student learning on geometry material based on research findings. Not only mathematics material, students can also learn about the history of the Moekhlas Sidik Mosque. Geometry learning needs to reflect social diversity in learning environments in an increasingly connected world (Sunzuma & Maharaj, 2020). This is in line with the findings of Lisnani and Gustira (2023) who stated that through ethnomatametics students can not only find new learning sources but can also learn about the history of the founding of mosques simultaneously. A similar opinion was also expressed by Meyundasari et al. (2024) that elements of mathematics and philosophy can be integrated in mathematics learning at school. Through ethnomathematics, the hope is to grow knowledge of culture and create a sense of pride in one's own culture.

Basically, ethnomathematics is the discovery of mathematical ideas in a culture (Fauzi & Gazali, 2022). In line with the results of this research, many triangular and rectangular elements were found in mosque buildings. Through ethnomathematics that is embedded in the students' own culture, it can provide mathematics learning that is more meaningful for them (Kusno et al., 2024). In this way, ethnomathematics studies at the Moekhlas Sidik Mosque can be used as an approach to learning mathematics. Provision on ethnomathematics is very necessary for educators (Abay & Parola, 2024). So it is hoped that teachers can develop ethnomathematics into an interesting lesson for students. The existence of Moekhlas Sidik Mosque is not only useful as a place of worship but also has other values, namely socio-economic. Many food and souvenir sellers around the mosque depend on income from visitors to Moekhlas Sidik Mosque.

Conclusion

In the Moekhlas Sidik Mosque building, obtained the results that the geometric objects found include findings of 2D shapes, 3D shapes, and geometric transformations. 2D shapes that can be found are triangles, trapeziums, squares, rectangles, rhombuses and semicircles. The 3D shapes that can be found are rectangular prisms. The geometric transformation found is the use of the principles of translation, reflection and rotation. Mathematical activities that can be explored include creating tile patterns and find the purpose of tile pattern, drawing 2D shapes using geometric transformation principles. From the findings, the design of Moekhlas Sidik Mosque has an aesthetic value, this can be seen in the form of symmetrical patterns and repeating patterns. In addition, the existence of Moekhlas Sidik Mosque provides socio-economic value that has an impact on the surrounding community. These findings can be applied in elementary school mathematics learning in accordance with the Learning Outcomes in the Independent Curriculum in each phase by generating various ideas for mathematical activities that can be developed. This research is limited only to the findings of mathematical objects and mathematics activities that have the potential to be applied in elementary school mathematics learning as well as possible mathematics activities. So that further research can present other mathematical concepts for higher school levels.

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Conflicts of Interest

The authors declare no conflict of interest regarding the publication of this manuscript. In addition, the authors have completed the ethical issues, including plagiarism, misconduct, data fabrication and/or falsification, double publication and/or submission, and redundancies.

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Author Contributions

Nabilla Namira Permata Putri: Conceptualization, writing - original draft, editing, and visualization; **Yoppy Wahyu Purnomo:** Writing - review & editing, formal analysis, and methodology.

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