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Ethnomathematics in the Architecture of the Great Mosque of Medan: Geometric Concepts and Transformations

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ABSTRACT

The Great Mosque of Medan embodies cultural and architectural elements that reflect various mathematical concepts. This study explored ethnomathematical concepts embedded in its architecture and examined their potential as contextual resources for mathematics learning. A descriptive qualitative design with an exploratory orientation was employed. Data were collected through observations, interviews, and documentation involving three purposively selected administrators of the Mosque Management Board (*Badan Kenaziran Masjid*, BKM). Data credibility was ensured through source and method triangulation and member checking. The data were analyzed through reduction, display, and conclusion drawing to identify mathematical concepts and interpret their relationships with architectural elements and the local cultural context. The findings revealed various geometric concepts, including plane figures such as squares, rectangles, rhombuses, circles, and octagons; solid figures such as cylinders, rectangular prisms, octagonal prisms, square pyramids, and hemispheres; and geometric transformations involving translation, reflection, and rotation. Translation was identified in ornamental patterns associated with elevators and escalators, whereas reflection was evident in staircase arrangements. These findings demonstrate that mathematical concepts are embedded in the mosque's architectural features and can be interpreted within their cultural context. The architecture of the Great Mosque of Medan therefore offers a contextual resource for connecting geometric concepts with local culture and supporting meaningful mathematics learning.

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Introduction

Mathematics is an integral part of community life and can be found in various cultural activities. Ethnomathematics views mathematics as knowledge that develops within particular cultural contexts, including through activities such as counting, measuring, identifying patterns, designing, and organizing the environment (Batiibwe, 2024; Kusuma et al., 2024). This approach enables mathematical concepts to be connected with students' experiences and cultural environments, making learning more contextual and meaningful (Rosa & Orey, 2016). Therefore, ethnomathematical studies should not merely identify mathematical forms in an object but should also consider their relationships with the knowledge, practices, values, functions, and cultural contexts surrounding the object.

Architecture is one of the objects that can illustrate the relationship between mathematics and culture (Mustofiyah & Sari, 2025). The forms, patterns, proportions, symmetry, and spatial arrangements of buildings can represent mathematical concepts. However, the presence of squares, circles, cylinders, or geometric transformations in a building does not automatically indicate ethnomathematical practices. Such relationships need to be explained through the cultural context, use of the objects, and knowledge of individuals who understand the objects. Research on the Jamik Mosque of Sumenep demonstrated that mathematical concepts in architecture can be examined alongside the cultural values attached to the objects (Alghar, 2024). Similarly, research by Arifin et al. (2025) found ethnomathematical concepts in the design of the Al-Mashun Grand Mosque, including plane figures, solid figures, and geometric transformations.

Studies of ethnomathematics in buildings have shown relatively consistent findings, particularly the identification of plane figures, solid figures, and geometric transformations in mosques, temples, traditional buildings, as well as historical sites and monuments. In mosque architecture, previous studies have identified various geometric concepts through observation, documentation, and interviews, while similar concepts in other historical buildings have been identified through the exploration of geometric forms, construction, and visualization (Cancerlia et al., 2025a; Nisa et al., 2023; Putri & Putri, 2024; Rofiq et al., 2022; S. A. Sari et al., 2024; Yudianto et al., 2021). These findings indicate that architecture is a potential source for ethnomathematical studies; however, most previous research has primarily focused on identifying geometric forms and concepts.

Studies of historical buildings have also revealed a diversity of ethnomathematical objects, ranging from temples and traditional buildings to modern sites and monuments. Research on Gedongsongo Temple, Sojiwan Temple, Plaosan Temple, Cetho Temple, Borobudur Temple, traditional Toraja houses, the Yogyakarta Palace, the Taman Sari complex, and the Jogja Monument has demonstrated that mathematical concepts can be examined through geometric characteristics and cultural artifacts (Azhar et al., 2025; Khasanah et al., 2022; Mahmudah, 2024; Mauluah & Putra, 2021; Muhammad et al., 2021; Purnamasari et al., 2022; L. W. Sari, 2023). However, this diversity of objects has not been sufficiently accompanied by studies that specifically explain the relationships among physical characteristics, the use of architectural elements, the functions of facilities, information provided by individuals who understand the objects, and mathematical concepts.

The Great Mosque of Medan is one of the buildings whose architectural elements, ornaments, spatial arrangements, and supporting facilities can be explored from this perspective. In addition to the building elements, facilities such as stairs, lifts, and escalators are used to support user mobility. The presence of these modern facilities is not directly positioned as a cultural element; rather, they are examined based on their characteristics, use, and information obtained from mosque administrators. Thus, the mathematical concepts identified are not based solely on similarities in shape but also on the context in which the objects are used within the mosque environment. Based on previous studies, ethnomathematical research on mosque buildings has largely focused on identifying geometric concepts in forms and ornaments. Meanwhile, the relationship between architectural elements, the context of

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spatial use, information provided by mosque administrators, and mathematical concepts needs to be explained more explicitly so that the study does not merely involve matching objects with geometric forms. In the Great Mosque of Medan, specifically, comprehensive field-based ethnomathematical research focusing on architectural elements and supporting facilities through observation, interviews, and documentation remains limited. This research gap provides a basis for expanding ethnomathematical studies of the Great Mosque of Medan.

The novelty of this study lies in exploring the relationship between the characteristics and use of architectural elements in the Great Mosque of Medan and mathematical concepts based on information obtained from the Mosque Management Board (Badan Kenaziran Masjid/BKM). The exploration encompasses plane figures, solid figures, and geometric transformations. The results indicate the presence of translation in the movement of lifts and escalators and reflection in the arrangement of the stairs. These findings are positioned as mathematical concepts within the architectural environment of the mosque, while their relationship to ethnomathematical practices is interpreted based on the cultural context and use of the objects, supported by the research data. This study aims to explore ethnomathematical concepts in the architecture of the Great Mosque of Medan by analyzing the relationships among building elements, the use of facilities, information provided by mosque administrators, and mathematical concepts. The findings are expected to enrich ethnomathematical studies of mosque architecture and provide a context for geometry learning that connects mathematics with students' cultural environment and real-life experiences.

Method

Research Design

This study employed a descriptive qualitative research method with an exploratory orientation. This approach was used to identify and describe ethnomathematical concepts found in the architecture of the Great Mosque of Medan. The study focused on exploring mathematical elements manifested in the forms, patterns, arrangements, and architectural components of the mosque. The findings were then interpreted by considering the cultural context and functions of the observed objects. This approach is consistent with ethnomathematical research that examines the relationships among mathematical concepts, culture, and community activities (Ahmed, 2024; Creswell & Poth, 2018).

Data Sources and Informants

The informants in this study consisted of three individuals selected using purposive sampling, namely the Chairperson of the Mosque Management Board (Badan Kenaziran Masjid/BKM) of the Great Mosque of Medan, Mr. Abdullah Matondang, as the Secretary of the BKM of the Great Mosque of Medan, and Mr. Musa Idishah, as the Deputy Chairperson of the Development Committee of the Great Mosque of Medan. The three informants were selected based on their competencies, as they were directly involved in the management and development planning of the mosque, had knowledge of its construction history, and understood the background behind the addition of modern facilities to the building.

The interview with the Chairperson of the BKM was conducted in mid-April 2026, while the interviews with the Secretary of the BKM and the Deputy Chairperson of the Development Committee were conducted on April 25, 2026. The interviews were conducted in a semi-structured format, with each interview lasting approximately 15–20 minutes. The interview questions covered the history of the mosque's construction, development plans and achievements, building capacity, and the reasons for adding lifts and escalators. Some quantitative information provided by the informants consisted of development plan data that had been publicly disclosed since the early stages of construction. Therefore, the data were reverified through an examination of official documents as part of technique triangulation.

Instruments

The research instrument in this qualitative study was the researcher as the primary instrument, supported by a non-participant observation guide, a semi-structured interview guide, and a documentation sheet. The observation guide was used to identify the forms, patterns, arrangements, spatial organization, and movement of facilities within the architecture of the Great Mosque of Medan. An example of an observation item was: “Identify the forms, patterns, arrangements, and geometric characteristics of the observed objects.” The interview guide was used to obtain information regarding the history, functions, meanings of ornaments, architectural philosophy, Islamic values, local knowledge, and use of facilities. Examples of interview questions included: “What are the functions and meanings of the ornaments found on this part of the building?” and “What is the reason for using lifts and escalators in the mosque building?” Questions regarding lifts and escalators focused on their functions and uses without directing the informants toward any particular mathematical concepts. The documentation sheet was used to record and collect photographs of the objects, field notes, and supporting documents as evidence and for verification of the observation and interview findings. These instruments were used to obtain data on mathematical characteristics and contextual data, which were subsequently analyzed qualitatively.

Data Collection

Data were collected through non-participant observation, semi-structured interviews, and documentation. Observations focused on the architectural forms, ornaments, patterns, spatial arrangements, and supporting facilities of the Great Mosque of Medan. Interviews were conducted with three administrators of the Mosque Management Board (Badan Kenaziran Masjid/BKM), using questions covering the history and functions of the building as well as its cultural context. These questions included the meanings of symbols or ornaments, the reasons for selecting particular patterns and forms, architectural philosophy, the relationship between the design and cultural traditions and Islamic values, and the local knowledge underlying the architectural elements. This approach followed the principles of ethnographic interviews, which emphasize exploring cultural meanings from the participants’ perspectives. It is also consistent with the ethnomathematical perspective, which situates mathematical concepts within cultural contexts and community experiences.

Questions regarding lifts and escalators focused on their functions and use rather than directing the informants toward any particular mathematical concepts. Documentation, including photographs, field notes, documents, and relevant literature, was used as supporting data and for verifying the results of observations and interviews. The use of observation, interviews, and documentation has also been applied in the exploration of ethnomathematics in mosque architecture by Cancerlia et al. (2025a).

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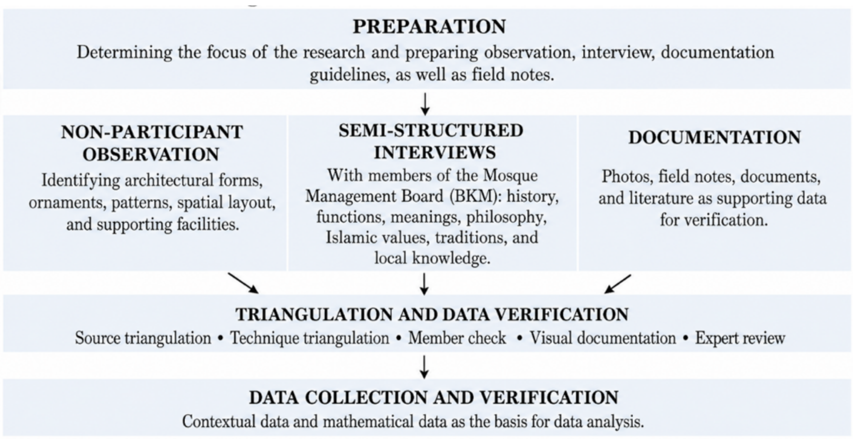

Figure 1. Research Data Collection Flow

Analysis

The data were analyzed interactively using the model proposed by Miles, Huberman, and Saldaña (2014), which consists of data condensation, data display, and conclusion drawing and verification. During the data condensation stage, observation, interview, and documentation data were identified based on data units consisting of architectural elements, ornaments, spatial arrangements, and supporting facilities. The data were then coded and grouped according to similarities in their characteristics (Istiqomah et al., 2026). The coding process focused on five aspects: (1) mathematical forms or characteristics, including forms, patterns, arrangements, and movements; (2) functions or uses of objects; (3) meanings, symbols, history, or philosophies of forms as expressed by the informants; (4) cultural context, including traditions, cultural values, and local knowledge; and (5) mathematical-cultural relationships, referring to the relationship between the mathematical characteristics of an object and its function, meaning, or cultural context, as supported by the research data. Interview data concerning history, functions, symbolic meanings, philosophies of forms, traditions, cultural and Islamic values, and local knowledge were interpreted as cultural context. Subsequently, the characteristics of each data unit were matched with mathematical concepts based on their forms, patterns, arrangements, and movements. The resulting findings were grouped into the categories of plane figures, solid figures, and geometric transformations.

At the data display stage, the findings were presented descriptively and supported by visual documentation. Conclusions were then drawn and verified by comparing the results of observations, interviews, and documentation to ensure the consistency of the interpretations. Thus, an object was not categorized as ethnomathematics merely because it resembled a geometric form; an object was categorized as ethnomathematical only when the relationship between its mathematical characteristics and its cultural context, function, meaning, or local knowledge was supported by the research data. An analytical approach involving reduction, classification, and interpretation has also been applied in ethnomathematical research on the architecture of the Great Mosque of Raja Hamidah (Cancerlia et al., 2025a).

Trustworthiness

Data trustworthiness was established through three procedures. First, source triangulation was conducted by comparing information obtained from the three informants to ensure the consistency of information regarding the history, functions, use, meanings, and cultural context of the objects. Second, technique triangulation was used to examine the consistency of contextual and functional information by comparing the results of field observations, interviews, and visual documentation. Technique triangulation was not used to determine whether an object was a prism, rectangular prism, or another specific geometric form, because the identification of mathematical concepts requires an examination of the mathematical characteristics of the object. Third, member checking was conducted by reconfirming the interview summaries with the informants to ensure that no errors occurred in the interpretation. In addition to assessing the trustworthiness of contextual data, the accuracy of mathematical concept identification was examined through visual documentation and expert review. Visual documentation was used to examine the characteristics, arrangements, and movements of the objects, while expert review was conducted by consulting the identification of mathematical concepts with the academic supervisor as an expert in mathematics education. Thus, information regarding the functions, history, use, and cultural context was examined through triangulation, whereas the accuracy of mathematical concept classification was assessed based on visual evidence and expert judgment.

Research Findings

The results showed that the architecture of the Great Mosque of Medan incorporates mathematical concepts that can be examined within an ethnomathematical context. The findings were obtained through observation, interviews, and documentation and were subsequently grouped based on the characteristics of the objects and the contexts in which they are used. Interview data were used to explain the functions, identity, use, and cultural context of the architectural elements, while the identification of mathematical concepts was determined by the researcher through an analysis of the forms, patterns, arrangements, and movements of the objects. To strengthen the presentation of the findings, interview data were presented for findings that contained contextual information provided by the informants. The Great Mosque of Medan demonstrates a combination of modern architecture and Islamic elements through its main dome, minarets, calligraphic ornaments, building patterns, and spatial arrangements. Interview data from the BKM administrators supported these findings. The informants explained that the architectural elements of the mosque continue to maintain its identity as an Islamic place of worship despite adopting a modern concept. Interview data from the BKM administrators also supported the findings regarding the functions and use of facilities in the Great Mosque of Medan. The informant Matondang explained that lifts and escalators are used to facilitate congregants' access between floors.

M: *"Lifts and escalators are used to help congregants move from one floor to another and to facilitate access to different parts of the building."*

The statement by M. was used as contextual data concerning the function and use of the facilities. Meanwhile, the identification of the concept of translation was based on observations of the movement characteristics of the objects. This statement provides contextual data regarding the identity and function of the architectural elements while also supporting the observations concerning the architectural characteristics of the Great Mosque of Medan.

This information provides context for the observations concerning the architectural characteristics of the mosque. From an ethnomathematical perspective, cultural context is necessary to ensure that the identification of mathematical concepts is not based solely on similarities in geometric forms (Riadi et al., 2025). Thus, the meanings attributed by the informants to the dome, minarets, and ornaments were used to explain the cultural context of the objects, while the determination of the geometric concepts remained based on the observed mathematical characteristics.

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The building elements and ornaments were found to contain squares, rectangles, rhombuses, circles, and octagons. These forms were identified based on their visual characteristics and geometric arrangements in the observed parts of the building. Interview data also reinforced the contextual understanding of the functions and uses of the ornaments. The informant Isdiah explained that calligraphy and ornaments function to strengthen the Islamic atmosphere and reflect Islamic values within the interior of the mosque.

I: *"Calligraphy and ornaments are used to strengthen the Islamic atmosphere while reflecting Islamic values within the interior of the mosque. The patterns used follow the overall design of the building."*

The statement by I. was used as contextual data concerning the function, values, and use of the ornaments. Meanwhile, the classification of geometric forms in the ornaments was the result of the researcher's analysis based on the observed visual characteristics and geometric arrangements. This statement provides information regarding the function, values, and cultural context of the ornaments, while the classification of geometric forms represents the researcher's mathematical analysis of the observed objects.

Three-dimensional elements were found to include cylinders, rectangular prisms, octagonal prisms, square pyramids, and hemispheres. These findings were determined based on the geometric characteristics observed in the objects rather than on the informants' assessment of the names of the mathematical solids. Interview data were used as contextual information to complement the observational findings, while the identification of solid figures resulted from the researcher's analysis of their mathematical characteristics.

In addition to geometric forms, transformation concepts were identified in certain facilities and arrangements. Lifts and escalators are used as facilities for movement between floors. Interview data from the informant Matondang supported the findings concerning the functions and use of these facilities.

M: *"Lifts and escalators are used to help congregants move from one floor to another and to facilitate access to different parts of the building."*

The statement by M. was used as contextual data concerning the function and use of lifts and escalators. Based on observations of their movement, lifts and escalators can be represented through the concept of translation because their movement involves a change in position while maintaining the same shape and orientation. Thus, the function of the facilities was obtained from the interview data, whereas the identification of translation was the result of the researcher's mathematical analysis based on the characteristics of the objects' movement. Based on observations of their movement, lifts and escalators can be represented through the concept of translation because their movement involves a change in position while maintaining the same shape and orientation. The concept of reflection was identified in the arrangement of the stairs, which demonstrates positional regularity with respect to a reference line. The informant's statement regarding the function of lifts and escalators was used to explain the context in which the facilities are used, whereas the identification of translation and reflection was the result of the researcher's mathematical analysis based on the movement and arrangement characteristics of the objects.

Overall, the findings demonstrate that the architecture of the Great Mosque of Medan incorporates concepts of plane figures, solid figures, and geometric transformations that can be utilized as contexts for mathematics learning. Interview data showed that the architectural elements and ornaments are understood by the BKM administrators in relation to Islamic identity, functions, use, and cultural values, whereas the mathematical concepts were determined through an analysis of the characteristics of the objects. Thus, the inclusion of interview data in the presentation of the findings strengthens the relationship between the observational findings and their cultural context and demonstrates that the ethnomathematical interpretation is supported by empirical data. The distinction between contextual data and mathematical analysis enables the mathematical-cultural relationship to be explained based on research evidence rather than merely on similarities in geometric forms. The relationship among architectural elements, cultural context, and mathematical concepts makes these objects relevant as learning resources that connect students' environmental experiences with geometric concepts. Studies of ethnomathematics in mosque architecture have likewise demonstrated that building elements can be used to contextualize geometric concepts in mathematics learning (Cancerlia et al., 2025a).

Profile and Development of the Great Mosque of Medan

Based on the interview results, the Secretary of the Mosque Management Board (Badan Kenaziran Masjid/BKM) of the Great Mosque of Medan, Mr. Abdullah Matondang, explained that the old mosque building had been standing since 1993 and is currently equipped with modern facilities, including two lifts and escalators. This information indicates that the development of the Great Mosque of Medan has taken place gradually, evolving from a relatively simple old building into a building equipped with modern accessibility technology.

The Deputy Chairperson of the Development Committee of the Great Mosque of Medan, Mr. Musa Idishah, explained that the place of worship stands on an area of 10,000 m². The old building, covering 1,000 m², had a capacity of 1,200 worshippers inside and 500 people in the courtyard, with parking facilities for 125 cars and 500 motorcycles. Through the development program, the building area was planned to be expanded to 5,000 m², with a capacity of 5,000 worshippers inside and 2,000 people in the courtyard, as well as multi-level parking facilities with a capacity of 400 cars and 1,000 motorcycles. Meanwhile, the 199-meter-high minaret was initially targeted for completion in 2018, with funding collected through donations from the Muslim community.

As part of technique triangulation, the quantitative information was re-examined through official documents and was found to be identical to the development plan data published at the beginning of the construction project in 2016 (Pemerintah Provinsi Sumatera Utara, 2016). Therefore, the figures above are treated as development plan data rather than measurements of the completed building at the time of the study. The document review also indicated that, as of April 2026, construction of the minaret was still ongoing; therefore, the height of 199 meters remained a planned specification.

The information most relevant to this study is Mr. Musa Idishah's statement that the old building was not demolished, while the new building was designed with lifts and escalators to enable people with disabilities to worship on the upper floors. This information indicates that the presence of lifts and escalators was not merely a matter of luxury but was part of accessibility considerations planned from the beginning of the development. This background further supports the selection of these two facilities as objects of ethnomathematical investigation in this study.

Geometry is a branch of mathematics that studies the forms, sizes, positions, and relationships among objects in space. According to Rofiq (2022), the study of geometry encompasses various elements, including points, lines, angles, planes, and solids, as well as different types of plane and solid figures. Based on the observations, the architecture of the Great Mosque of Medan demonstrates the application of various geometric concepts that can be identified through the forms of the building, ornaments, and structural elements. The

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concepts of plane figures, solid figures, and geometric transformations identified in the Great Mosque of Medan are presented as follows.

Plane Geometry

Plane geometry is a branch of mathematics that studies two-dimensional shapes with only two dimensions, namely length and width. Plane figures have no thickness or volume; therefore, they have only area and perimeter.

Square

In Figure 2, the ceiling ornaments of the Great Mosque of Medan consist of square-shaped panels arranged in a regular pattern. A square is a plane figure with four equal sides and four right angles (90°). This shape is chosen because it has a high degree of symmetry, creating a balanced, orderly, and harmonious appearance. The formulas for the area and perimeter of a square are as follows:

Area of a square:
$$A = s \times s$$
Perimeter of a square:
$$C = 4 \times s$$

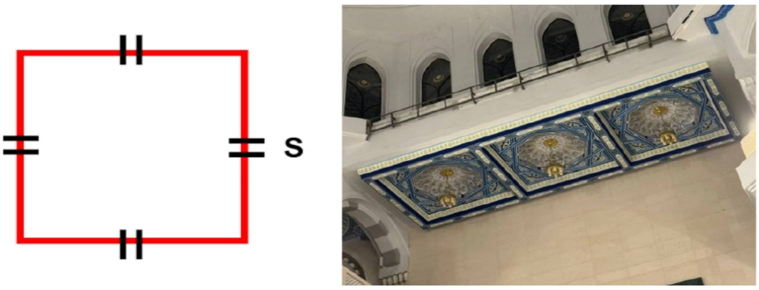

Figure 2. Ceiling Design of the Great Mosque of Medan

Rectangle

One of the plane geometry concepts observed in the mihrab of the Great Mosque of Medan is the rectangle. This shape can be seen in the outer frame of the mihrab ornament, which encloses the main decorative area. Mathematically, a rectangle is a plane figure with four sides, in which each pair of opposite sides is equal in length and parallel, and all four angles are right angles. The use of a rectangular shape as an ornamental frame demonstrates the application of geometric principles that create order, balance, and visual harmony throughout the building's design.

Area of a rectangle:
$$A = l \times w$$
Perimeter of a rectangle:
$$C = 2 \times (l + w)$$

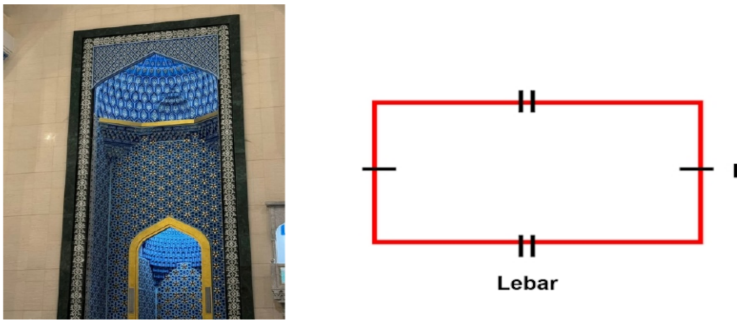

Figure 3. Mihrab Ornament of the Great Mosque of Medan

Rhombus

On the floor of the Great Mosque of Medan, rhombus-shaped ornaments can be seen as decorative accents arranged regularly among the floor tiles. A rhombus is a plane figure with four equal sides, two pairs of equal opposite angles, and diagonals that intersect perpendicularly and bisect each other.

Area of a rhombus:

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

Perimeter of a rhombus:

$$C = 4 \times s$$

Figure 4. Floor Motif of the Great Mosque of Medan

Circle

In this ceiling ornament, the concept of a circle can be observed through the presence of a center point, radius, diameter, and circumference. The motifs surrounding the center are arranged along the circumference, forming a regular and repetitive pattern. In addition to its aesthetic value, the circular shape is often interpreted as a symbol of perfection, unity, and eternity. Thus, it functions not only as a decorative element but also embodies interconnected cultural, artistic, and mathematical values.

Area of a circle:

$$A = \pi r^2$$

Circumference of a circle:

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$$C = 2\pi r \text{ or } C = \pi d$$

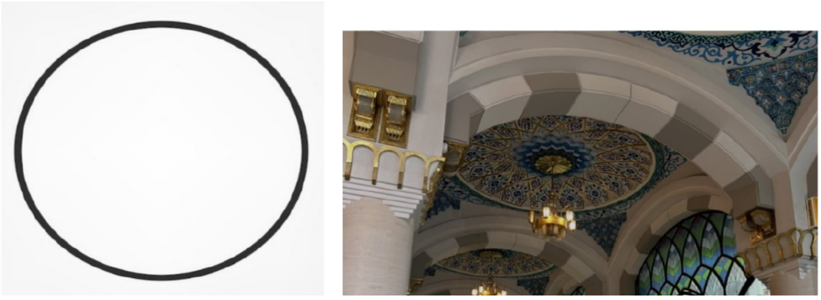

Figure 5. Central Ceiling Ornament of the Great Mosque of Medan

Octagon

The octagon on this ceiling serves not only as a decorative element but also reflects a mathematical concept integrated with culture. The symmetrical octagonal shape creates a balanced, orderly, and aesthetically pleasing pattern. From an ethnomathematical perspective, the ceiling ornament in the main prayer hall demonstrates how geometric shapes, such as octagons, can be utilized to create artworks that possess both aesthetic value and cultural meaning. For a regular octagon with a side length of s, the following formulas apply:

Area of a regular octagon:

$$A = 2(1 + \sqrt{2})s^2$$

Perimeter of a regular octagon:

$$K = 8 \times s$$

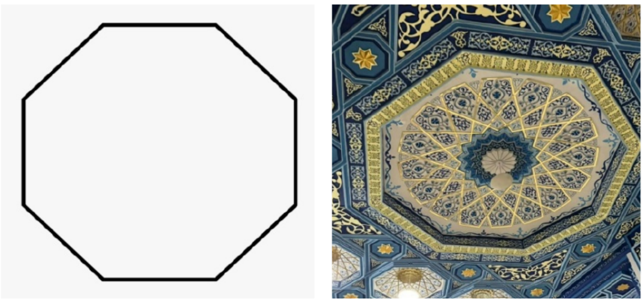

Figure 6. Main Prayer Hall Ceiling of the Great Mosque of Medan

Solid Geometry

Solid geometry studies three-dimensional shapes with three dimensions, namely length, width, and height, giving them volume and surface area. Several solid figures found in the Great Mosque of Medan are described as follows.

Octagonal Prism and Square Pyramid

The main structure of the ablution area is shaped like an octagonal prism, a solid figure with octagonal bases and rectangular lateral faces. This shape makes the ablution area sturdy and symmetrical while allowing faucets to be installed around its eight sides, making it practical for many worshippers to use simultaneously. At the top, there is a square pyramid, a solid figure with a square base and four triangular lateral faces that meet at a single apex. This shape serves as both a cover and a decorative element that enhances the appearance of the ablution area. Its upward-pointing apex creates an elegant impression and can be interpreted as a symbol of the relationship between humans and the Creator.

Area of the base of an octagonal prism:

$$L_{base} = 2(1 + \sqrt{2})s^2$$

Volume of a prism:

$$V = L_{base} \times t$$

Area of the base of a square pyramid:

$$L_{base} = s \times s$$

Volume of a square pyramid:

$$V = \frac{1}{3} \times L_{base} \times t$$

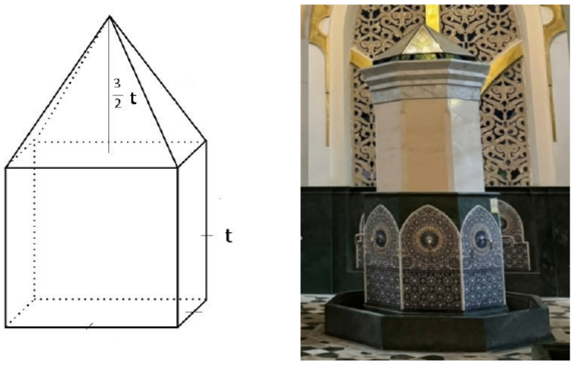

Figure 7. Octagonal Prism and Square Pyramid

Cylinder

The pillars or columns of the Great Mosque of Medan are cylindrical in shape, representing a solid figure with two parallel circular faces at the top and bottom and one curved surface connecting them. The cylindrical shape is chosen because it can support the weight of the roof and the mosque's arches strongly and evenly. In addition to serving as structural supports, the pillars also contribute to the aesthetic appeal of the building through decorative elements added to their capitals and bases, reflecting distinctive features of Islamic architecture.

Volume of a cylinder:

$$V = \pi r^2 h$$

Surface area of a cylinder:

$$A = 2\pi r^2 + 2\pi r h$$

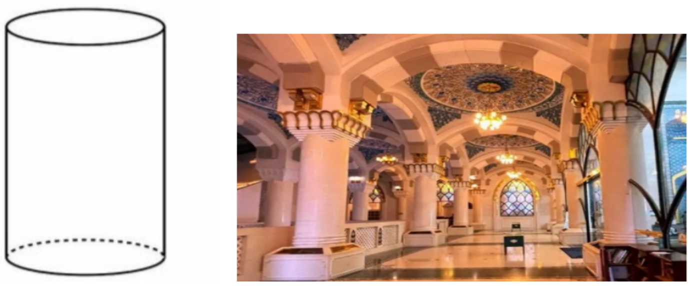

Figure 8. Columns of the Great Mosque of Medan

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Rectangular Prism

The blue rectangular prism-shaped ornament found at the Great Mosque of Medan is one of the architectural elements that serves a purpose beyond merely decorating the building. The surface of the rectangular prism features white geometric motifs arranged repeatedly from top to bottom. This arrangement demonstrates a repeating pattern with relatively consistent spacing and dimensions. In addition, the black panel decorated with golden vine motifs also exhibits symmetry. The shapes on the right and left sides appear nearly identical, creating visual balance. This concept of symmetry is one of the fundamental principles of Islamic architectural art, symbolizing harmony, order, and the perfection of God’s creation.

Volume of a rectangular prism:

$$V = l \times w \times h$$

Surface area of a rectangular prism:

$$A = 2 \times [(l \times wl) + (l \times h) + (w \times h)]$$

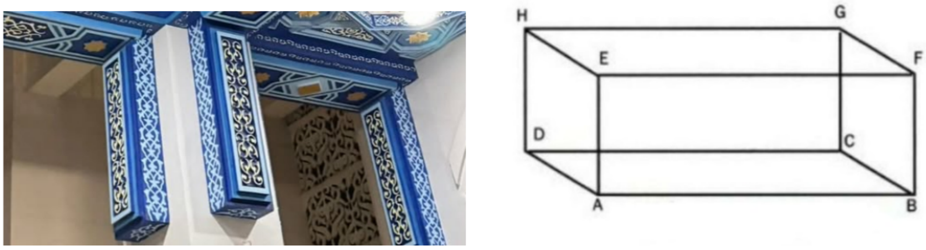

Figure 9. Wall Ornament of the Great Mosque of Medan

Hemisphere

The main dome of the Great Mosque of Medan, which is shaped like a hemisphere, symbolizes the perfection, greatness, and majesty of Allah SWT. Its upper part, which points toward the sky, seems to remind us that every prayer and hope of human beings is directed toward the Creator. The golden color of the dome not only enhances the aesthetic appearance of the mosque but also symbolizes nobility, magnificence, and spiritual values. The combination of its shape and color gives the mosque a strong character as a place of worship filled with tranquility, devotion, and religious significance.

Volume of a hemisphere:

$$V = \frac{2}{3} \pi r^3$$

Surface area of a hemisphere (including the base):

$$A = 2\pi r^2 + \pi r^2 = 3\pi r^2$$

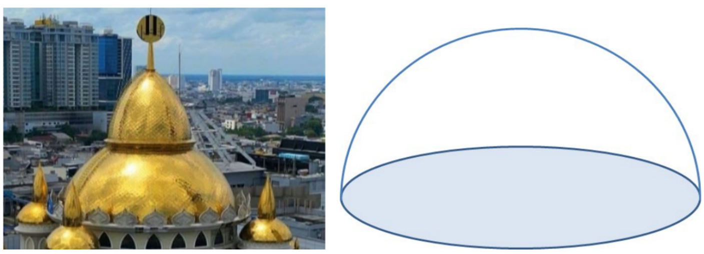
Figure 10. Dome of the Great Mosque of Medan

Geometric Transformations

Geometric transformations are mathematical concepts that study changes in the position, size, or shape of an object through processes such as translation (shifting), reflection, rotation, and dilation (enlargement or reduction). According to Rahman et al. (2022), these concepts can be found not only in decorative patterns on buildings but also in various elements of modern architecture and building facilities, as well as in other cultural artifacts, such as the traditional clothing motifs of the Dayak Kenyah people (Abbas et al., 2024).

Lift

11 shows the presence of a lift as one of the facilities added to the Great Mosque of Medan. According to the Secretary of the BKM, there are currently two lift units in the mosque building. This is consistent with the explanation provided by the Deputy Chairperson of the Development Committee, who stated that the lifts were installed to enable people with disabilities to access the upper floors. Thus, the facility functions to improve accessibility and provide more inclusive services for all worshippers. From a mathematical perspective, the lift at the Great Mosque of Medan can serve as an example of the application of geometric transformation, specifically translation (shifting). This is because the lift cabin moves upward and downward along a straight path without changing its shape, size, or orientation. Mathematically, the upward movement of the lift cabin by h units can be represented as a translation with the vector $(0, h)$, such that each point (x, y) on the cabin is mapped to $(x, y + h)$.

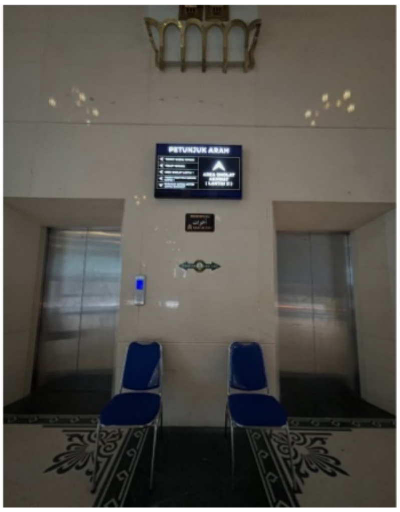

Figure 11. Lift at the Great Mosque of Medan

Stairs and Escalators

Figure 12 shows that the Great Mosque of Medan not only provides lifts but also has stairs and escalators designed to make it easier and more comfortable for worshippers to access the upper floors. The stairs and escalators at the Great Mosque of Medan provide clear examples of the application of geometric transformation concepts. Reflection is evident in the right and left staircases, which are symmetrical with respect to the central axis of the building, while translation can be observed in the repeated arrangement of the steps at regular intervals and in the movement of the escalator steps along an inclined path. In addition, the inclination of the

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escalator can be related to the concept of gradient, which is the ratio of the vertical height between floors to the horizontal distance of the span.

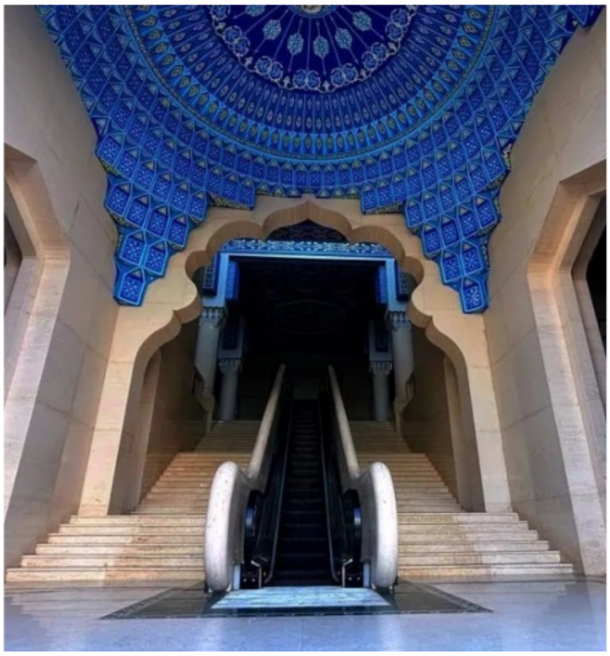

Figure 12. Stairs and Escalators at the Great Mosque of Medan

Discussion

The findings of this study indicate that the presence of mathematical concepts in the architecture of the Great Mosque of Medan should be understood not merely as the occurrence of geometric forms but also in relation to the context of use and the cultural environment of the building. The geometric forms identified represent the mathematical characteristics of the objects, while the architectural context, functions, Islamic identity, and use of space were obtained through observation, interviews, and documentation. Interview data provided contextual evidence that the architectural elements and ornaments are understood by the BKM administrators in relation to the building's identity as an Islamic place of worship, the functions of its elements, and Islamic values. Therefore, mathematical-cultural relationships were discussed based on objects supported by data concerning relevant knowledge, values, meanings, functions, or experiences of use. Objects that only demonstrated geometric or movement characteristics were positioned as mathematical contexts within the mosque environment and were not automatically claimed as ethnomathematical practices. This distinction is important because ethnomathematics views mathematics in relation to cultural aspects and everyday experiences rather than merely identifying mathematical forms in cultural objects (Riadi et al., 2025).

In the architecture of the Great Mosque of Medan, geometric patterns and arrangements can be observed in various building elements and ornaments. These findings demonstrate that regularity, repetition, proportion, and spatial arrangement form part of the visual organization of the architecture. However, this study does not automatically interpret every square, circle, or solid figure as ethnomathematics. Its ethnomathematical relevance is determined by the relationship between the mathematical characteristics of the objects and their context of use, as well as information regarding the identity and function of the building obtained from field data. As empirical evidence, Informant M explained that the building was designed with a modern concept while maintaining its identity as an Islamic place of worship, while the dome, minarets, and ornaments were understood as elements that reinforce the mosque's identity. This statement provides contextual data regarding the identity and function of the architectural elements, whereas the geometric classification remains the result of the researcher's mathematical analysis of the characteristics of the objects. Thus, mathematical concepts are positioned as a means of interpreting the structure of the objects, while the cultural context provides a basis for understanding why these objects exist within the architectural environment of the mosque.

These findings are consistent with the study by Cancerlia et al. (2025a) on the Great Mosque of Raja Hamidah in Batam, which identified plane figures, solid figures, and geometric transformations through observation, documentation, and interviews. That study also demonstrated the importance of architectural and cultural contexts in making building elements relevant as contextual learning resources. The difference is that the present study uses interview information concerning identity, function, use, and Islamic values as contextual data considered together with the mathematical characteristics of the objects, so that mathematical-cultural relationships are not determined solely by similarities in form (Cancerlia et al., 2025b).

Modern facilities such as lifts and escalators also need to be positioned appropriately. They are not specifically cultural forms but can serve as contextual objects for learning geometric transformations. The movement of lifts and escalators was analyzed as translation based on changes in position while maintaining the same shape and orientation. Interview data from Informant M indicated that the functions of the lifts and escalators are to help worshippers move between floors and facilitate access to different parts of the mosque. These data support the interpretation of the functions and uses of the facilities but are insufficient to claim that translation in lifts or escalators constitutes a cultural practice. Therefore, the finding of translation in these facilities is positioned as a mathematical concept within the architectural environment of the mosque and as a learning context, rather than as an independent claim of ethnomathematical practice. Accordingly, the value of this study does not lie in considering the technology itself as an ethnomathematical practice, but rather in utilizing it as part of the mosque's architectural environment to connect mathematical concepts with students' real-life experiences.

Regarding the ornaments, Informant I explained that calligraphy and ornaments are used to strengthen the Islamic atmosphere and reflect Islamic values within the mosque, while the patterns follow the overall design of the building. This information provides empirical evidence concerning the functions, values, and cultural context of the ornaments. Meanwhile, the squares, rectangles, rhombuses, circles, and octagons identified in the building elements and ornaments were determined through observations of the visual characteristics and geometric arrangements of the objects. Thus, the informant data explain the cultural context and use of the ornaments, whereas the mathematical classification is the result of the researcher's analysis. From a learning perspective, the findings expand the use of mosque architecture as a contextual learning resource. Students are not only directed to identify the names of geometric figures but can also observe patterns, arrangements, proportions, transformations, spatial functions, and the contexts in which objects are used. This approach is consistent with the objectives of ethnomathematics, which seek to connect mathematical concepts with cultural experiences and everyday life, thereby making learning more meaningful (Group, 2024).

The similarities between the present findings and previous studies are particularly evident in the use of geometric concepts in mosque architectural elements. Such similarities may occur because form, regularity, symmetry, and proportion are commonly used principles in the organization of structures and visual compositions of buildings. Rahmah and Kusno (2024), for

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example, identified plane figures, solid figures, and transformations at the Muhammad Cheng Hoo Mosque in Purbalingga, while Cancerlia et al. identified similar concepts in the architecture of the Great Mosque of Raja Hamidah in Batam. These findings demonstrate that mathematical concepts can emerge in architectural objects with different cultural characteristics.

The differences in findings are related to the architectural characteristics and facilities available at each site. Previous studies have largely explored ornaments, roof forms, and structural elements that characterize the mosque architectures under investigation. The Great Mosque of Medan has a modern-contemporary character, providing additional contexts in the form of lifts, stairs, and escalators. These distinctive characteristics allow the identification of translation in the movement of lifts and escalators and reflection in the arrangement of the stairs. However, these differences do not necessarily indicate differences in cultural practices; rather, they primarily reflect the characteristics of the objects and the ways in which mathematical concepts can be explored within different architectural environments.

From an ethnomathematical perspective, architectural context is important because mathematics is understood in relation to cultural experiences and everyday life (Fitrianawati et al., 2020). Therefore, the modern facilities in this study are not positioned directly as cultural symbols but as parts of the architectural environment and community activities that provide a context for the use of mathematical concepts. Claims regarding cultural relationships are limited to contexts supported by field data, such as the building's Islamic identity, the functions and uses of ornaments, and the use of facilities by worshippers. These data provide a contextual basis for interpreting the mathematical findings, while the determination of geometric concepts remains based on an analysis of the characteristics of the objects. The implication is that ethnomathematical studies of mosque architecture can be expanded from traditional ornaments and forms to contemporary architectural environments, while still requiring a relationship between the mathematical characteristics of the objects and their cultural or functional contexts.

The findings also reinforce the potential of mosque architecture as a contextual learning resource. Students can connect geometric concepts with objects encountered in real-life environments, allowing mathematics to be understood not merely as an abstract form but as knowledge that exists within community life and cultural contexts (Turmuzi et al., 2023). The finding concerning the inclination of the escalator can be developed as a learning context for the gradient of a straight line in Grade VIII of junior secondary school (SMP/MTs). Students can work in small groups using photographs of the escalator at the Great Mosque of Medan together with available data on the vertical height between floors and the corresponding horizontal distance. Based on these data, each group can construct a right-triangle representation of the escalator, with the vertical height representing the change in (y) and the horizontal distance representing the change in (x). Students can then calculate the gradient using the formula $\left(\frac{\Delta y}{\Delta x}\right)$ and, as an enrichment activity, determine the angle of inclination using the relationship $(\tan\theta = m)$. The results can subsequently be compared with technical requirements for escalator inclination. EN 115-1:2017 specifies limitations on escalator inclination, while Schindler's planning guidelines indicate that a 30° inclination provides greater travel comfort and safety, whereas a 35° inclination is more space-efficient but is subject to restrictions for larger vertical rises. Through this activity, students can discuss the relationships among gradient, angle of inclination, comfort, safety, and space requirements, thereby connecting mathematical concepts with their application in real-world building facilities.

Similar activities can be developed for geometric transformation topics in Grade XI by asking students to model the movement of the lift cabin as a translation on a coordinate plane and determine the axis of symmetry in the arrangement of the stairs as an application of reflection. In the topic of curved-surface solids, students can be asked to estimate the volume and surface area of the mosque dome based on the available diameter data. Thus, the use of the Great Mosque of Medan as a learning resource does not stop at identifying shapes but extends to mathematical calculations and reasoning. Through an ethnomathematical approach, students can learn mathematics while simultaneously becoming familiar with local culture (Yudianto et al., 2021). Learning becomes more concrete, engaging, and easier to understand because it is connected to objects in the surrounding environment. In addition to helping students understand geometric concepts, this approach can also increase curiosity and appreciation for Islamic architecture, in line with findings that the use of the cultural context of Islam in the Nusantara region can strengthen the relevance of mathematics learning for students in Indonesia (Richardo et al., 2020). Therefore, the Great Mosque of Medan is suitable for use as a culture-based mathematics learning resource.

Conclusion

The findings show that the architecture of the Great Mosque of Medan contains various mathematical concepts, including plane and solid figures, symmetry, repetitive patterns, and geometric transformations. These concepts can be examined in relation to the functions, uses, and cultural information associated with the mosque. However, geometric forms alone should not automatically be interpreted as ethnomathematical practices. In particular, translation in lifts and escalators and reflection in stair arrangements are more appropriately viewed as mathematical contexts for learning within a modern mosque environment because the available data do not indicate specific cultural meanings or practices associated with these elements. This study is limited by the small number of informants, short interview duration, limited observation, and the absence of perspectives from architects or building designers. The study also did not conduct comprehensive direct measurements or test the findings in classroom learning. Therefore, the results should be interpreted as exploratory evidence rather than proof of instructional effectiveness. The findings provide a basis for developing contextual mathematics learning resources related to geometry, transformations, and gradients. Future research should involve more diverse informants, include architects or designers, expand observations and direct measurements, and develop and test learning materials based on the identified mathematical and cultural contexts.

Conflict of Interest

The authors declare that there is no conflict of interest in the research and writing of this article.

Auhor Contributions

D. P. H. contributed to formulating the research idea, collecting field data, analyzing the data, and preparing the initial draft of the article. E. K. H. contributed to developing the research concept and methodology, supervising the research process, and reviewing and finalizing the manuscript. Both authors state that they have read and approved the final version of this article. The percentage contributions of each author were D. P. H.: 70%, and E. K. H.: 30%.

Data Availability Statement

The authors state that the data supporting the results of this study will be made available by the corresponding author, D. P. H. , upon reasonable request.

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