The Geometrical Patterns and Philosophical Value of Javanese Traditional Mosque Architecture for Mathematics Learning in Primary School: An Ethnomathematic Study

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Abstract

Aim. This study is an ethnomathematical study that aims to describe and interpret the philosophical value and geometrical patterns of the famous architecture and ornament of the Indonesian traditional Mosque.

Methods. This report subsequently used an ethnographic method, with data being obtained through observation, documentation, and Focus Group Discussion (FGD). Furthermore, the study subjects were a cultural practitioner and a group of educators, containing five primary school teachers in Central Java, Indonesia. Interviews, observation, and documentation were conducted during the research. The data was analysed qualitatively.

Results. First, from the data analysis, it was found that there are several philosophical values contained in the architecture and ornaments of a Javanese traditional mosque such as the relationship that must always exist between humans and God and fellow human beings, Islam, *iman* (faith), *Ihsan* (kindness), openness, honesty, obedience, and humility. The second indicates the relationship between the Javanese architecture and ornament of the Indonesian traditional Mosque and the geometrical patterns (the cuboid, and cylinder), symmetrical patterns, and geometry transformation (rotation) used as the source of learning and starting point to the mathematical learning process.

Conclusions. These results were specifically useful to primary school teachers when teaching geometry. Through culture as a context or starting point, the new mathematical learning resource was also used for geometric learning. In addition, the philosophical significance of these artifacts fostered an interest in the indigenous culture and good character values.

Keywords: Geometrical Patterns, Philosophical Value, Javanese Traditional Mosque Architecture, Ethnomathematics, Primary School.

Introduction

Mathematics is designed to explain daily life experiences, based on the provision of solutions to social, cultural, and natural ecosystem problems (Abdullahi et al., 2021; Jawad, 2022; Laurens et al., 2018; O**ğul** & Arnas, 2022; Şahin & Danaci, 2020). Meanwhile, ethnomathematics presents the relationship between cultural heritage and mathematics, due to significantly contributing to several knowledgeable contexts in the cultural societies connected to the mathematics (Alangui, 2017; D'Ambrosio, 2018; Rosa & Orey, 2021; Sunzuma & Maharaj, 2020). In the school curriculum, mathematical concepts can be connected to the students' cultural and daily experiences (Albanese et al., 2017; Amit & Abu Qouder, 2017; Rosa & Orey, 2011). Ethnomathematics also helps in the development of social, emotional, and intellectual knowledge, through unique culture. This provides students with methods to protect and maintain identities while succeeding in their academic abilities.

Indonesia is known as a multicultural country due to its cultural diversity extension from Sabang to Merauke (Iskandar & Marini, 2020; Rodgers, 2017; Setyono & Widodo, 2019). Mathematical knowledge in every culture appears in three forms: mentifacts (ideas, the origin and creation of myths

and mysteries, and knowledge), sociofacts (rules governing relationships between individuals in society), and artifacts (material objects and technology) (D'Ambrosio & Rosa, 2017). Many anthropologists have reported shown evidence of mathematically-related practices, such as counting, locating, measuring, playing, designing, and explaining, which was carried out through different methods from those normally taught in the school system (Bishop, 1988; Katsap & Silverman, 2016). The process of producing culture often involves activities that are indirectly related to mathematical concepts. The mathematical process associated with this culture is subsequently known as ethnomathematics (D'Ambrosio, 1997). Ethnomatematics also explain the reality of connection between mathematics and local culture in solving everyday life problems (Salma et al., 2022; Aini et al., 2023; Candrasari et al., 2023).

Among mathematical domains, geometry is considered one of the most frequently studied subjects in the field of ethnomathematics, due to the concept being a very important part of building architecture. Architects also use geometric concepts to create various building design patterns (Bonner, 2017; Mahmoud, 2017). The concept of the symmetrical building was initially developed in Asia and Africa, e.g., the cotangent and equilateral triangles were used to design pyramids, with the Mozambicans constructing rectangular houses through similar rope lengths as the diagonals. The indigenous tribes with a pristine cultural background also had a high level of expertise in mathematics, geometry, and related fields (Ezeife, 2002). Moreover, some studies related to architecture and geometry are reportedly shown from various countries with their respective characteristics, for instance, the roof of the Kelantan kingdom mosque, Malaysia, had a triangular-shaped roof layered (Husain, et al., 2017). The Chinese Guangxi sanctuary and the ancient Haka houses, as well as the Indonesian Borobudur Temple also exhibited great measurement and geometrical works (Zaenuri et al., 2019). In *Bantayo Po'Boide*, a traditional house of Gorontalo Regency, some geometrical concepts were subsequently observed, such as triangular ornament (Ali, 2019). These conditions demonstrate that the indigenous people are often identical to well-organised traditional houses. For example, the design of the traditional house in Kampung Naga, Tasikmalaya, Indonesia, was realistically similar to the use of geometrical concepts (Hermanto et al., 2019). Other fields of geometry such as cartesian and symmetry, were also found in many original American designs, e.g., textiles, saint paintings, and pottery. Furthermore, four cardinal directions are providing an original analogue to the complete cartesian coordinate system with abscissa and ordinate (Eglash, 2001), with the symmetry groups being explored by batik and carving motifs (Juniati & Budayasa, 2017). In Hamburg, Germany, the traditional architecture of the Maori meeting house also illustrates mathematical symmetry (Trinick et al., 2017), with symmetrical concepts and reflection shown in local Balinese carvings (Suharta et al., 2017).

Similar to other civilisations, Indonesia has many mathematically-related works, such as buildings. In Central Java, Demak Regency is also one of the districts popular for its past glory, due to being firmly perched on an Islamic kingdom led and supported by Raden Patah and Walisongo. This is because Walisongo is a respected Indonesian leader playing a major role in the spread of Islam, especially on Java island. The occurrence of cultural acculturation in the Demak kingdom is also based on the great contribution of Walisongo. Through several considerations, especially in the prominence of religion, Walisongo and Raden Patah (the King of Demak) established Glagahwangi Mosque as the place for religious activities. This is the oldest sanctuary on Java island, which is also known as The Great Demak Mosque. A cultural heritage still presently utilised and preserved was also established by the kingdom, with a mosque being used for gathering, evaluating, deliberating, and praying. It was also used as a place of deliberation for guests, including Walisongo, Java noblemen, and beyond. This indicates that the great mosque is a beautiful and proper heritage for the Demak kingdom in Java (Sastronaryatmo, 1981). In Central Java, the most popular traditional mosque is Masjid Agung Demak (the great mosque of Demak), which integrates the values of Islam with the local culture. With similar essence and orientation as all global sanctuaries (qibla of Mecca), this is a national cultural heritage site playing a role as an internationally-integrated mosque. As a cultural heritage related to artifacts, every corner of the Mosque has beautiful artistic ornament and geometric architectural values, which elevates the local wisdom interpretation of the kingdom. These geometric concepts are an important part of the spatial and architectural art of the mosque. In Islamic geometric patterns, geometry is also determined and applied by Muslim culture as a universal language, which is one of the most important multicultural design symbols (Dabbour, 2012; Ghasemzadeh et al., 2013; Sidawi, 2013). Therefore, this study aims to explore and evaluate the geometrical patterns and philosophical values underlying the architecture and ornaments of the Javanese traditional Mosque, which are used for the mathematical learning process in primary school.

Methods

This was an ethnographic study, where attempts were carried out to explain and interpret a cultural and social group within the society. In ethnography, two important keywords are often observed, namely culture description and interpretation (Alangui, 2010; Creswell & Poth, 2018; Geertz, 1973; Spradley, 2016). In this study, the participants included cultural practitioners and 5 primary teachers in Central Java, Indonesia, selected through the purposive sampling method. This is a non-random sampling technique used to determine the groups of individuals willing to participate in a study, as well as communicate their opinions and ideas regarding the relevant related knowledge and experience to the topic (Etikan et al., 2016). An

ethnographic report also requires a group of people as participants, based on the ability to interpret culture through several artifacts, interviews, and observations (Creswell & Creswell, 2018). In addition, the data was obtained through interview, Focus Group Discussion (FGD), documentation, and observation techniques. The utilised instruments were also the interview guidelines, observation sheets, and artefact documentation of the Great Demak Mosque. To determine the artifacts' identity and their philosophical values, the interviews were conducted with the cultural practitioners (Mr. Raden Edi Sumarsono), with the guidelines shown in Table 1.

Table 1
Interview guideline to the cultural practitioner

No	Interview Points
1	The architect
2	Type of the architectural design & ornament and the philosophical values

Source. Own research.

The observation was conducted by the study expert and the primary teacher group through the FGD technique, with the selected participants representing the educators' required characteristics. This focused on the evaluation and observation of the traditional Mosque's artifact documents, to determine and interpret the geometrical patterns within the architectural structure. It also aims to determine the mosque ornament in the geometrical learning process and the relationship to the Indonesian Mathematics Curriculum. In this condition, observations were also conducted on the artifacts and ornament of the traditional Mosque, as shown in Figure 1.

The Artifacts and Ornaments of Javanese Traditional Mosque	Geometrical Patterns (GP)	Basic competencies in Indonesian curriculum (BC)
The name of the artifacts	GP_1	BC_1
⋮	⋮	⋮
⋮	⋮	⋮
The name of the ornaments	⋮	⋮
⋮	⋮	⋮
⋮	GP_n	BC_n

Figure 1
Observation guideline for a group of primary school teachers during FGD

Source. Own research.

After observation, a mathematical problem related to the Javanese traditional Mosque was produced by the FGD. An ethnographic data analysis method was also used for interpretation, through the general descriptive procedures. In addition, the utilised analytical method adopted the procedure of John W. Creswell & J. David Creswell (2018) as described in Figure 2 below.

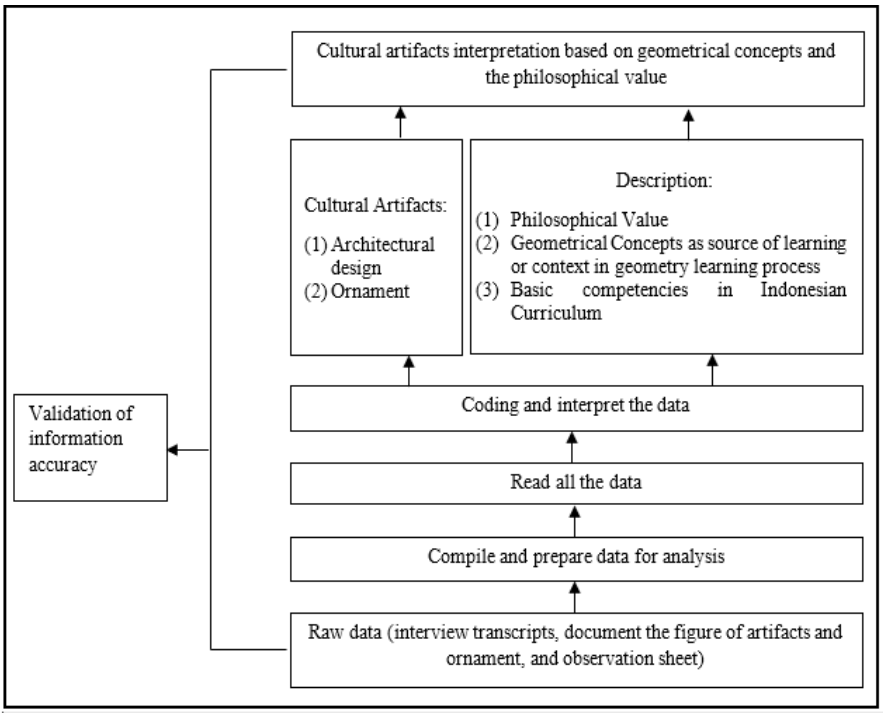


Figure 2
Schema of Data Analysis

Source. Adapted from *Research design: qualitative, quantitative, and mixed methods approaches (4th ed)* (269), by J. W. Creswell & J. D. Creswell, 2018, SAGE Publication.

Results and Discussion

In this study, the ethnographic analysis used (Creswell & Poth, 2018; Geertz, 1973), where the culture and philosophical values from interview transcripts were initially described. This was accompanied by the interpretation of the geometrical concept culture, for the primary school learning process from FGD.

Qualitative Data from the Cultural Practitioner Interview

Based on the results, two analytical interview points were classified as the architect, as well as the type of architectural design/ornament and the philosophical value.

The Architect. The cultural practitioner explained that the architect of the mosque construction was *Sunan Kalijaga*, who created actual mockup sizes as a reference for craftsmen. This was carried out with several con-

siderations such as wood material, relative hot climate adjustment, and the adoption of the traditional Javanese house.

The Type of Architectural Design & Ornament and The Philosophical Value.

***Tajug/limasan roof* (Pyramid roof).** The roof contains overlapping wooden *tajug* shades *(sirap*), which protects the main room and *limasan* (the pyramid) covering the veranda of the mosque. This has a specific shape that portrays the mosque as a spiritual and sacred nuance, a worship house, and a strong traditional Javanese sanctuary. The shape of the *tajug* roof is similar to a three-tiered pyramid, with a crown culmination at the top of the smaller pyramid. From this building, the philosophical value is based on the relationship of verticality, due to overshadowing the main room. In this condition, three existing *tajug* were observed to have a deep interpretation, where *tajug* 1, 2, and 3 (the lowest, moderate, and highest) are the Islamic foundation, faith, and *ihsan* (kindness). Meanwhile, the philosophical value of the limasan creates a horizontal relationship with fellow human beings and their environment. This shades the foyer of the mosque, due to being horizontal/immanent, profane, and open. From the concept of dualism, there are also many functional differences in function, which complement and reinforce one another. The illustration of the shape of a mosque roof is shown in Figure 3.

Figure 3
The Philosophy of the Roof
Source. Own research.

***Mustaka* (The Crown).** The crown is a symbol of the ultimate goal of human worship, namely the return to God. This is an important part of the mosque's roof cover. The crown is shown in Figure 4.

Figure 4
The Crown
Source. Own research.

The Main Prayer Hall. *Dalem Room* (The main Prayer Hall) is a sacred room, which is observed at the centre of the building. This has closed characteristics due to being used as the main praying room. A *mihrab* is also found at the front of this room, based on being the prayer area for the priest. Moreover, the room is found to be a square with four *soko guru* (centre pillars), supported by 12 *soko pengarak* (*pengarak* pillars) and *emperan* (*emperan* pillars). Based on the central position, the main room has *soko guru*, *tajug* roofs, crowns and pendants. All these artifacts ensure a balance and harmony in realising human relations with God. The axis of the main hall is also vertically integrated with four pillars providing spiritual values, with the palace room and limasan-roofed pavilion representing the transcendent and immanent aspects (*habblumminallah* and *hablumminannas*), respectively. Figure 5 shows the floor plan and the geometrical analysis of the *Dalem* room.

Figure 5
The Main Prayer Hall

Source. Own research.

***Veranda and Umpak (*base foundation on Majapahit pillars).** The veranda is also known as the *pendopo*, which is an important part of the Great Demak Mosque structure. This porch is an open and profane space without walls, used for discussion and deliberation. In this structure, a *Majapahit* pillar, *soko penanggap* (*penanggap* pillars), *umpak* foundation, and chandeliers are often observed, with the building plan being slightly different from

the *Dalem* room. It is also rectangular, as well as supported by 8 Majapahit pillars and 28 *soko penanggap*. Subsequently, the base foundation (*umpak*) of the Majapahit pillars and *Soko penanggap* are found in this structure, as the external foyer *umpak* is different to the *Dalem* room, due to representing openness and honesty. At the base, a letter representation, *mim-ha-mim-dal*, is also depicting the Prophet Muhammad. Therefore, every Muslim should abide by the straight path of the Prophet Muhammad. As a cornerstone Majapahit, the *umpak* illustrated the written motifs of the Prophet Muhammad, indicating the abiding with every spiritual teaching and made path based on guidance. This base supports the Majapahit pillar as the legacy of the Kingdom, verifying the identity of the maintained historical aspects still depending on an Islamic foundation. In addition, Figure 6 illustrates the mosque's porch floor plan and *umpak*.

Figure 6
Veranda and Umpak
Source. Own research.

Mihrab, Maksurah* and *Dampar Kencana. *Mihrab* is the positional area of the imam during prayer, which serves as a sign of Qibla direction. In this structure, a *condro sengkolo* symbol representing *sariro sunyi kiblating gusti* is observed, indicating 1401 saka or 1479 M. Figure 7 illustrates the *mihrab* and the turtle symbol contained within the structure, which represents *yen mlebu kudu alus*, i.e., anyone entering the mosque to worship should be inwardly and spiritually subtle and humble (*tawadlu*) to God. Meanwhile, Maksurah and Dampar Kencana are also an important part of the mosque's artifacts. This explains that Maksurah is a building on the left side of the mihrab for a sultan or king to pray, with a measurement of 28 x 182 x 319 cm. In this structure, the contemplation room was used for prayers by the aristocrats,

with guidance being sought after within the *munajat and khalwat*. The *maksurah* is also decorated with a Majapahit style carving from the relief of Arabic script, representing the glorification of the oneness of Allah SWT. Meanwhile, *Dampar Kencana* is the throne of the Majapahit king, *Mihrab, Maksurah,* and *Dampar Kencana* are shown in Figure 7.

(a) Mihrab (b) Maksurah (c) Dampar Kencana

Figure 7
Mihrab, Maksurah and *Dampar Kencana*
Source. Own research.

***Surya Majapahit* (Majapahit Solar Ornament).** Majapahit solar ornament is located on the wall above the mihrab, due to being one of the decorations of the mosque. This serves as a respect for the Majapahit Kingdom, which previously controlled the Demak territory. It also represents a continuous symbol of the Islamic and pre-Islamic cultures. Additionally, the ornament is a symbol of *hasta brata*, which are the eight characteristics that should be possessed by a leader. It's shown in Figure 8.

Figure 8
Hasta Brata in Solar Ornament
Source. Own research

Based on Figure 8, the eight characteristics are highlighted as follows,

a) The nature of the Earth is to provide a habitat for humans, animals, and plants,
b) The Sun is a source of energy based on the provision of strength to support life. This explains that solar energy provides strength to all living things on earth,
c) The nature of the Moon represents a source of light when night falls, subsequently serving as the luminary of living things from the darkness on earth,
d) The Ocean is found to be wide and airy, due to being a symbol of the chest broadness and heart breadth. This shows that a leader should contemporarily have the ability to gracefully accept criticism and be ready to consider several suggestions. The leader should also be open to accommodate the complaints of the people,
e) The nature of the Star represents a high position, demonstrating that the leader should have a noble personality, occupy an honourable and respected position (maqam),
f) The Wind is found to be able to enter (infiltrate) anywhere, with nature being observed as thoroughness and caution in Javanese philosophy. This proves that the leader is always measured in speaking (not just talking), as each word is often accompanied by adequate arguments with data and facts.
g) Fire is known to indiscriminately burn anything, with nature being positively interpreted as a symbol of firmness and straightforwardness.
h) Unlike the Ocean, the nature of Water is more observed regarding the broadness (airy) of the heart, due to having a frequent low-level characteristic. This confirms that a leader should always be humble and not arrogant to the people.

***Bledeg* Door.** This is the primary door connecting the foyer and main rooms of the mosque. It is also the only carved door that marks the construction year of the sanctuary. In addition, the presence of carvings provides special interpretations related to Javanese cultural patterns. *Bledeg* door also has a horizontal axis parallel to the *mihrab* and the *pancer* (centre), among the four pillars. In addition, Figure 9 below illustrates the *Bledeg* Door.

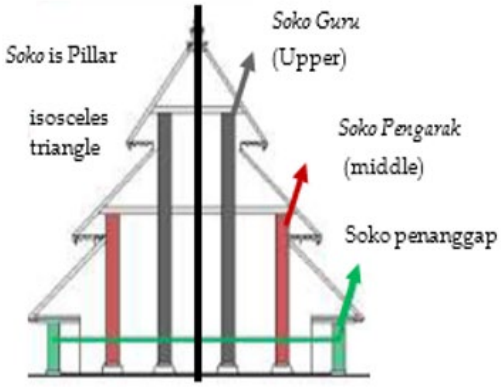
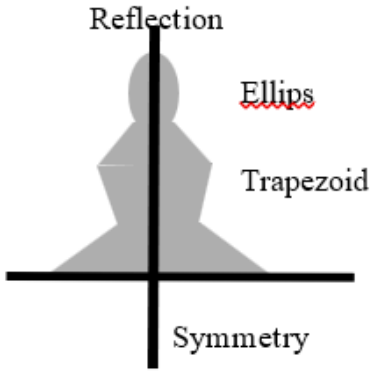
Figure 9
Bledeg Door
Source. Own research.

Relationship between Cultural Artifacts (Javanese Traditional Mosque Architectural Design and Geometrical Patterns)

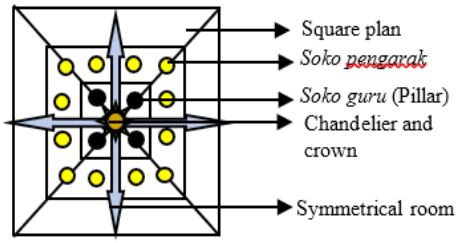
For learning resources or contexts, the primary school teachers conducted a Forum Group Discussion (FGD), to classify the artifacts and ornament in the Mosque into various types of geometrical patterns. It was also performed to categorise these sanctified designs into numerous learning resources for students' geometrical material content, as shown in Table 2.

Table 2

Geometrical Patterns in Javanese Traditional Mosque

Cultural Artifacts and Ornaments of Javanese Tradiotonal Mosque	Geometrical Patterns (GP)
 *Tajug* and Pyramid Roof	– Beheaded pyramid – Isosceles triangle – Symmetrical
 *Mustaka* (The Crown)	– Ellipse – a convex tipped – cylindrical tube – trapezoid – Symmetry and reflection

Cultural Artifacts and Ornaments of Javanese Tradiotonal Mosque	Geometrical Patterns (GP)

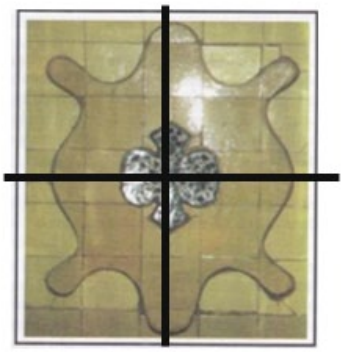


Main Prayer Hall represent Square Sketch and Symmetry

– Square plan
– Symmetrical room
– Pillar showing cylinder

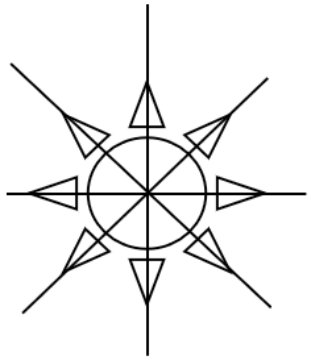
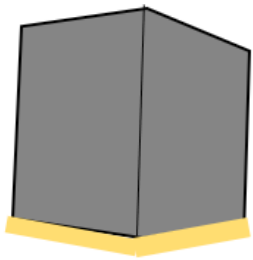
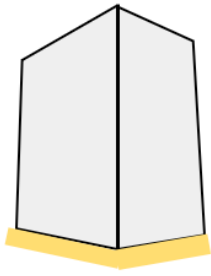
Soko Guru and *Soko Pengarak* (Pillar)

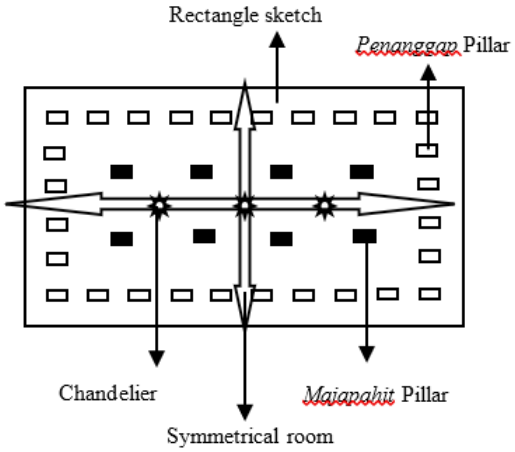
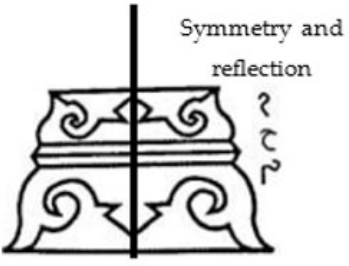
– Pillar showing cylinder

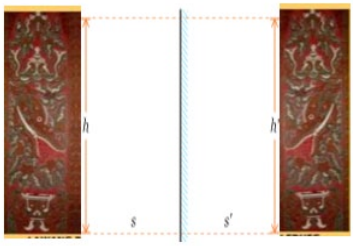


Turtle ornament

– Symmetrical turtle ornament

Cultural Artifacts and Ornaments of Javanese Tradiotonal Mosque	Geometrical Patterns (GP)
 Majapahit Solar Ornament	– Symmetrical object and reflection concept – Rotating symmetry
 *Maksurah* (28 x 182 x 319) cm	– Cuboid room
 *Dampar Kencana* (246 x 195 x 292) cm	– Cuboid room

Cultural Artifacts and Ornaments of Javanese Tradiotonal Mosque	Geometrical Patterns (GP)
 Veranda represent a rectangle sketch	– Rectangle plan – Symmetrical room – Pillar showing cuboid
 *Soko Penanggap* (Penanggap Pillar)	– Pillar showing cuboid
 *Umpak*	– Symmetrical ornament – Geometrical transformation (rotation and dilatation)

Cultural Artifacts and Ornaments of Javanese Tradiotonal Mosque	Geometrical Patterns (GP)
 *Bedug* and *Kentongan*	– *Bedug* and *Kentongan* showing cylinder
 Bledeg Door	– Symmetrical object and reflection concept

Source. Own research.

The relevancy of the artifacts and ornament of Demak Great Mosque in the basic competencies of the Indonesian curriculum for primary school in the mathematics learning process are grouping solid and plane based on specific properties, through various concrete objects, identifying the folding and rotational symmetry in shapes, using concrete objects, classifying solid and plane based on their characteristics, and grouping various planes based on their properties (Ministry of Education and Culture Republic of Indonesia, 2018).

Designing Geometry learning activities and Mathematics Problems through Cultural Artifacts during FGD.

FGD was conducted by the study expert and teachers, to produce geometry learning activities through the artifacts and ornaments of Javanese Traditional Mosque. First step, we are using culture, especially an artifacts, as a start in learning or context in the learning process. Second step, we can invite students to connect the culture with a mathematical idea. Third step, when there is a match with the mathematical idea, students are invited to temporarily deconstruct and focus on geometrical concepts/knowledge. An

in the last step we can get process of mathematical knowledge reconstruction. The sample of schema geometry learning process by using Majapahit Solar Ornament is shown in Figure 10.

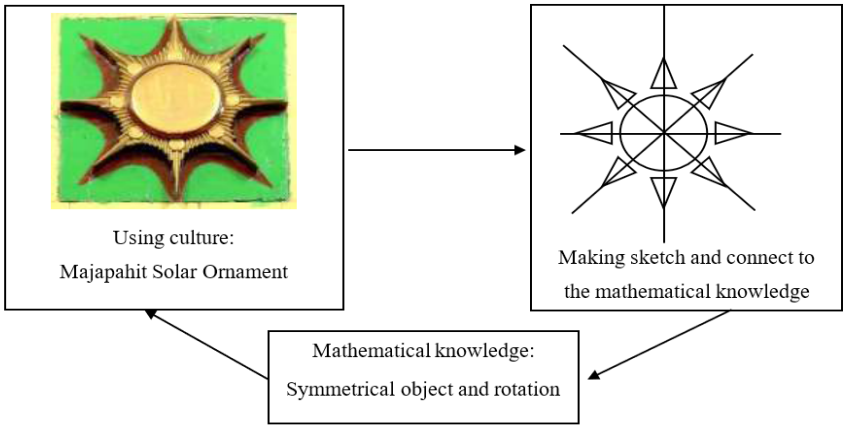


Figure 10
Sample of schema geometry learning process by using Majapahit Solar Ornament
Source. Own research.

The next activity during FGD is produce sample of mathematical problems with classifying the cultural artifacts based on their properties and characteristics. Here is the sample of mathematical problems.

The artifacts of Dalem Room include the Maksurah, Damar Kencana, Saka Guru, and Saka Tatal:

- The *Maksurah* has a size of 280 x 182 x 319 cm.
- *Damar Kencana* is an artefact that proves the victory of *Raden Fatah*, with the golden room having a size of 246 x 165 x 292 cm. The results showed that this artefact and the *Maksurah* are still used in the *Dalem room* of the Mosque.
- The *saka guru* and *saka tatal* also have a height and diameter of 16 and 70 cm, respectively.
- The artifacts in the veranda, i.e., the hall of the mosque, are also *Bedug* and *Kentongan*, as shown in Figure 11.

Figure 11
Bedug and *Kentongan*
Source. Own research.

Table 3 below shows examples of some of the statements in the mathematics problem and the answer options that students will choose. The third column of Table 3 shows the correct answer option.

Table 3
Example of mathematical problems with the correct answer option
Search the following statements and choose the appropriate answer.

The Artifacts	Answer Choice	The Correct Answer
Maksurah and *Damar Kencana* are both cuboids	True/False	True
One of the artifacts in the Dalem room is a cone	True/False	False
The artifacts located on the mosque's veranda are cylindrical	True/False	True

Source. Own research.

In the geometrical learning process, the architecture and ornaments of Javanese traditional mosque, were able to become learning contexts and starting points. Based on the Indonesian curriculum for primary school mathematics, two important competencies were observed, especially in geometry, i.e., (1) using various concrete objects for teaching solid and plane (geometry), and (2) using the concrete object to classify the characteristics and properties of various two and three-dimensional planes (Ministry of Education and Culture Republic of Indonesia, 2018).

This research gives the meaning that mathematics is around us. Even inside our cultural artifacts. As mentioned by (Sharma & Orey, 2017) the concrete object was represented in the cultural artifacts and can be connected to the mathematical idea. The expansion of reality to the students was also carried out by including mathematical artifacts as simulation and models.

Conclusion

The artifacts existing in the architecture and ornaments of the Javanese traditional mosque had several elements of ethnomathematics knowledge, especially in geometrical patterns, such as quadrilateral pyramids, cuboid, cylinder, isosceles triangle, square, rectangle, ellipse, trapezoid, symmetry, and geometry transformation (reflection, rotation, and dilatation). They also had many philosophical values, due to being used to introduce the real shapes of geometry to the primary students, while strengthening their interests in Indonesian cultural heritage.

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