



Ethnomathematical studies on the Gedong Songo temple

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Abstract: The lack of information about designing buildings, measuring, patterning and calculating from ancient people, makes the concept of mathematics applied by people in the past remains unknown. It is necessary to study mathematics from a cultural point of view of society. This study is carried out through a cultural approach, or what is commonly referred to as ethnomathematics. Mathematics that is used by recognized cultural groups, such as national communities, ethnic groups, labor organizations, children of particular age groups, and professional classes, is known as ethnomathematics. Finding the mathematical principles used to construct the Gedong Songo Temple in Candi Village, Bandungan, Semarang Regency, Central Java, is the goal of this study. The object of research in this case is the Gedong Songo Temple. The approach taken is a qualitative one. In this study, an ethnographic technique was used. Data collection is done by literature study and observation. This research is structured descriptively, starting from reviewing problems related to ethnomathematics, formulating problems, collecting theories, analyzing, discussing data, and making conclusions. The findings demonstrated that geometry, symmetry, periodic patterns, and ratios are among the mathematical concepts used in the construction of the Gedong Songo Temple. The findings of this study can be used to improve mathematics instruction in cultural contexts. In addition, further studies on ethnomathematics can be carried out to see more comprehensively the mathematical concepts applied to the structure of the temple building.

Keywords: Ethnomathematics; Ethnographic approach; Gedong Songo

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INTRODUCTION

Mathematics has existed since ancient times. It is impossible to isolate the impact of culture on mathematical development (Hardiarti, 2017). Culture affects various aspects of people's lives such as clothes, houses, customs, food and so on. Society only applied this knowledge in everyday life. Mathematics has played a role in life and has become part of the human activities (Turmuzi et al., 2022). Mathematics must be grounded in reality, stay approachable to children, and be applicable to everyday life. In order to respond to their surroundings, people have created a variety of strategies, styles, and techniques, such as seeking explanations, insights, firsthand knowledge, and solutions to the things they observe (Prahmana et al., 2021). This viewpoint considers mathematics not only as a field of study but also as a human endeavor that is intricately linked to regional culture (Zaenuri & Dwidayanti, 2018). For instance, measuring, creating patterns, and counting are all activities that culminate in the use of mathematics (Faiziyah et al., 2021). It can be revealed from cultural relics such as temples and temples inscription. Temples and inscriptions are relics of the kingdoms in Indonesia. The influx



of Hindu and Buddhist influences in Indonesia also influenced this relic. Temples in Indonesia can be found on the islands of Java, Bali, Sumatra, and Kalimantan, but the most common temples found in Central Java and East Java.

The temple as mentioned in various sources is intended as a tomb, garden, place of worship, or other religious activities. Thus, the temple has a religious meaning. Temples were built with the intent or intention related to religion, namely Hinduism and Buddhism. Temples as buildings such as burials are only found in Hinduism, while in Buddhism temples are intended as places of worship (Syafii & Supatmo, 2019).

In the history of Indonesia, namely in 8th century to 10th century, it was recorded as the most productive period of the construction of the temple (Damayanti et al., 2014). During the Mataram Kingdom, large and small temples filled Central Java and Yogyakarta such as Borobudur, Prambanan and others. Some of the Hindu-style temples in Indonesia are Prambanan Temple, Jajaghu Temple (Jago Temple), Gedong Songo Temple, Dieng Temple, Panataran Temple, Angin Temple, Selogrio Temple, Pringapus Temple, Singosari Temple, and Kidal Temple. Buddhist-style temples include Borobudur Temple and Sewu Temple.

Lack of information about designing buildings, measuring, fabricating patterns and counting from previous societies, making concepts about mathematics that was applied by society in the past was not known. Although it is well known that there was no such thing as modern technology evolving at the time. Unknowingly, the idea of mathematics was used and turned into a task in the ancient culture (Utami, 2020). Need study or the study of mathematics as seen from the culture of society. This study is done through a cultural approach called ethnomathematics. Ethnomathematics is the study of mathematical concepts from ancient societies (Ascher, 2017). Ethnomathematics is the study of emerging mathematics or used in certain ethnic groups of society. In 1977, Brazilian mathematician D'Ambrosio introduced ethnomathematics. According to d'Ambrosio (1985), ethnomathematics is the study of mathematics within cultural groups that can be categorized based on their nationality, ethnicity, labor groups, children, and age ranges (d'Ambrosio, 1985). According to this definition, the term "ethnomathematics" encompasses more than merely ethnicity. A mathematical anthropology of culture is what ethnomathematics is.

In this study, the author focuses on ethnomathematical studies on Gedong Songo Temple. In Candi Village, Bandungan, Semarang Regency, Central Java, there is a temple called Gedong Songo. If we look at the characteristics that attached to Gedong Songo Temple, for example on the statues that occupying temple niches, Gedong Songo Temple is a Hindu temple. Gedong Songo Temple has very distinctive historical value. Therefore, the ethnomathematical side of Gedong Songo Temple can be studied, especially in the form and structure of the building.

The temple was discovered in 1740 (Wisjachudin et al., 2001). It is not known for sure when the temple was built, but it is estimated between The 8th to 15th centuries. Estimation of the establishment of the temple are calculated archaeologically and geologically at several temple locations. The results of the analysis show that the Gedong Songo temple is estimated to have been founded in 1181 to 1420 or between the 12th to 15th century (Wisjachudin et al., 2001). In other locations obtained in 772 (8th century) to 988 (10th century). From these two results, it is concluded that the cultural site of the Gedong Songo temple apparently continued at least until the 15th century.

The site of Gedong Songo Temple occupies an area of approximately 5 hectares. The existence of the temples scattered on the hills. Based on history, this site is called Gedong Songo because there are nine groups of temples. Gedong in Javanese means house, songo in Javanese means nine, so Gedong Songo Temple means nine houses (Wisjachudin et al., 2001). But in reality, only five groups of temples still exist, while the rest are the ruins of temple stones. The five groups of temples include Gedong Temple I, Gedong Temple II, Gedong Temple III, Gedong Temple IV, and Gedong Temple V.

As it is known that the temple is vertically divided into three main parts, there are the legs, body, and roof of the temple (Istari et al., 2013). Each of them is a symbol of one world level.

The levels in Hinduism are called *Bhurloka*, *Bhuwarloka*, and *Swarloka*. In Buddhism it is called *Kamadhatu*, *Rupadhatu*, and *Arupadhatu*. The foot of the temple (*Bhurloka/Kamadhatu*) represents the universe where we live, the temple's roof (*Swarloka/Arupadhatu*) symbolizes the heaven where the gods are, while the temple's body (*Bhuwarloka/Rupadhatu*) symbolizes the earth between the universe and heaven.

The place where Gedong I Temple is close to the entrance of the Gedong Songo Temple. There is one temple building that is still intact. Gedong I Temple faces west. This building has three parts, there are the legs, body, and roof of the temple. The location of Gedong II Temple is about 337 m to the northwest of Gedong I Temple and is located at a height of approximately 1270 masl (meters above sea level) (Istari et al., 2013). There are two temple buildings. Temple IIa which is still intact has three parts, namely, the legs, the body, and the roof of the temple. Temple IIa faces west. Temple IIb is only part of the building's foundation and is located directly opposite Temple IIa. Gedong III Temple consists of three temple buildings that are still intact. Located at an altitude of about 1298 masl and the distance from Gedong II Temple is about 118 meters (Istari et al., 2013). Temple IIIa is the largest building in the form of a square and the entrance faces west. Temple IIIb is located to the north of Temple IIIa, smaller in size, square in shape and the entrance faces west. Temple IIIc is located to the west of Temple IIIa, square in shape and the entrance faces east. Temples IIIb and IIIc are commonly called Perwara Temples.

The location of Gedong IV Temple is about 220 m to the west of Temple III and is located at an altitude of about 1300 masl (Istari et al., 2013). The building is the main temple located in the south, which is shaped the same as the other temples, which are square. The entrance is on the west side with a decorative doorway. Many remains of ruins and foundations around the main temple of Gedong IV. There is an Perwara Temple from Gedong IV Temple, which is not far from Gedong IV Temple. The location of Gedong V Temple is about 500 m from Gedong I Temple and on a hill with a height of about 1310 masl (Istari et al., 2013).

According to the description above, the formulation of the issue in this study is how the mathematical notion of the Gedong Songo Temple structure. The goal of this study was to identify the mathematical idea and the symbolism used in the Gedong Songo Temple based on culture and religion. The benefits of this research are to enrich creativity in ethnomathematical studies, especially in ethnomathematical studies of Gedong Songo Temple and provide an overview of the mathematical relationship with Gedong Songo Temple. The novelty of this research is the discovery of the golden ratio in the Gedong Songo temple building.

METHOD

A key phenomenon can be explored and understood using a qualitative research approach (Creswell, 2012). Qualitative research generates analytical methodologies without the use of statistical analysis or other quantification techniques (Moleong, 2009). In this study, an ethnographic technique was used. The ethnographic approach is a theoretical or empirical method that seeks to describe and analyze culture in-depth through extensive fieldwork (Indriyani, 2018). This study describes the mathematical concept of the structure of the Gedong Songo Temple and its symbol representation based on culture and religion.

Data collection is done by literature study and observation. Reading, documenting, and analyzing research materials are all actions that fall under the category of literature study (Zed, 2008). A literature review was conducted to gather factual information from numerous ethnomathematics-related literatures as well as from other hypotheses that lend credence to the study. To obtain these scientific data, the authors examine references to previous research, journals, and internet. There are about dozens of journals that are references for this research. Observation is a systematic activity towards symptoms both physical and mental (Rukajat, 2018). Observations were made to observe directly the layout, building layout and other relics at Gedong Songo Temple. At the Gedong Songo Temple in Candi Village, Bandungan, Semarang Regency, Central Java, observations were made. In collecting data through observation, the

researcher acts as an instrument (Patton, 1990). There are three stages to the data analysis technique utilized there: data reduction, data display, and conclusions.

RESULTS AND DISCUSSION

First, the researcher found several shapes on the temple building such as rectangles, circles, octagons, blocks, triangular prisms and cylinders. As is the case in other studies, the reliefs on the walls of the Borobudur Temple show flat shapes, such as circles, rectangles, triangles, squares and parallelograms (Nur et al., 2020). There are geometric shapes of blocks and cubes on the wall reliefs of Borobudur Temple. The mathematical concepts in the Cangkuang Temple are geometry (Nursyeli & Puspitasari, 2021). In geometry itself there are many parts, for example in plane shapes and geometric shapes.

Second, the concept of symmetry and periodic pattern is found in the reliefs and temple buildings. Research on the Singosari temple, in general, the shape of the temple has a balance of symmetry in which the center line is a reflection (Sayekti et al., 2014). Within the Ratu Boko Temple building site there are several buildings that are related to mathematics, such as the material plane geometry and symmetry (Rani, 2018). There are other studies about the Borobudur temple.

Although not quite true, it appears that the shape of the Borobudur Temple is symmetrical when seen from the side or the top (Kurniawan & Hidayati, 2020). A complex set of measurements and computations went into the building, as seen by its symmetrical shape. There are also self-similar geometric patterns found in many Borobudur architecture. That stupa forms and ornaments produced in fractal pattern. The other interesting thing is, even though they are have a similar shape and pattern. This shape corresponds to structural fractals in natural forms, such as the patterns found in conch shells, leaves, and flowers in plants (Kurniawan & Hidayati, 2020). There are many symmetrical and related, but not identical, forms in nature.

Third, the researchers found a golden rectangle and a golden triangle in the Gedong Songo temple building. Based on research that was done (Raja et al., 2020), It is well known that the Brihadeeshwarar temple in Tanjavur, Tamil Nadu, India, which was constructed in 1010 AD, contains the golden ratio. The golden ratio, which adds to the Brihadeeshwarar temple's beauty, had an impact on its design and building strategies. Tanjavur is home to the Hindu temple Brihadeeshwarar Temple, which honors Lord Shiva. This temple uses the principles of axial and symmetrical geometry practically and effectively. The golden section and the golden section rectangle are two architectural elements that incorporate the golden ratio into the Lengkong traditional house design (Yuningsih et al., 2021). One of the two applications of the golden ratio employed in the overall design of the Lengkong traditional house has a perfect value or is identical to its specifications.



Figure 1. Several shapes found in Gedong Songo Temple.



Figure 2. Symmetric and periodic pattern found in Gedong Songo Temple

The following are the results of measurements of the base and body of the temple.

Table 1. Results of the Temple's Base and Body

Temple Building	The length of the base of the top temple	The width of the temple's side
Gedong Temple I	6,62 m	3,96 m
Gedong Temple II	5,89 m	3,48 m
Gedong Temple IIIa	6,04 m	3,49 m
Gedong Temple IIIb	-	-
Gedong Temple IV	5,94 m	3,38 m
Perwara Gedong Temple IV	2,65 m	1,7 m
Gedong Temple V	6,11 m	3,44 m

Table 2. Measurement Results on Gedong IIIc Temple

Temple Building	length	Width	Ratio
Gedong Temple IIIc (Bhuwarloka)	2,76 m	1,69 m	1,6331360095
Gedong Temple IIIc (Bhurloka)	2,84	1,77	1,604519774

Table 3. Measurement Results at Gedong Temple IV and V on their Swarloka

Temple Building	Ratio between base and other sides	Angle
Gedong Temple IV	1,66666	33,57°
Gedong Temple V	1,6	36,8°

In various studies that have been carried out, it has been found that historical buildings have applied various mathematical concepts. Around our environment, no matter our country or our culture, there are places of worship in specific buildings. These structures differ mathematically in terms of their architecture and ornamentation. Many symbols used in places of worship use mathematical objects to convey meaning (Gage, 2008). Based on the literature review and direct observation at Gedong Songo Temple, the authors found several mathematical concepts that were applied to the temple building.

First, the researcher found several shapes on the temple building such as rectangles, circles, octagons, blocks, triangular prisms and cylinders. In Figure 1, the upper left shows a rectangular shape on the relief of the temple, on the upper right you can see an octagonal shape, on the lower left you can see a circular relief, and on the lower right is part of the roof of the temple,

some of which have cylindrical shapes on it. For the return form, it can be seen in Figure 2 on the lower left and the triangular prism shape in Figure 2 on the upper left. Certain forms or symbols in Hinduism have their own meaning. A yantra, which is a symbol for *Hyang Widhi Wasa*, can be created by arranging particular objects or characters that represent the sun or disk (wheel), as well as specific lines such as squares, triangles (stars), and circles (Suryasa & Wirawan, 2020). Religious symbols may be used to represent circles in general (Gage, 2008).

Second, the concept of symmetry and periodic pattern is found in the reliefs and temple buildings. The concept of symmetry can be seen in Figure 2 on the top right, namely the front temple building which looks symmetrical and some of the reliefs which look symmetrical. See in picture 2 on the lower left you can see a relief that has a periodic pattern and also on the lower right of the door wall.

The concept of symmetry is also often found in historic buildings. For religious and aesthetic reasons, the concept of symmetry is often used to describe religious buildings. The use of symmetrical patterns in places of worship is common for both aesthetic and theological reasons since they also appeal to our senses. The result of their initial invention then becomes a type of worship, and people who seek it include it in their worship (Gage, 2008). Therefore, the concept of symmetry plays an important role in historical buildings especially places of worship. The concept of symmetry is another very important mathematical concept in places of worship (Gage, 2008).

Third, the researchers found a golden rectangle and a golden triangle in the Gedong Songo temple building. Table 2 and Table 3 show the outcome. The Greek letter Phi (ϕ), which stands for an irrational number roughly equal to 1.6180339887, is typically used to symbolize the Golden Proportion or Golden Ratio (Akhtaruzzaman & Shafie, 2011). In addition to the golden ratio, there are also golden rectangles and golden triangles. Golden rectangle is a rectangle that can be associated with the golden ratio. A unique rectangle whose length to width ratio is exactly equal to the numerical value of phi (ϕ). The result can be seen in Table 2. Clear that the ratio between length and width on Gedong Ilc Temple Bhurloka and Bhuwarloka is approximately close to the value of phi (ϕ). An isosceles triangle is said to be golden if its base and apex have angles of 72° and 36° , respectively, or 36° and 108° , respectively. The result can be seen in Table 3. Clear that the ratio between base and other sides at Gedong Temple IV and V on their Swarloka is approximately close to the value of phi (ϕ) and the angles are approximately close to the angles of golden triangle.

CONCLUSION

Based on the findings and analysis, the writer can conclude that the Javanese people in the 8th century AD had applied various mathematical concepts in building places of worship, one of which was the Gedong Songo Temple. The mathematical concepts applied include the concepts of geometrical shapes, symmetry, periodic patterns, and ratios. We found these concepts in the temple buildings and reliefs. In fact, in some temple buildings found a ratio that is close to the golden ratio. For further research, this research procedure can be used to study ethnomathematics in other temple buildings, especially Buddhist temples. The findings of this study can be used in cultural-based mathematics learning. In addition, further studies on ethnomathematics can be carried out to see more comprehensively the mathematical concepts applied to the structure of the temple building.

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