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An Ethnomathematics Study of Flat-Building Geometry on Traditional Central Javanese Musical Instruments

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ABSTRACT

The purpose of this study is to explore the mathematical elements contained in Central Javanese gamelan musical instruments by applying qualitative research methods and ethnographic approaches. Data were collected through observation, interviews, and documentation, analyzed using Miles and Huberman's model, with validity ensured through triangulation. The findings indicate that Central Javanese gamelan instruments embody various two-dimensional geometric shapes, including squares, rectangles, circles, and isosceles trapezoids, represented across the kethuk kempyang, bonang, peking, gender, saron, kempul, and gambang. The results of ethnomathematical exploration on traditional Central Javanese musical instruments can be applied to mathematics learning, particularly flat or two-dimensional geometry, by providing visual representations of geometric shapes found in Central Javanese gamelan instruments.

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1. Introduction

Mathematics education plays a role in training the ability to think logically, analytically, and critically, so that the next generation of children is better prepared to face obstacles and take advantage of opportunities that exist in the future (Siregar et al., 2024). It can be explained that mathematics is a science derived from human experiences that aims to prepare the younger generation to be able to think

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logically, analytically, and critically. Geometry material is a mathematical subject in education. Students find this subject difficult to learn. This difficulty creates obstacles for students and prospective teachers and math teachers. Students require improved understanding of geometry concepts.

Geometric concepts such as circles, rectangles, squares, and trapezoids can be identified through the forms and arrangements of traditional musical instruments. A circle consists of points equidistant from a fixed center. Its elements include the center, radius, diameter, arc, chord, sector, and segment. According to Nur'aeni & Muharram (2016), a rectangle has four right angles, two pairs of equal parallel sides, and two lines of symmetry.

According to the research by Zaky & Khotimah (2024), a square is a quadrilateral with four sides of equal length and four equal angles of 90° because it forms right angles. A square also has four axes of symmetry and four axes of rotational symmetry. Quoted from Suharjana (2008), an isosceles trapezoid is a trapezoid with two parallel sides and two legs or vertical sides of equal length, and none of its angles are right angles. These geometric forms provide a mathematical perspective for understanding how traditional instruments are constructed and arranged.

Integrating Gamelan-based ethnomathematics media connects abstract geometric concepts with tangible cultural artifacts, enabling students to observe shapes directly and develop deeper mathematical reasoning through engaging contextual learning experiences effectively. In learning two-dimensional geometry, difficulties are still found, including difficulties in understanding basic concepts, challenges in solving or finding a way out of the problem completely, difficulties in applying material from imaginative forms to real objects, obstacles in applying stages to perform mathematical procedures, and incomprehension in solving problems contained in the problem (Ali et al., 2023).

This situation can arise because students do not understand the parts and characteristics of two-dimensional shapes. Students are unable to identify the necessary parts which may be caused by students' inability to visualize the given problem (Sulistiowati, 2022). Therefore, there is a need for activity-based mathematics learning that connects mathematical concepts with students' cultural environment. One approach is ethnomathematics, which integrates mathematics with cultural contexts to make learning more meaningful (Auliya, 2018). Culturally rooted learning is a way of teaching that prioritizes student activities with the many diverse cultural backgrounds they have in society, this method can be incorporated into the process of teaching certain lessons and assessing learning outcomes, can be assessed with a variety of assessments (Sardiyo & Pannen, 2005).

Ethnomathematics is the study of cultural communities, historical heritage in indigenous peoples, and various other things related to mathematics and the process of learning mathematics (Richardo et al., 2020). In addition, ethnomathematics can also be described as a method that is rarely used in mathematical activities by certain community entities and cultural activists

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(Machaba & Dhlamini, 2021). Through play activities, students can apply math learning concepts such as counting the number of tiles in a room, traditional games (engklek, clogs, etc.), in order to facilitate the concept of area measurement (Manurung, 2018). There are many variations of math learning media, such as textbooks, digital materials, math manipulatives, educational software, and various other tools (Nainggolan, 2023).

Based on information from Hadi et al. (2021), there are 1,239 traditions that have been recognized as tangible and intangible cultural heritage from Indonesia. Central Java Province is one that has cultural diversity, one of which is regional musical instruments. There are various traditional musical instruments of Central Java including bonang, saron, gong, gender, demung, kenong, etc. Culturally rooted learning prioritizes student activities based on diverse societal cultural backgrounds (Sardiyo & Pannen, 2005). Educators incorporate this method into specific lesson processes and learning outcome assessments. Previous studies extensively explore general ethnomathematics applications in mathematics education. Existing literature reveals a critical gap regarding the targeted integration of Gamelan instruments into geometry instruction and assessment. This specific study presents the results of an exploration into the spatial mathematical elements of Central Javanese gamelan instruments.

Previous research results mentioned that the traditional musical instrument Kenong can help teachers in applying ethnomathematics in the teaching and learning process in the classroom (Sari et al., 2022). Research by Fajarianty et al. (2022), also showed the results that the musical instrument drums in Javanese gamelan can convey information about mathematical concepts on the curved side of a truncated cone. In research from Mu'asaroh & Noor (2021), it was concluded that the exploration of tambourine musical instruments could be used as a learning resource in learning geometry at school. In addition, based on research by Prastowo et al. (2022), it is stated that the types of traditional gong musical instruments such as kempul, suwukan, and gong can represent mathematical concepts, namely the concept of relations, circle equations, three dimensions in the form of tubes and hemispheres and integral calculus. Based on the results of the research that has been carried out, this research aims to explore the elements of two-dimensional geometry contained in traditional gamelan musical instruments in Central Java.

2. Method

The qualitative method with an ethnographic approach was chosen as the method of this research. The ethnographic research method in this qualitative research involves researchers investigating the culture of a group that can be understood through observation in its natural environment and interviews (Ramdhan, 2021). The data used came from primary sources obtained from observations, interviews and documentation at the studio in Sukoharjo Regency, with five main narrators, namely the puppeteer, trainer, two pengrawit and studio owner. Data validity

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used triangulation techniques and sources. The data from the current investigation were examined utilizing the Miles and Huberman methodology. Data processing procedures are carried out in a way that includes data reduction, data presentation, and conclusion making.

3. Results and Discussion

3.1 Result

Interviews with several informants (dalang, karawitan teachers, pengrawit, and studio owners) provided some information about traditional musical instruments in the Central Java region. Traditional musical instruments originate from a particular region or culture passed down from ancestors or predecessors. Visually, the form has not changed. Traditional musical instruments in the Central Java region are gamelan consisting of saron, demung, slenthem, drum, gong, kenong, xylophone, gender, kempul, bonang, kethuk kempyang. The technique in playing the instrument is by dipithet (held by hand) and hit. If the pithetannya is not good, the resulting sound will echo.

The following information is the result of interviews with a number of informants (dalang, karawitan teachers, pengrawit, and studio owners) about the use of traditional musical instruments in the Central Java region. Traditional musical instruments in Central Java have several uses, one of which is as a traditional or religious ceremony, for example when there is a wedding, then Tayub, and Wayangan. Traditional musical instruments in Central Java, especially in Solo, can be used as a medium for proselytizing to convert to Islam. There are Guntur Madu and Guntur Sari gamelan in the Palace, which were played by Sunan Kalijaga to invite people to come to the mosque. People who want to come and see the gamelan are given conditions by Sunan Kalijaga to read the creed, so that in the past one of the uses of this traditional musical instrument was for religious propagation.

The interview findings reveal several geometric elements in traditional musical instruments from Central Java, particularly circles, semicircles, rectangles, cylinders, and trapezoids. The circular shape is evident in the outer part of the gong and in the diameter of the drum skin. The central part of the gong forms a convex shape resembling a hemisphere, which is also a geometric representation of a curved surface. The rectangular shape appears in the individual wilahan of the saron, demung, peking, and gambang. When several rectangular wilahan are arranged sequentially according to their respective sizes, their overall arrangement forms a trapezoidal pattern. These geometric forms are not merely aesthetic but are closely related to the mathematical calculations used to determine the appropriate dimensions and proportions of the instruments so that the resulting tones are accurate and harmonious.

Furthermore, data regarding geometric elements in traditional Central Javanese musical instruments were obtained from the results of interviews,

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observations, and documentation conducted, with the following results:

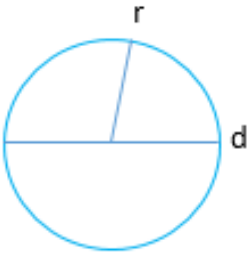
1. Kempul

   In the traditional kempul musical instrument, there is a mathematical element in the form of a circular two-dimensional shape, as shown in Figure 1.



Figure 1. Kempul

Figure 1 can be visualized in the following form:



Circle

This illustration is circular because the kempul has a radius and diameter.

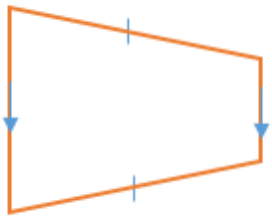
2. Peking

   In traditional peking musical instruments, mathematical elements are found in the form of rectangular two-dimensional shapes and isosceles trapezoids as shown in Figure 2.

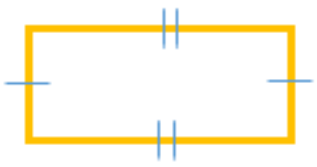


Figure 2. Peking

Figure 2 can be illustrated in the following form:



(1) Iscosceles



(2) Rectangle

The combined peking wilahan illustrated in figure (1) is in the shape of an isosceles trapezoid, as it has parallel sides on the base side, and two equal leg sides. Figure (2) illustrates a rectangular Peking wilahan because it has two opposite sides that are equal in length.

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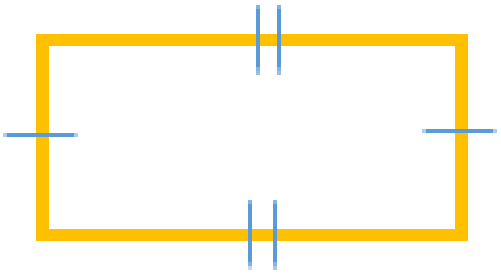
3. Gender

   In traditional gender musical instruments, mathematical elements are found in the form of rectangular two-dimensional shapes as shown in figure 3.



Figure 3. Gender

Figure 3 can be illustrated as follows:



(1) Rectangle

As illustrated in figure (1), a gender wilahan and a row of gender wilahan have a rectangular shape because they have two sides that face each other of equal length.

4. Kethuk Kempyang

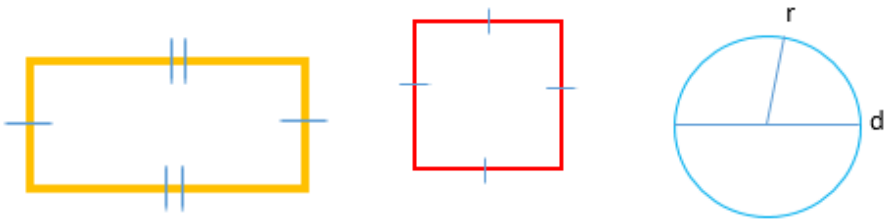
   In the traditional kethuk kempyang musical instrument, mathematical elements are found in the form of square, rectangle, and circle two-dimensional shapes as shown in figure 4.



Figure 4. Kethuk kempyang

Figure 4 can be illustrated as follows:

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(1) Rectangle (2) Square (3) Circle

The box on the kethuk kempyang illustrated in figure (1) is rectangular because it has two sides facing each other of equal length. Figure (2), illustrates the bulkhead on the kethuk kempyang is square because it has 4 sides that are the same length. While figure (3), the illustration of kethuk kempyang is circular because it has a radius and diameter.

5. Gambang

The traditional gambang musical instrument found mathematical elements in the form of rectangular two-dimensional shapes and isosceles trapezoids as shown in figure 5.

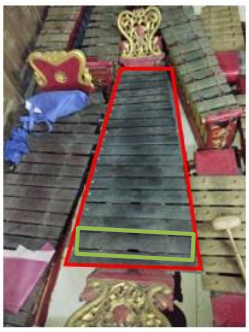
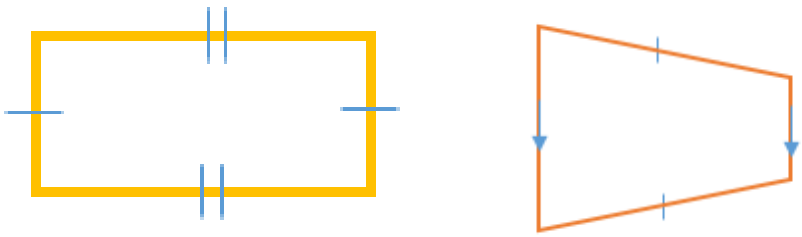


Figure 5. Gambang

Figure 5 can be illustrated as follows:



(1) Rectangle (2) Isosceles trapezoid

The wilahan on the gambang illustrated in figure (1) is rectangular because it has two sides that are opposite each other and of equal length. Meanwhile, figure (2) shows an illustration of a combined wilahan gambang in the shape of an isosceles trapezoid, because it has parallel sides at the base and two sides of equal length.

6. Bonang

In the traditional musical instrument bonang, mathematical elements in the form of two-dimensional shapes such as squares, rectangles, and circles can

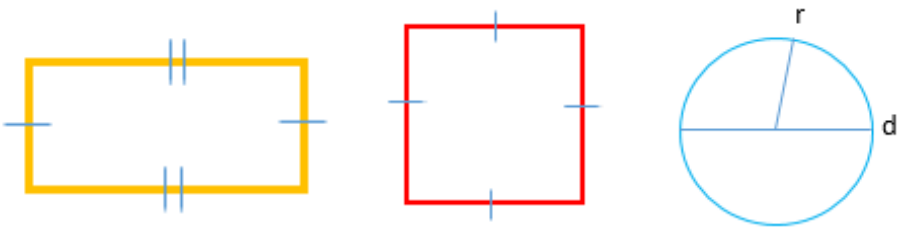
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be found, as shown in figure 6.



Figure 6. Bonang

Figure 6 can be illustrated as follows:



(1) Rectangle (2) Square (3) Cicle

The large bonang box illustrated in figure (1) is rectangular because it has two sides that are the same length. Figure (2) shows a bonang partition that is square because it has four sides that are the same length. Meanwhile, figure (3) shows a bonang that is circular because it has a radius and diameter.

7. Saron

In the traditional musical instrument saron, mathematical elements are found in the form of rectangles and isosceles trapezoids, as shown in figure 7.

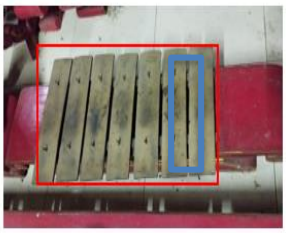


Figure 7. Saron

Figure 7 can be illustrated as follows:



(1) Rectangle (2) Isosceles trapezoid

The saron wilahan illustrated in figure (1) is rectangular because it has two sides that are opposite each other and of equal length. Figure (2) shows a combined illustration of a saron wilahan in the shape of an isosceles trapezoid, because it has parallel sides at the base and two sides of equal

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length.

3.2 Discussion

Based on this research, it can be understood that traditional musical instruments originate from a region or culture that is passed down from generation to generation by ancestor. Traditional musical instruments originate from the term tradition, which is related to customs passed down from ancestors to future generations, according to research conducted by (Salsabil, 2022).

Statements obtained from sources can be seen froms their form; there are mathematical elements in traditional Central Javanese musical instruments, such as the gong. If mathematical elements were not used, the form would be chaotic and irregular, resulting in a sound that would not resonate. In line with the research conducted by Nurzaytun & Susilowati (2025), it is stated that every musical instrument not only functions as an instrument but also reflects the geometric principles embedded in Nusantara culture. The physical forms of instruments such as gongs, saron, bonang, flutes, kendang, kempul, and demung, and their mallets demonstrate the concept of diversity in spatial and two-dimensional shapes.

The findings of this study indicate that the geometric shapes found include squares on the kethuk kempyang and bonang musical instruments, rectangles on the peking, gender, kethuk kempyang, bonang, and saron musical instruments, circles on the kempul, kethuk kempyang, and bonang musical instruments, and isosceles trapezoids on the peking, gambang, and saron. This is in alignment with the perspective of Valda et al. (2022), who state that two-dimensional shapes consist of several types, such as circles, isosceles trapezoids, squares, and rectangles.

Geometry is a branch of mathematics that focuses on shapes, sizes, and spatial relationships. Plane geometry specifically deals with two-dimensional shapes characterized by length and width, such as squares, rectangles, circles, and trapezoid (Zhu et al., 2021). The findings of this ethnomathematical exploration show that these geometric concepts are represented in the physical forms and arrangements of several traditional Central Javanese musical instruments. Squares and rectangles can be observed in several instruments, while circular forms are found in the kempul, kethuk kempyang, and bonang, and isosceles trapezoidal forms are identified in the peking, gambang, and saron.

These findings are relevant to students' difficulties in learning geometry, particularly in visualizing geometric concepts and relating them to real-world objects. The geometric forms identified in gamelan provide concrete visual examples that help students recognize, describe, compare, and analyze shapes. Thus, gamelan can contextualize abstract geometric concepts through tangible cultural objects and support meaningful geometry learning. This finding is consistent with (Sari et al., 2022), who reported that traditional Kenong musical instruments can be utilized by teachers as a context for implementing

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ethnomathematics in mathematics learning. Their findings support the view that traditional musical instruments can function not only as cultural artifacts but also as concrete learning resources through which students can explore mathematical concepts.

The use of gamelan as a learning context also strengthens the application of ethnomathematics in mathematics education. By integrating traditional musical instruments into geometry learning, teachers can present learning activities that connect mathematical concepts with students' cultural surroundings. This approach can make geometry more contextual and meaningful while helping students develop their ability to visualize and apply geometric concepts to real-world objects. Furthermore, Prastowo et al. (2022) demonstrated that traditional gong instruments, including kempul, suwukan, and gong, can represent various mathematical concepts, such as relations, circle equations, three-dimensional shapes including cylinders and hemispheres, and integral calculus. These findings reinforce the present study by demonstrating that traditional musical instruments embody diverse mathematical concepts beyond plane geometry. The identified geometric forms can support culturally relevant mathematics learning materials, enabling students to progress from concrete visual experiences toward abstract concepts while promoting contextual, accessible, and culturally meaningful geometry learning.

4. Conclusions

Central Javanese traditional musical instruments, particularly gamelan, are not only used in traditional ceremonies and cultural activities but also contain mathematical elements that can be identified in their physical forms. The findings of this study show that several gamelan instruments represent two-dimensional geometric shapes, including circles found in the kempul, kethuk kempyang, and bonang; squares in the kethuk kempyang and bonang; rectangles in the peking, gender, kethuk kempyang, bonang, and saron; and isosceles trapezoids in the peking, gambang, and saron. These findings demonstrate that geometric concepts can be observed in cultural objects that are familiar within students' everyday environments.

The identification of these geometric elements has pedagogical implications for mathematics education. Integrating gamelan into geometry learning provides concrete visual contexts that help students recognize, visualize, describe, compare, and relate abstract concepts to real-world objects. This approach supports conceptual understanding, spatial and visualization skills, cultural literacy, and meaningful geometry learning through local cultural heritage.

Author Contributions

Rifa Aulia Ratih was responsible for designing the research, conducting fieldwork including observations and interviews, collecting and analyzing the data, and drafting the manuscript. Rita Pramujiyanti Khotimah provided research

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supervision, contributed to the refinement of the research framework and analysis.

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Declaration of Competing Interest
This study belongs to the author. There is no conflict of interest for this study.

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