Exploring Ethnomathematical Geometry in Indonesian Shadow Puppetry *Gunungan*: Philosophical and Educational Implications

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ABSTRACT

This study delves into the philosophical dimensions of traditional architecture and the ethnomathematical geometry inherent in the mountains of shadow puppets, a significant aspect of Indonesia's cultural heritage. Utilizing a qualitative methodology with an ethnographic design, data were collected through observations and interviews with primary, secondary, and additional informants. The objective of this research is to uncover the mathematical concepts embedded in the mountains of shadow puppets, including geometry, algebra, arithmetic, and statistics, using an ethnographic approach that addresses four principal inquiries: "Where should I begin my investigation?", "How do I proceed with the search?", "How can I identify significant findings?", and "How do I interpret these findings?". The results indicate that among the four mathematical concepts investigated, only geometric concepts are present in the puppet mountains, as validated by a geometer. The geometric sub-concepts identified encompass (1) geometric transformations such as translation and reflection, (2) plane geometry including rhombuses, rectangles, triangles, and circles, and (3) congruence and symmetry. This research holds significant implications for enhancing students' mathematical education by incorporating geometric examples from local cultural contexts. Integrating ethnomathematics into school curricula can expand students' artistic horizons, boost their engagement in learning, and deepen their comprehension of mathematical concepts.

Keywords: ethnography; ethnomathematics; the mountains of shadow puppets

INTRODUCTION

Indonesia is a country rich in cultural heritage, including puppetry. As a traditional art form, puppets have grown and developed throughout history and still exist today because they contain positive values and provide insight through every performance and character it play (Nurcahyo & Yulianto, 2021). The existence of puppets in Java until now shows that the supporting community still favors this art. Puppets, with various types such as purwa puppets, gedhog puppets, chine puppets, beber puppets, and human puppets, each have the characteristics that make them unique. Surakarta's tradition of

considering shadow puppets still has many fans, especially among the older generation. Among the many characters in shadow puppets, the mountain shadow plays an essential role in the opening and closing of the show. It symbolizes starting and ending the event with sacred and traditional nuances. According to Nur Awalin (2019), the sustainability and adaptability of puppets in facing the times shows that this art is not only entertainment but also a medium of education and cultural preservation that is important for Indonesian society.

The Mountains of Shadow Puppets

The performances of the mountains in shadow puppets are essential elements with symbolic meanings and ritual functions in puppetry. The mountains in shadow puppet, according to Rinus (2017), known as "kayon" or "kayonan" is shaped like a mountain depicted with various ornaments and symbols representing the universe. Visually, mountains in shadow puppets are often decorated with images of flora and fauna, temples, and other natural elements that symbolize the balance and harmonization of the universe. In puppet shows, mountains in shadow puppets are used as the opening and closing of the story, marking the beginning and end of a play. It creates a sacred framework that frames the entire narrative and gives structure to the staging.

Symbolically, mountains in shadow puppets represent the macrocosm and microcosm concepts in Javanese belief. The macrocosm is a large universe, while the microcosm is a small universe within humans. The mountains in the shadow puppet unite these two dimensions, showing the close relationship between man and nature (Ian Perasutiyo et al., 2022). In some interpretations, mountains in shadow puppets are also considered a symbol of Mount Mahameru, a sacred mountain believed to be the center of the world in Hindu-Buddhist cosmology. Therefore, mountains in shadow puppets are decorative elements with deep philosophical meaning.

In addition to its symbolic meaning, mountains in shadow puppets also serve as a dramaturgical tool in shadow puppet performances. As the narrator and controller of the story, the puppeteer uses mountains in shadow puppet to set the storyline, set scene changes, and mark key moments in the narrative. When a mountain in shadow puppet is inserted into a puppet screen, it can show a change in atmosphere, a time transition, or a change of place. This function gives the puppeteer flexibility in dynamically and entertainingly conveying the story while maintaining the integrity of the traditional narrative (Purnama et al, 2022).
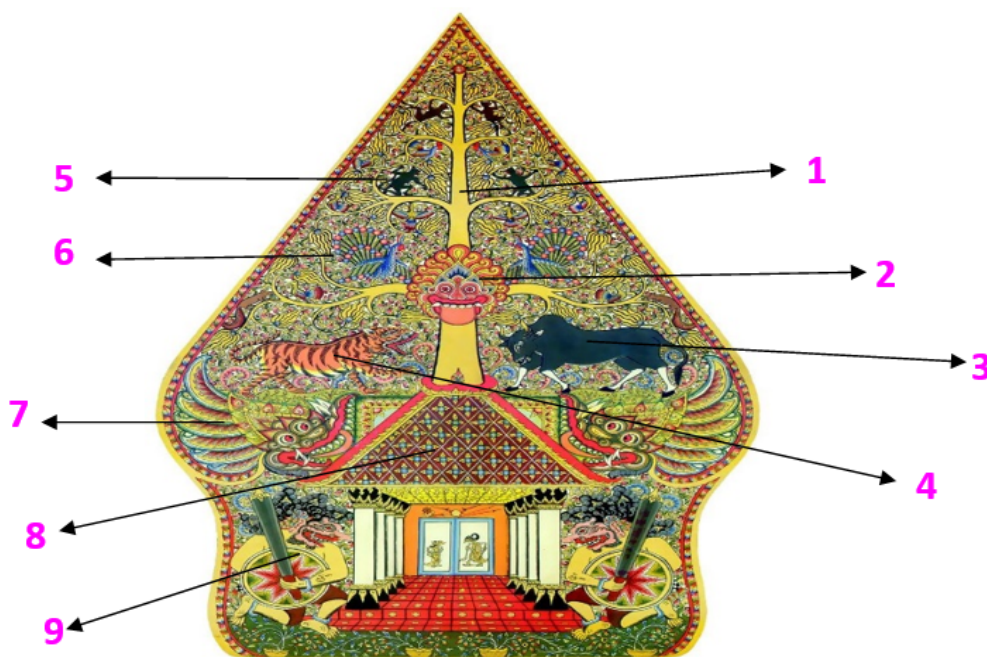
Figure 1. Mountains in Shadow Puppet

Philosophically, the mountain of shadow puppets contains the meaning of virtuous (Loita Aini, 2018). This is in line with information from Ki Hernot Sapari, manager of Saman Hudi Museum Surakarta and a puppet maker in Sondakan, Laweyan, Surakarta. Based on the picture of the mountain and its philosophy is as follows:

1. Kalpataru tree, the tree of life, the tree that gives life to living beings (Sidratul Muntaha)
2. Giant head, symbolizing the trials that lie ahead in the pursuit of perfection in life
3. Buffalo, the epitome of honest, tenacious, rigid and unyielding character
4. Tiger, a symbol of leadership, courage and authority
5. Monkeys, symbolize agility and ingenuity in life
6. Peacocks, symbolize joy and beauty
7. Bledegan or two giants with wide mouths and wings garuda, is a symbol of the ruler of the four passions: mutmainah, supiah, aluamah, marah
8. Joglo House, symbolizes home (country) in which there is a safe, peaceful and happy life
9. Two twin giants, symbolizing the guardians of the dark realm and the light realm (angels Munkar and Nakir)

The mountain of shadow puppets also has a vital role in ceremonies and rituals associated with shadow puppet performances (Muhajirin, 2015). Before the performance begins, the puppeteer usually performs a ritual with mountains to ask for blessings and protection from ancestral spirits and gods. This ritual emphasizes the importance of mountains as a spiritual symbol connecting the human and

supernatural worlds. Through this ritual, the mountain becomes more than just a stage tool; it became a bridge between the physical and metaphysical worlds, strengthening the connection between the performing arts and Javanese spiritual traditions.

Efforts to Preserve Shadow Puppet Culture

As one of Indonesia's most precious cultural heritages, Shadow Puppets has faced significant challenges in this modern era (Nurcahyo & Yulianto, 2021). Various parties have carried out preservation efforts, ranging from the government, cultural communities, to individuals who care about the sustainability of this traditional art. The government, for example, has designated shadow puppets as an Intangible Cultural Heritage and supports holding various festivals and puppet performances in multiple regions. In addition, different educational institutions and cultural communities often hold workshops and seminars to educate the younger generation about the importance of shadow puppets as part of the nation's cultural identity.

The shadow puppets performances as Indonesia's cultural heritage must continue to be developed and created to remain relevant in the modern era (Setiawan, 2020). The puppet artists such as the late Ki Enthus Susmono from Tegal, Central Java, have made various interesting innovations to revive this art. Ki Enthus, who also served as Regent of Tegal, introduced contemporary puppet figures such as Jokowi and Ahok, making the performances more attractive and per the current social context. Through this innovation, shadow puppets not only maintain their existence but also become a dynamic medium and can adapt to socio-cultural changes in society.

However, despite these efforts, shortcomings still need to be corrected to ensure the survival of shadow puppets. One of the main problems is the lack of attention and support from the younger generation who tend to be more interested in pop culture and modern technology. The educational curriculum in formal schools still lacks space for the teaching and practice of shadow puppet art, so knowledge about this art is declining among students. Integrating shadow puppets into art and culture lessons in schools can be essential in introducing and cultivating a love for traditional arts from an early age.

Ethnomathematics In Mountains of Shadow Puppets

According to Maryati & Prahmana (2019) mathematics needs to be designed and integrated in society's culture. According to Ishartono & Ningtyas (2021) Ethnomathematics is a science that studies the relationship between culture and mathematics or mathematics education, aims to contribute to understanding culture from a mathematical point of view and more importantly, as an appreciation for connecting the two. This research uses the ethnomathematical context to explore and uncover mathematical concepts in the mountains of shadow puppets. These concepts can later be used as material

to introduce mountains of shadow puppets as a national culture, and in the context of mathematics learning can be more contextual for students to learn.

From previous studies, there have not been many studies that examine mathematical concepts in shadow puppet mountains. Some studies conducted by (1) Maryati dan Rully Charitas Indra Prahmana (2019) which discusses ethnomathematics in festival activities, (2) Ian Perasutiyo, Arif Muchyidin, Indah Nursuprianah (2022) who learned the mathematical concepts of the Cirebon shadow puppet mountain from the golden ratio aspect, (3) Setiawan (2020) which discusses the philosophy of wayang kulit as a medium of Islamic da'wah that inherits the teachings of Sunan Kalijaga, (4) Purnama, I. M., Wiratomo, Y., & Karim, A. (2022) who studied the concept of geometry in the elements of shadow puppet characters, From some of these studies, no research has been found related to the exploration of mathematical concepts in shadow puppet mountains.

Therefore, conducting studies related to mathematical concepts in shadow puppet mountains is necessary to preserve puppets as a culture in Indonesia. Efforts to protect shadow puppets according to Nyoman Astawan & Ketut Muada (2019) Requires intervention from various parties, one of which is the education sector so that from an early age students are familiar with wayang kulit culture and learn geometry concepts on mountains of shadow puppets. The results of this study can be a reference for teachers in teaching mathematics contextually. Therefore, this study aims to describe the process of exploring mathematical concepts in shadow puppet mountains.

METHOD

The current study is ethnomathematics using an ethnographic approach where four main questions must be answered, namely "where do I start looking for it?", "how do I find it?", "how do I recognize that it has found something significant?", and "How do I understand what it is?" (Maryati & Prahmana, 2019). The research procedures or steps in conducting ethnographic research are in Table 1.

Table 1. Research Design

Initial Questions	Initial Answer	Starting Point	Specific Activities
Where to start looking?	Observation began to analyze the place where there was a mountain of puppets	Culture	Conduct interviews with people who know the mountain of puppets
How do I find it?	Investigate the puppet mountain firsthand	Alternative Thought	Analyze how the mountain of puppets
How to find something meaningful?	Evidence of alternative (thought-provoking) in the process	Philosophy of mathematics	Identify the concept in mathematics
How to understand?	Necessary for cultural preservation and learning of mathematics	Methodological anthropology	Explain the relationship between culture and mathematics Explaining mathematical concepts in Wayang Mountains

The data was collected from March 23, 2024, to June 15, 2024, in various places such as wayang-making places, universities, and wayang museums in Surakarta. The object of this research is the mathematical concepts found in the mountains in shadow puppets. The concepts studied are based on four prominent branches of mathematics: geometry, algebra, arithmetic, and statistics (Rubenstein & Schwartz, 1999). Apart from that, the subject of this research is the puppet mountains.

The type of data in this study is qualitative data consisting of observation, interview, and documentation data. To obtain data, data collection techniques are observation techniques, such as observing mathematical forms/concepts on puppet mountains, semi-structured interview techniques used to strengthen observation data, and documentation techniques to document both the interview process and observed puppet motifs. Specifically for interview techniques, interviews were conducted with two mathematicians (who hold doctoral degrees) from one of the private universities in Indonesia and one puppet-making expert.

In addition to researchers as the primary research instrument, other instruments are also used to obtain the desired data, namely a semi-structured interview design consisting of two points, namely (1) the existence of mathematical concepts in the mountains in shadow puppet and (2) the possibility of whether the mountains in shadow puppet can be used as a context for teaching mathematics (geometry, algebra, arithmetic, and statistics). The data obtained will be processed through three stages: data reduction, data presentation, and conclusion drawing (Sutama et al., 2021). Then, the author analyzes the data based on mathematics and knowledge of wayang mountains to determine the existence of mathematical concepts. Furthermore, experts confirm the analysis results as a form of data validity test (triangulation of data sources).

RESULTS & DISCUSSION

Where do I start looking?

This research begins by discovering who and where the experts are making shadow puppets. He is Ki Hernot Sapari, Saman Hudi Museum Surakarta's manager and a puppet maker in Sondakan, Laweyan, Surakarta. Furthermore, the author conducted an interview with him related to the values and philosophy of the Wayang mountains. In addition, this interview was conducted to see samples from the mountains in shadow puppets and some shadow puppet characters, which were then used as study material. This can be shown in Figure 2.

Figure 2. The interview process with Ki Hernot Sapari

Based on the results of interviews related to the mountains in Shadow Puppet, Gunungan or Kayon comes from the word "kayyun" which contains the myth of "sangkan paraning dumadi", the origin and end of life. There are two kayon types: Kayon Wadon (Yoni symbol) and Kayon Lanang (Linga symbol). Kayon Wadon was then called blumbangan because a lake was painted on the lower front side. The lake contains various types of fish and is the root of the kalpataru tree that rises to the top end of the kayon. This type of mountain is quite fat and has symmetrical paintings on the right and left. This can be shown in Figure 3.

Figure 3. Kayon Wadon (female mountain)

The Kayon Lanang, also known as Gapuran, is distinguished by the depiction of a gate on its lower front side. Flanking the entrance are two twin giants, symbolizing human desires when venturing into the digital realm. Atop the archway sits a kalpataru tree teeming with various monkeys and birds, representing human arrogance. On one of the tree's branches, a tiger faces off against a bull, symbolizing the persistent threat of desires lurking within humans. This mountain has a slightly pointed shape and its painting lacks symmetry. The reverse side of both types of Kayon features red flames and kemamang

(a giant face with its tongue protruding). Alternatively, the painting can be blue, depicting bubbles to represent overflowing water or gusts of wind, as illustrated in Figure 4.

Figure 4. Kayon Lanang (male mountain)

How do I find it?

Of the two types of puppet mountains, the author began to make observations related to what mathematical concepts are contained in the puppet mountains. Then, the author analyzes the relationship between the puppet mountain and mathematical concepts. The author's observations can be seen in Table 2.

**Table 2**. Analysis of Mathematical Concepts

Concept	Concept Existence	Sub Concept	Topics
Geometry	Yes	Geometry Transformation	Reflection
		Plane Geometry	Rhombus
			Triangle
			Rectangle
			Trapezoid
			Circle
		Symmetry	Axis of symmetry
Algebra	No	-	-
Arithmetics	No	-	-
Statistics	No	-	-

How did I know that he had discovered something significant

Based on the results of the author's initial analysis related to mathematical concepts, as shown in Table 2, it was found that of the four mathematical concepts studied, only the concept of Geometry was found. As for the idea of geometry obtained, the author found three subconcepts: geometric transformations consisting of reflections, plane geometry consisting of rhombuses, triangles, rectangles, trapezoids, and circles, and symmetry composed of the axes of symmetry and congruence.

Based on the results of the author's analysis, the sub-concept of geometric transformation in reflection on peacocks, giant heads, joglo roofs, joglo doors, joglo floors, and joglo support poles, which are buildings reflected to the y-axis (symmetry axis). In principle, reflection is one of the forms of geometric transformations in which the mapping of Euclidean space is isometry with the hyperplane as a fixed set of points; this set is called the plane of the reflection axis (Martin, 1982). So, if a point is taken on one side of the house motif, the end has the closest distance to the line of imagination, equal to the distance of the corresponding point on the reverse side. An example of reflection on a mountain can be seen in Figure 5.
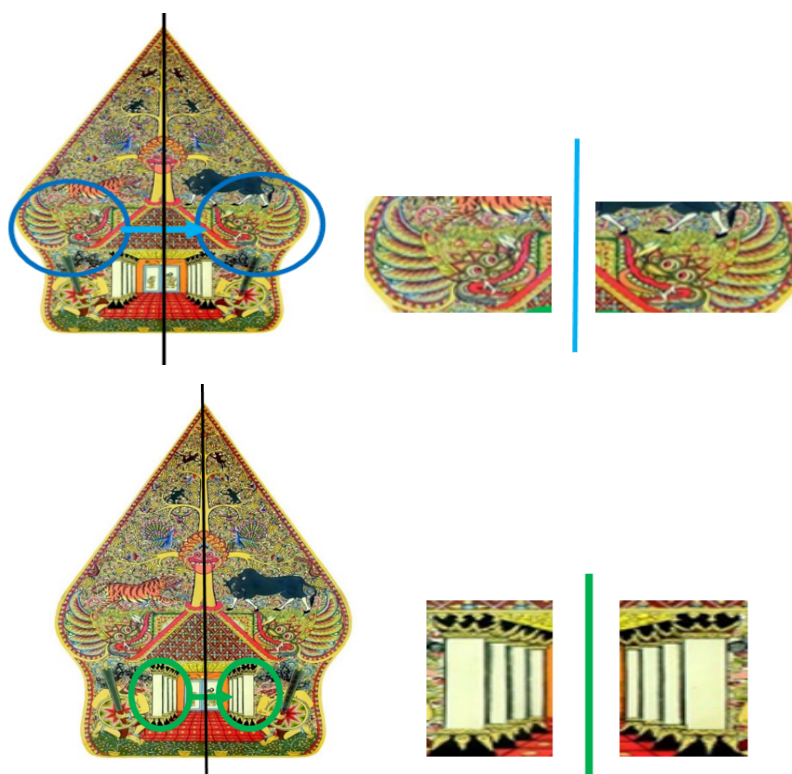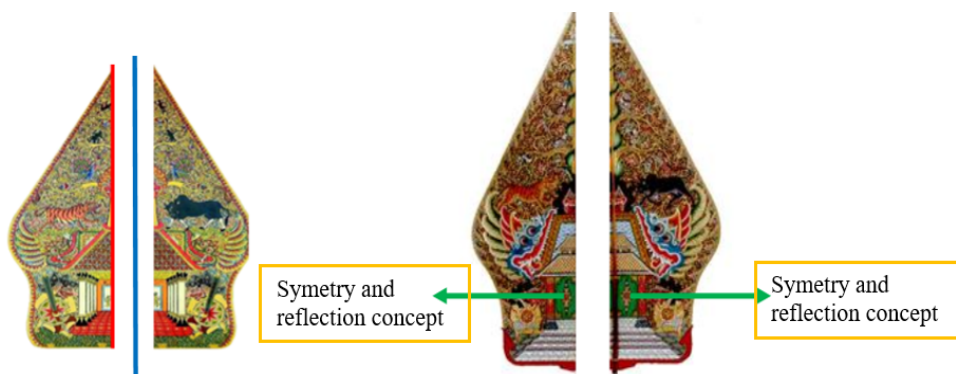

Figure 5. Analysis of reflection sub-concepts

Another geometric concept is plane geometry, where shapes such as triangles, trapezoids, rhombuses, rectangles, and circles are found. A triangle is a polygon consisting of three lines and three angles. We can see this shape at the top of the mountain shadow puppet. An isosceles trapezoid is a trapezoid that has a pair of sides of equal length and a pair of parallel sides. We can see this shape on the roof of a joglo house. A rhombus is a quadrangular hemisphere with two parallel sides. Contained in the roof motif. While the rectangle is rectangular with two pairs of parallel sides and a large corner 90°, we can see it at the door of the joglo house. Next is the definition of a circle as a set of points central to a certain point seen on the giant shield. This can be shown in Figure 6.

Figure 6. Sub-concept analysis of flat plane

The sub-concept of symmetry lies in the shape of a mountain that is cut into two parts, becoming the axis of folding symmetry. Two flat planes are congruent if they have the same corresponding shape and size. This can be seen in the picture of a pair of peacocks, a pair of giant heads, a pair of big guards, and a pair of joglo doors on the roof, poles, and floors. This can be seen in Figure 7.

Figure 7. Sub-concept analysis of symmetry and reflection

In the mountains, there is also a form of flat plane congruence, which occurs when two flat planes have the same corresponding shape and size. This can be seen in the picture of a pair of peacocks, a pair of giant heads, a pair of giant guards, and a pair of joglo doors on the roof, poles, and floors. It can be seen in Figure 8.
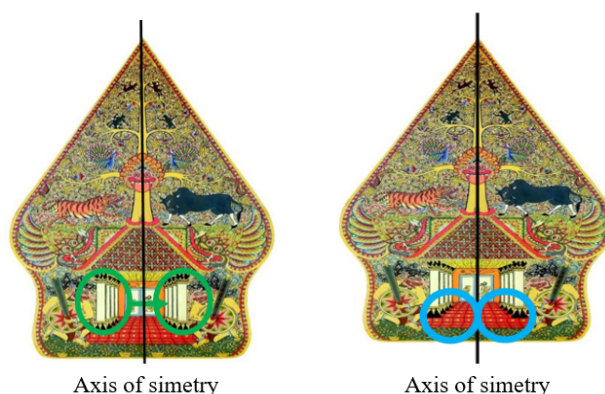
Figure 8. Sub-concept of geometry on congruence topics

How do you understand what it is?

As an effort to test the validity of the data, a process of triangulation of data sources has been carried out by comparing the author's assumptions related to mathematical concepts in the puppet mountains, as shown in Table 2, with the point of view of experts in the field of geometry, algebra, arithmetic, and statistics. The triangulation process is carried out by the walkthrough interview method, where the author communicates directly with experts to compare what the author finds with the opinions of experts (Prahmana & D'Ambrosio, 2020). Two fundamental questions want to be asked to experts related to (1) their perspective on mathematical concepts in the mountain shadow puppets (this is used to ascertain whether they find the same mathematical concepts as the author) and (2) whether the context of mountains shadow puppets can be used in mathematics learning.

The first concept confirmed is the concept of geometry, which is asked directly by a geometry expert. In response to the first question, the expert found the same sub-concept as the authors, namely geometry transformation and plane geometry. However, the member found an additional sub-concept, namely the concept of congruency. This sub-concept is found in all motifs in the batik. One example is the motif of the house/loji, where all the house motifs are the same size and shape. According to the expert analysis, it can happen because making it is done by using a stamp so that the shape and size of the image can be the same and precise, and indirectly, the process applies the concept of image translation. Mathematically, translation is the operation changing the positions of all points(x, y, z) of an object according to the formula$(x, y, z) \rightarrow (x + \Delta x, y + \Delta y, z + \Delta z)$ where(x, y, z) it is the same vector for each point of the object (Smith, 1999).

For the second question, the geometrician believed that the mountain shadow puppets could be used as an essential context to teach mathematics comprehensively. According to him, teachers can employ GeoGebra (a dynamic geometry software to visualize mathematical objects during the learning process of geometry transformation, where the teacher sketches the mountain shadow puppets in GeoGebra (Ishartono et al., 2022). Then, students will be able to transform it geometrically (translation

and reflection) by using GeoGebra. The same condition can be applied to the sub-concept plane geometry and congruency where the students, for instance, analyze the use of the mountain shadow puppets based on the area of the used drawn in the GeoGebra. The use of GeoGebra as a model of using the mountain shadow puppets context in the learning of mathematics can also be found in the previous studies (Lisnani et al., 2020)

The second concept confirmed by the experts is the concept of algebra, which is based on the first and second question points of the interview; the algebraist states that he did not find any algebraic concept that can be excavated on the motif contained in the mountains shadow puppets, so he is not sure if the mountains shadow puppets can be used as a context to teach algebra. This condition is like the results of the authors' confirmation to the arithmetic expert and the statistician. The two experts found nothing that could be unearthed related to arithmetic and statistic concepts. So, since both have typical opinions associated with the second interview question, they are not sure they can use the context of the mountains shadow puppets to teach the concept of arithmetic or statistics. This is in line with D'Ambrosio's (1985) statements that the idea of mathematics in a culture cannot be forced to exist. This means that if indeed a mathematical concept is not found in a cultural product, then the cultural product cannot be forced to be used as a context to teach the concept of mathematics that is not found.

The mountains of shadow puppets can also be described as objects that are a combination of several flat planes so that we can determine the area of each and the area as a whole. Students were asked to recall the formula for triangles, trapezoids, and rectangles. As depicted in Figure 9.
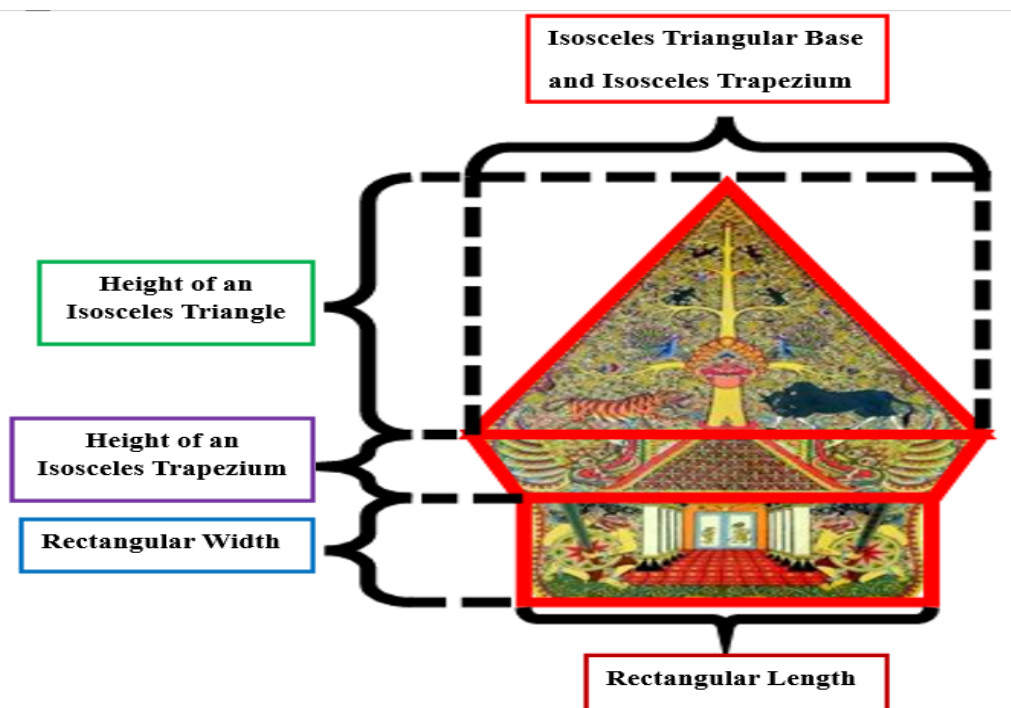

Figure 9. The area concept

An example of a problem as the application of ethnomathematics in the exploration of the mountains of shadow puppets is as follows:

Mr. Slamet is a person who produces puppets made from buffalo skin. It is known that per sheet, the buffalo skin has a width ranging from 100 cm and a length of around 200 cm. It is known that Mr. Seno will make a mountain of shadow puppets with details, as shown in figure 10, when Pak Slamet's order amounted to 10 mountain puppets. How many pieces of buffalo skin do you have to provide Mr. Slamet?
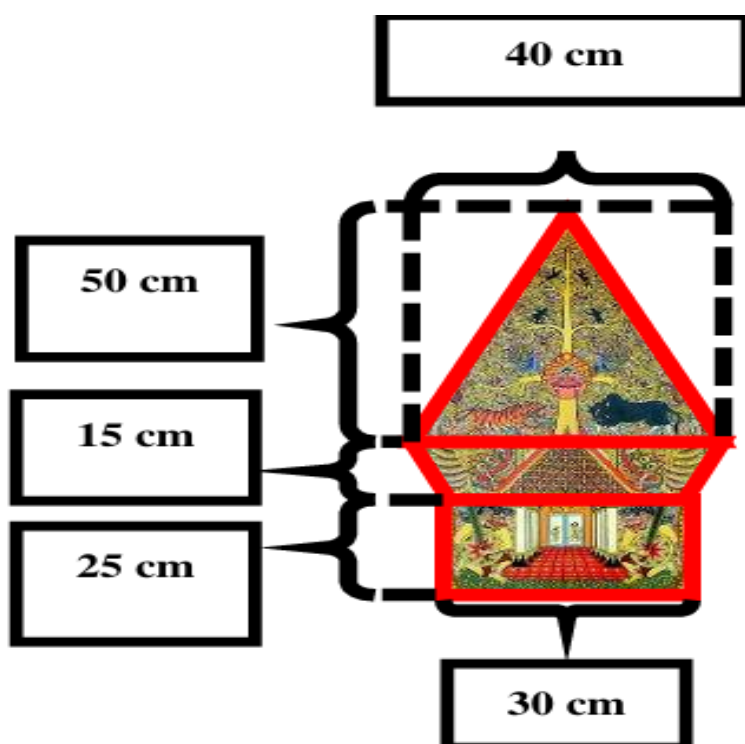
Figure 10. Application of ethnomathematics problems in the mountains of Shadow Puppets

Alternative solution:

Area of triangle $= \frac{1}{2} \times 50 \times 30 = 750 \text{ cm}^2$

Area of trapezium $= \frac{1}{2} \times (40 + 30) \times 50 = 1750 \text{ cm}^2$

Area of rectanguler $= 25 \times 30 = 750 \text{ cm}^2$

Total area $= 750 + 1750 + 750 = 3250 \text{ cm}^2 \times 10 = 32500 \text{ cm}^2$

Available materials $= 100 \times 200 = 20000 \text{ cm}^2$

Additional materials $= 32500 - 20000 = 12500 \text{ cm}^2$. So it takes two sheets

Of course, there is still much to be studied from the results of this study, such as how to apply mountains shadow puppets-based mathematics learning and how effective it is. So, the benefits of this research can have a broader and more comprehensive impact on improving students' understanding of mathematics and promoting mountain shadow puppets simultaneously.

CONCLUSION

To promote the conservation of mountain shadow puppets through mathematics education, researchers must identify the mathematical concepts embedded within them via an ethnomathematical study. This study employed an ethnographic approach to investigate the mathematical concepts in mountain shadow puppets, guided by four key questions: "Where do I start looking?", "How do I find it?" "How do I recognize significant findings?" and "How do I understand what it is?". The research commenced with an examination of puppet makers in Laweyan, Solo, and analyzed the mathematical aspects of the puppets. The findings were subsequently validated by experts to ensure accuracy and deepen understanding. Through this process, the researchers successfully identified that of the four explored mathematical concepts—geometry, algebra, statistics, and arithmetic—only geometric concepts were present and confirmed by a geometry expert. The identified sub-concepts include geometric transformations such as translation and reflection, plane geometry including rhombuses, rectangles, triangles, and circles, and congruence. This study reveals that these geometric concepts can be used to enhance mathematics education from elementary to secondary levels, thus aiding in the conservation of mountain shadow puppets. Future research could focus on testing the effectiveness of integrating mountain shadow puppets-based learning to improve students' mathematical understanding. The conclusions drawn from this research underscore its significance and potential applications, providing a basis for future studies to explore new areas of interest.

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