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Learning the concept of two-dimensional figure through Borobudur artifacts for lower graders of elementary school mathematics

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Abstract

Important changes in mathematics teaching need to be made to accommodate the constantly changing students' demography in the lower grades of Elementary Schools, particularly in mathematics competence. Teachers must contextualize mathematics learning by linking mathematics content to the culture and real-life experiences of low-grade students at the Elementary School level. Mathematical concepts taught in elementary schools shall be relevant with students' personal experiences in everyday life. Throughout history, mathematics has been widely used by different groups in a variety of ways. Arithmetic and geometry are used to meet the daily needs of society, both culturally and socially. Ethnomathematics is defined as the way people from different cultures use mathematics in their daily lives. Elementary school students are only required to learn the concept of simple two-dimensional figure in their mathematics learning. Some complexities in this topic are related to the way to deal with irregular shape of two-dimensional figures or the different length of the sides, which can actually be solved through the removal or addition of the different parts of the shape to resemble the main shape.

Keywords: *Borobudur temple, ethnomathematics, elementary school math, two-dimensional figure area*

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INTRODUCTION

Important changes in the teaching of mathematics need to be made to accommodate the constantly changing demographics of students in the lower grades of elementary school in mathematics competence. Several scholars have developed culturally relevant pedagogical theories that examine the teaching and learning process in a critical paradigm and through the explicit relationship between student's culture and school subject matters (D'Ambrosio, 2013; Gay, 2002; Ladson-Billings, 1995; Rosa & Orey, 2006). In this perspective, it is necessary to integrate the culturally relevant curriculum in the current mathematics curriculum at elementary level. According to Torres-Velasquez and Lobo (2005), this perspective serves as an important component of culturally relevant education because it encourages teachers to contextualize mathematics learning by linking mathematics content to the culture and real-life experiences of lower grade students at the primary school.

The connection between mathematics and everyday life is unavoidable. Mathematical concepts that are interrelated with everyday life are known to provide beneficial functions, including facilitating the buying and selling process, both in the community trading and in large shopping centers shopping. National Council for Teachers of Mathematics (2011) also highlighted the importance of establishing connections between mathematics, personal life, and student culture.

According to this approach, Rosa and Orey (2006) asserted that when practical or culture-based problems are examined in an appropriate social context, the practical mathematics of social groups is n longer something trivial, because students can learn from themes that are closely related to students' daily lives. Culturally relevant primary school mathematics curriculum should focus on the role of mathematics in a sociocultural context involving ideas and concepts related to ethnomathematics, using an ethnomathematical perspective to solve contextual problems (Orey & Rosa, 2008). Therefore, the concept can be applied both in classroom mathematics learning and in the student surroundings or community.

This type of mathematics curriculum at elementary school examines the cultural conformity between student communication and school, which demonstrates the teacher's respect for students' own cultural experiences. According to Zeichner (1996), in order for teachers to apply the principle of cultural conformity, students must have sufficient knowledge and materials on the various cultural and linguistic traditions of students in the classroom. Thus, students must develop a sense of love for their own ethnic and cultural identity to understand and appreciate mathematics as a socially and culturally constructed discipline (Banks, 1991; Danoebroto, 2012; Lee, 2003; Marsigit, 2016). On this basis, teachers need to understand what constitutes mathematical knowledge as well as how this knowledge adequately relates to the local norms and values of cultural diversity. In other words, the integration of cultural diversity in the classroom requires a conceptual framework for teachers to make well-ordered pedagogical decisions, thereby helping elementary school students understand the culture that can influence the assessment on their performance.

According to Kordaki and Potari (1998), mathematical concepts delivered in schools have to do with students' personal experiences in everyday life. Kordaki and Potari (1998) also implied that school practice needs to better focus on integrated orientation. Cultural practice is generally derived from the regional concept of and places with less emphasis on direct calculations and without the use of formulas. Furthermore, Kordaki and Potari (1998) also delineated that most of students are generally inclined to use given formulas in measuring the area of two-dimensional figures, especially for familiar shapes. Therefore, it is very necessary to help them understand about arbitrary or irregular two-dimensional figures and ask them to measure it.

Research in the field of mathematics education often reveals students' poor understanding of the broad topic of two-dimensional figures (Zacharos, 2006). In addition, this poor understanding is not only experienced by students but also by teachers (Baturo & Nason, 1996; Zacharos, 2006). Baturo and Nason (1996) also found that teacher’s knowledge on nature and material about the integration between mathematics, culture, and society has been alarming. Teacher’s perspective seems to be based on widely held assumptions, such as: 1.) Mathematics is primarily a random collection of facts and rules; and 2.) Most mathematical ideas have little or no relation to real objects. Therefore, learning materials on mathematics can only be represented symbolically and that the main learning objective of the area of a two-dimensional figure is to calculate the area of a regular two-dimensional figure.

That said, students merely learn the mathematical concepts of simple two-dimensional figures. For example, the geometry materials of the low graders of elementary school are limited to the introduction of two-dimensional figures, areas, and perimeters of two-dimensional figures. The geometry material of the first graders of elementary school (SD) is only an introduction to simple two-dimensional figures and three-dimensional figures. The geometry material of the second graders is about two-dimensional figures, simple three-dimensional figures, characteristics, and perimeter of two-dimensional figures. The geometry materials provided to third graders of elementary school are related to elements, properties, as well as the area and perimeter of two-dimensional figures (Ministry of Education and Culture of the Republic of Indonesia, 2017).

The area of a two-dimensional figure refers to the size of a two-dimensional part of a clearly demarcated surface, usually an area bounded by a closed curve (Kementerian Pendidikan dan Kebudayaan Republik Indonesia, 2017). In accordance with the definition of the area of the two-dimensional figure, this area is fully covered without any gaps with boundaries at the edges. According to Fauzan (2002), area measurement refers to the number of units needed to cover an area. The area of any two-dimensional figure with an irregular shape or unequal side length is calculated through the transfer or formation of parts of the two-dimensional figure to resemble the main two-dimensional figure. The main two-dimensional figure refers to the two-dimensional figure which serves as the main reference or the origin of the existing two-dimensional figures. In this case, the main two-dimensional figure is a square, and thus the area of the other two-dimensional figures, in this study, is generalized to the area of a square.

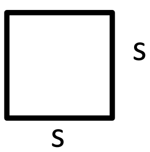
METHOD

This is a descriptive research with an inventory approach, which aims to describe, narrate, and report a situation, object, or event that derived from online sources (internet) and generated documentation without drawing a general conclusion. A descriptive research is designed to make a systematic, factual, and accurate description, depiction, or illustration of the facts, characteristics and relationships between the phenomena understudy. This research covers the following steps: 1.) Selecting topics; 2.) Exploring information; 3.) Determining the research focus; 4.) Collecting data; 5.) Preparing data presentation; and 6.) Reporting preparation. In this study, the data were collected from online sources (internet) and documentation, by way of looking for data about things or variables in the form of notes, books, research papers or articles, and relevant journals. The research instrument in this study is a check-list for the classification of research materials, a schema or a writing plan, and the format of research notes. The data were analyzed by data reduction or data categorization. This analytical method is used as a process of selecting, focusing on simplifying, abstracting, and transforming raw data from written records of online sources (the internet) (Miles & Huberman, 2009). In this analysis, the process of selecting, comparing, combining, and sorting various definitions aims to find relevant information for this research.

RESULTS AND DISCUSSION

The area of any two-dimensional figures with irregular shapes or unequal side lengths is calculated by moving or forming parts of the unequal two-dimensional figures to resemble the main two-dimensional figures. The main two-dimensional figure in this study refers to the mainly referred two-dimensional figure or the origin of the existing two-dimensional figures. In this case, the main two-dimensional figure is a square, while other two-dimensional figures refer to some modifications of the square. That said, the area of other two-dimensional figures is generalized to the area of a square. The ethnomathematical value of the Borobudur Temple, which resembles a two dimensional square is presented in Table 1.

Table 1. Ethnomathematics of the Borobudur Temple, which resembles a square

Sections containing mathematical elements	Aspects of school mathematics to learn
	One part of the wall of Borobudur Temple consists of several shapes that resemble a two-dimensional figure, including a square shape  This two-dimensional figure element can serve as a learning material for the first graders (introduction of two-dimensional figures), the second graders (characteristics of two-dimensional figures), and third graders (elements, properties and area of two-dimensional figures).

A two-dimensional figure with four equal sides is known as a square. In accordance with the concept of area in Table 1, the formula for the area is side x side. Given the equal and regular sides of the sides, the square can serve as the origin of all other two-dimensional figures. This material can be applied to third graders of elementary school (elements, properties, area and perimeter of two-dimensional figures). In subsequence, Table 2 presents the ethnomathematical value of the Borobudur Temple, which resembles a two-dimensional rectangle.

Table 2. Ethnomathematics of the Borobudur Temple, which resembles a rectangle

Sections containing mathematical elements	Aspects of school mathematics to learn
	One part of the walls of the Borobudur Temple consists of several shapes that resemble a two-dimensional rectangle.  The material on this two-dimensional figure is applicable for the first graders (introduction of two-dimensional figures), the second graders (characteristics of two-dimensional figures), and the third graders (elements, properties, and area of two-dimensional figures).

Rectangles have equal sides like squares, but one side is longer than the other. Thus, in essence, the area of a rectangle is almost the same as the area of a square, and thus the formula to calculate the area is almost the same as side x side (Table 2), but is appropriated to: L = length × width = for the longer sides. This material can be applied to the third graders of elementary school (elements, properties, area and perimeter of two-dimensional figures).

A triangle has a base and a height. The base and height of a triangle are equivalent to the sides of a quadrilateral, while the shape of the hypotenuse can be covered by the other hypotenuse, or a line or side can be drawn to form a quadrilateral. Table 3 presents the ethnomathematical value of the Borobudur Temple, which resembles a two-dimensional triangle.

Table 3. Ethnomathematics at the Borobudur Temple which resembles a triangle

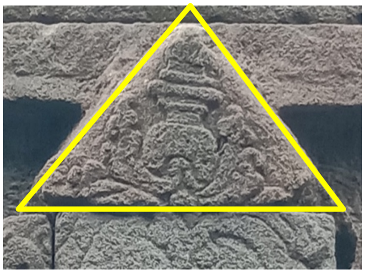
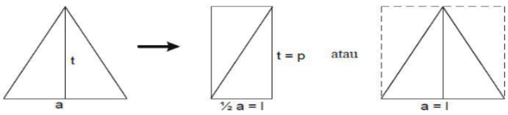
Sections containing mathematical elements	Aspects of school mathematics to learn
	Aspects of school mathematics to learn.  This two-dimensional figure can serve as a learning material applicable for the first graders (introduction of two-dimensional figures), second graders (characteristics of two-dimensional figures), and third graders (elements, properties, and area of two-dimensional figures).

Table 3 indicates that the area of the triangle is half of the area of the quadrilateral. For this reason, the formula is written as A = b x h, meaning that the area of a triangle can also be understood as half of the short side x long side. This material can be applied to elementary school third graders (element, properties, area and perimeter of two-dimensional figures). Figure 1 presents that moving the triangle on the left to the right will turn the parallelogram into a rectangle, so that the area of the parallelogram is: base x height = longer side x shorter side. This parallelogram material can be applied to elementary school third graders (elements, properties, area and perimeter of two-dimensional figures).

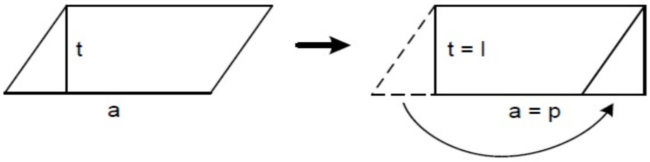


Figure 1. Area of a Parallelogram

A rhombus is a quadrilateral obtained by bringing together the bases of two congruent triangles. This material can be applied to elementary school third graders (elements, properties, and area of two-dimensional figures). The ethnomathematical value of the Borobudur Temple, which resembles a flat rhombus is presented in Table 4.

Table 4. Ethnomathematics of the Borobudur Temple, which resembles a rhombus

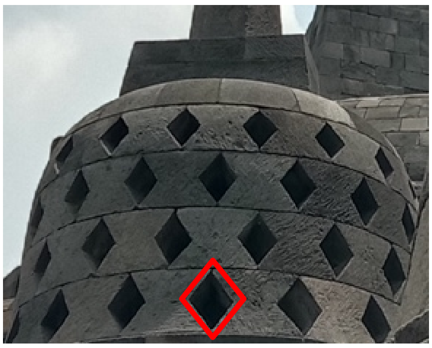
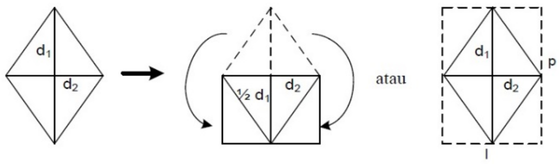
Sections containing mathematical elements	Aspects of school mathematics to learn
	One part of the walls of the Borobudur Temple consists of several shapes that resemble a flat rhombus.  This two-dimensional figure material can be applied to the first graders (introduction of two-dimensional figures), the second graders (characteristics of two-dimensional figures), and the third graders (elements, properties, and area of two-dimensional figures).

Figure 2 denotes that the two-dimensional figure of a kite is half of a quadrilateral, so the formula for the area is: A = ½ x d1 x d2 = ½ × short side x long side. The material of this two-dimensional kite can be applied to elementary school third graders (elements, properties, area and perimeter of two-dimensional figures).

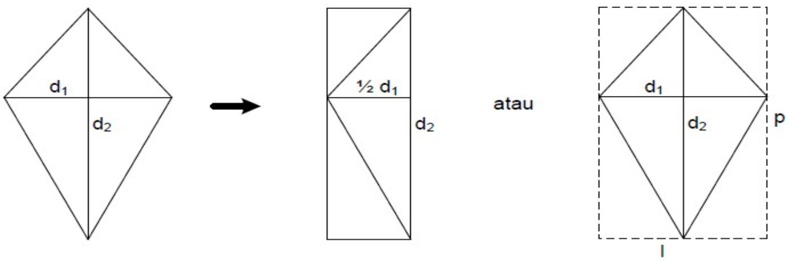


Figure 2. Area of a kite

A trapezoid has two parallel sides, and the formula for its area is: half of the number of parallel sides × high. A = ½ × (a1 + a2) × h. This material on trapezoid can be applied to elementary school third graders (elements, properties, area and perimeter of two-dimensional figures). An explanation of the area of a trapezoid can be seen in Figure 3.

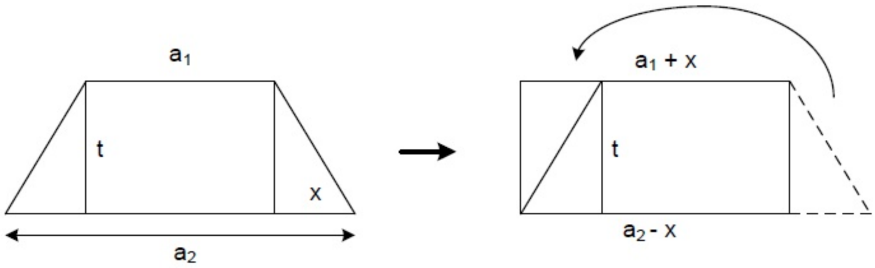


Figure 3. Area of a Trapezoid

Figure 3 illustrates that the triangle on the right side of the trapezoid is moved to the left, which will turn the trapezoid into a rectangle, and thus: the length of the rectangle = $a_1 + x = a_2 - x$. Hence, the formula of a rectangle:

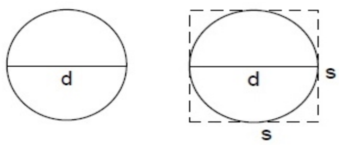
$$P = \frac{(a_1 + x) + (a_2 - x)}{2} = \frac{a_1 + a_2}{2}$$

On this basis, $a = h$ which means that the area of the trapezoid = area of rectangle $\frac{a_1+a_2}{2} \times t = p \times l$.

In other words, it is analogous that the area of a trapezoid = the longer side x the shorter side. This material can be applied to elementary school third graders (elements, properties, area and perimeter of two-dimensional figures). A circle has a curved or circular shape on all its sides, and the formula for its area is = $\pi.r^2$. L = $\pi.r^2$ = ½ . $2\pi.r^2$ = ½ . $2\pi.r.r$ = half × circumference × radius. This material can be applied to elementary school third graders (elements, properties, area and perimeter of two-dimensional figures).

Furthermore, from this circle a rectangular sketch is made. Table 5 presents the ethnomathematical value of the Borobudur Temple, which resembles a two-dimensional circle.

Table 5. Ethnomathematics of the Borobudur Temple, which resembles a circle

Sections containing mathematical elements	Aspects of school mathematics to learn
	One part of the walls of Borobudur Temple consists of several shapes that resemble a two-dimensional circle.  The material of this two-dimensional figure can be applied to the first graders (Introduction to two-dimensional figures), the second graders (characteristics of two-dimensional figures), and the third graders (elements, properties and area of two-dimensional figures).

It clear that the circle is resulted from some changes made on the square. On this basis, the formula for the area of a circle is:

$$L = \pi r^2 = \pi(\frac{1}{2} \times d)^2 = \frac{1}{4} \times \pi \times d \times d = \frac{1}{4} \times \pi \times sisi \times sisi = \frac{1}{4} \times \pi \times Luas\ Persegi$$
$$= 0,7857 \text{ dari Luas Persegi}$$

Thus, these changes result in the area of the missing square of $\frac{4-\pi}{4}$ or = 0.2143 square area. This material can be applied to elementary school third graders (elements, properties, area and perimeter of two-dimensional figures).

CONCLUSION

From this study, it is clear that in general the area of a two dimensional figure refers to the regular two-dimensional figure. In this case, the two dimensional figure is a square with the formula of side × side. Furthermore, the formula for the area of another two-dimensional figure is determined by some modifications from the original shape (square). To calculate the area of a two-dimensional figure that has undergone a change in shape can be done by looking for the trend of the change. The area of the rectangle is A = length x width = longer side x shorter side, the area of the triangle is A = ½ × b× h, the area of the parallelogram is the base × height = longer side × shorter side, the area of the kite is A = ½ . d1 . d2 = ½ × shorter side × longer side, area of trapezoid is A = ½ × (a1 + a2) × h or the longer side × shorter side, $L = \pi r^2 = \pi(\frac{1}{2} \times d)^2 = \frac{1}{4} \times \pi \times d \times d = \frac{1}{4} \times \pi \times sisi \times sisi$.

The area of the two-dimensional figure can be applied and developed to calculate the area of another two-dimensional figure, as well as the area of the three-dimensional figures. Therefore, it is necessary to develop various formulas for the area of two-dimensional figures and the area of three-dimensional figures based on artifacts from the Borobudur Temple that resemble two-dimensional figures and three-dimensional figures. In addition, the artifacts of the Borobudur Temple can also be used to provide learning materials for high-grade elementary school students. The formula for the area of two-dimensional figures and the area of the three-dimensional figures can help students measure some non-intact artifacts of the Borobudur Temple.

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