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Ethnomathematics of Balinese Traditional Houses

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Abstract

The purpose of this research is to explore the Ethnomathematics of Balinese Traditional Houses primarily concerned with Balinese Traditional Carvings and Buildings. The type of this research is exploration. Objects of this research are 3 carvers and 2 builders of Balinese Traditional Houses. Ethnomathematical Data of Balinese Traditional Houses were collected through observations, questionnaires, and interviews. Observations were conducted to obtain data on the application of mathematical ideas on Balinese Traditional Carvings and Buildings while questionnaires were used to obtain data on the profile of research objects and Ethnomathematics. Interviews were conducted to verify data. Furthermore, the research data were analyzed descriptively. The result of this research is a kind of Ethnomathematics about Balinese Traditional House Carvings using a concept of similarity, shift and reflection; and Ethnomathematics of Balinese Traditional Buildings using measurements of *lengkat*, *nyari*, and *rai*.

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1. Introduction

Bali is well known as a tourism destination with the uniqueness of various art-culture. Bali is also known as the Island of the Gods. According to Balinese philosophy, the dynamics of life will be achieved when there is a harmonious relationship between aspects of *Parahyangan*, *Pawongan*, and *Palemahan*. For the construction of a house, it should pay attention to these aspects or called *Tri Hita Karana*. In the housing context, *parahyangan* is meant as a harmonious relationship between occupants of a house and God Almighty; *pawongan* is a harmonious relationship between occupants of a house, and *palemahan* is meant as a harmonious relationship between occupants

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of a house and environment. A Balinese Traditional House has a unique shape and appearance which is filled with carvings or ornaments. The process of building a Balinese Traditional House takes a relatively long time starting from the process of measuring the ground *(nyikut karang), mecaru* ritual, the ritual of cornerstone-laying *(nasarin), the* process of construction, and *melaspas* ceremony. All of these processes have a purpose in order that the built house provides the best benefits both to the owner and its occupants (Figures 1a and 1b). The measurement of construction or layout of the building is based on the rules of *Asta Kosala Kosali* and *Asta Bhumi* (part of Vedas that governs the layout of rooms, buildings, and distances between buildings). The rules of *Asta Kosala Kosali* and *Asta Bhumi* use Balinese Traditional Measurement, i.e. parts of the house owner's body or the oldest person's body in the house, such as *depa, hasta, tapak, alengkat, petang nyari, tampak lima,* etc. (Pulasari *et al.*, 2008; Widana, 2011).

Figure 1a. Balinese Traditional House (Ilman Santoso, 2015)

Figure 1b. Balinese Traditional House

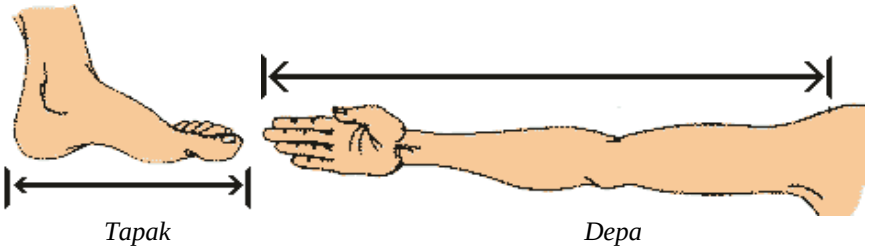

Figure 2. Balinese Traditional Measurements of *Tapak* and *Depa*

Mathematics is used in various aspects of life. Mathematics is close to daily life. In any case, mathematical knowledge is always used. Habits or daily activities are laden with mathematics. The whole system of thoughts, values, morals, norms, and beliefs of human society is culture (Balitbang Puskur, 2010). The term used to associate mathematics and culture is called Ethnomathematics. The term Ethnomathematics was first used in the late 1960s by a Brazilian mathematician, D'Ambrosio, to describe the identification of mathematical practice in cultural groups.

According to Jenni L. Harding-DeKam (2007); François (2010), Ethnomathematics aims to attract cultural experiences and the use of mathematics so as to not only make learning mathematics more meaningful, but also to give students insights that mathematical knowledge is embedded or inherent in social and cultural environments, as well as students could more appreciate the use of mathematics in daily life. Mohammed Waziri Yusuf *et al.*, (2010) found that by using Ethnomathematics game on Hausa culture, mathematics can be learned more easily. Rosa and Orey (2011) found that the implementation of Ethnomathematics in the school's mathematics curriculum helps students to develop their own cognitive abilities, social and emotional attitudes. Studies conducted by Unodiaku (2013) found that the implementation of Ethnomathematics can improve student achievement in learning cylinder volume. Similar studies show that the implementation of Ethnomathematics-based learning can improve student learning achievement (Iluno and Taylor, 2013; Patrick Obere Abiam *et al.*, 2016). Therefore, the main purpose of this research is to explore Ethnomathematics on Balinese Traditional Houses.

2. Materials and Methods

The focus of this research is to obtain information about Ethnomathematics of Balinese Traditional Houses. Therefore, the design of this research is exploration. Objects of this research are 3 carvers and 2 builders of Balinese Traditional Houses. Characteristics of the research objects are male, elementary school graduate, having average 12 years of experience, and the average age of 25 years. Data were collected through observations, questionnaires, and interviews. Observations were made at several Balinese Traditional Houses, using recording and documentation techniques. Questionnaire respondents are Carvers and Builders of Balinese Traditional Houses. Interviews were conducted to complete data and to verify data. Ethnomathematical Data on Balinese Traditional Carvings and Buildings are analyzed descriptively.

3. Results and Discussions

3.1 Ethnomathematics on Balinese Traditional House Carvings.

Balinese Traditional House has a very high aesthetic value. This value results from Balinese carving. Balinese carving becomes one of Balinese Traditional House features. The shape of carving is based on certain motives. The motives are developed based on certain inspirations such as environmental conditions, plants, animals, human activities, etc. One of Balinese carving examples existing on the door of Balinese Traditional Houses is as follows.

Figure 3. Balinese Carving

The results showed that one way to make Balinese carvings is by making sketches of carvings with certain motives. These sketches are usually made with papers. This is supported by the following interview results.

R : In making ornaments, do you carve directly on timber?
O : Depends ..... if easy .. hmm .. it is carved directly on the timber, but if it is a bit hard then I make a molding first.
R : then what else?
O : The molding is affixed to timber, and then carved.
R : What ornaments are popular?
O : *Bun, Goak ,,*

Note:
R = researcher, O = research object

For example, in making Balinese carvings such as in Figure 3a, carvers create motives on sketches of paper that have been folded into two equal parts and carved to get carvings as Figure 3b.

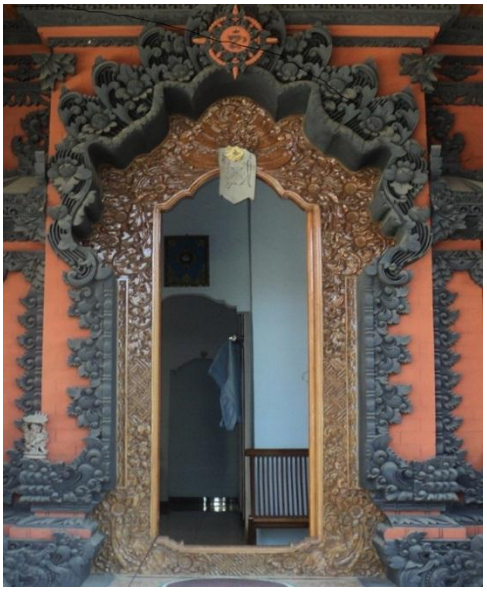

Figure 3a. Balinese Carving

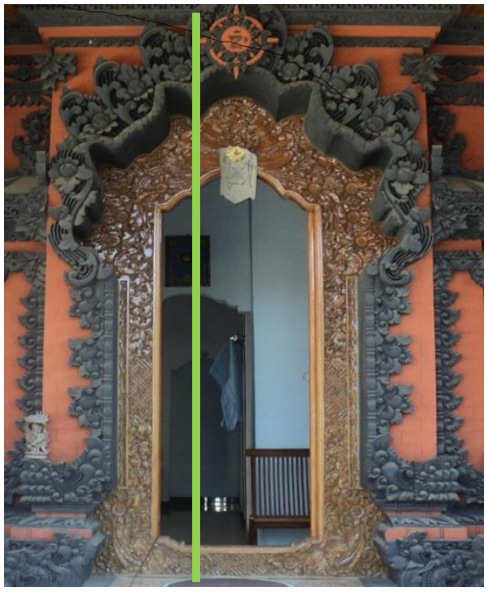

Figure 3b. Bali Carvings with Symmetrical Line

If we look closely, the ornaments or carvings on the Balinese Traditional Houses contain the concept of symmetry. The bold line in Figure 3b shows the symmetry line.

Observations show that one of the ways in which sculptors make patterns. Next, the pattern is shifted sideways so as to get the desired shape.

Figure 4. Balinese Carving Pattern

In the following figure, the shapes b, c, or d are obtained by shifting the shape a.

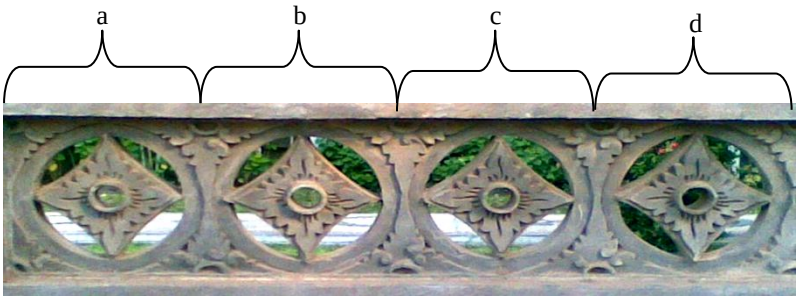

Figure 5. Shift

In accordance with the above explanation, the carvings on Balinese Traditional Houses use Ethnomathematics such as symmetry, shift, etc.

3.2 Ethnomathematics on Balinese Traditional Building

In Balinese Traditional House building, the placement of door or window frames is crucial. The doors and windows of Balinese Traditional Houses are separate and distinct from minimalist or modern houses. Therefore, the installation of door or window frames require special techniques to maintain the aesthetics of the building. The installation of frames begins with measuring the length of the lobby, then determining the midpoint and installing "Axis" with yarn *sepat*-shaped. The door width is measured, and half of the door width is measured to the left and to the right as "Axis" for the door. Next, determining the position of window frames through the same process with the installation of door frames. It is clear that the builders use "Axis" as the same distance between the left and the right borders. In other words, it uses Ethnomathematics of "Axis" or symmetry. If the length of the lobby is d meter, then "Axis" for the door is ½ d. Similarly, for the left or right window axis is ¼ d and ¾ d.

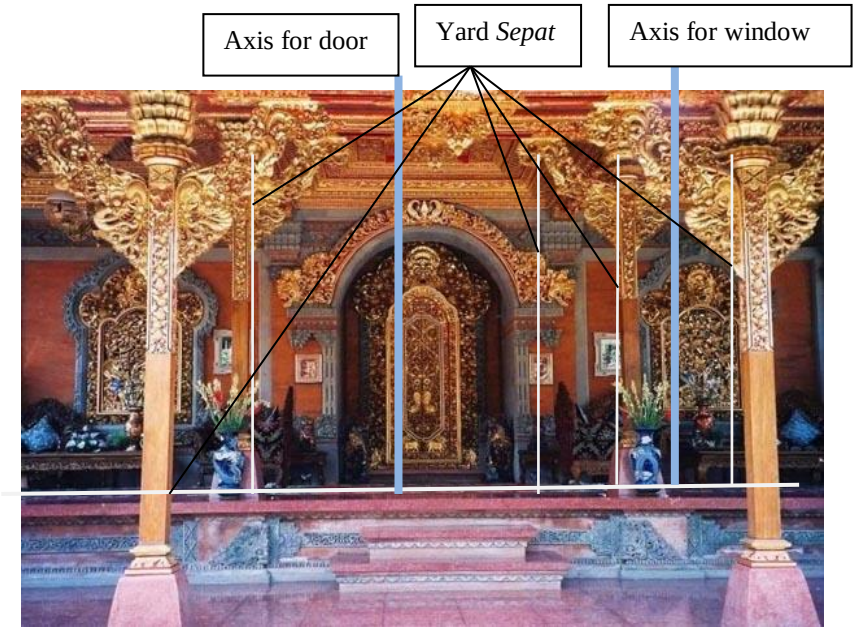

Figure 6. Determining the position of door and windows

In general, the type of Balinese Traditional House that is most frequently made is *seketus* (pillar 8) and *sange* (pillar 9). This process uses the measurements of *nyari*, *rai*, or *lengkat*, aside from using a meter. In addition, it also uses the size of body width (*tuked bangkiyang*) especially for the size of *angkul-angkul* and *instink* (determination of proportion) is used as well. The size of *nyari* and *lengkat* are respectively shown in the following figure.

Figure 7. Balinese Traditional Measurements

Another thing is in making *Saka 1 Rai* calculated 10 cm or 11 cm. When 1 *Rai* shows 10 cm, then the height of *Saka* is made 2,25 m. And if 1 *Rai* is 11 cm then its *Saka* height is 111x 225 = 24,75 m. *Rai* is the width of *Saka*. *Saka* height is adjusted with its width. The most important, it is good to see, for example, 15 times, 20 times, and so on. In the practice of determining *Saka* height, the meter is often used. The height of *Saka* is made about 2,25 m times *Saka* width. As revealed by the research objects, that *Saka* width is called *rai*, then the height of *Saka* is measured about 2,25 m times, and often measured only with the feeling of "good to see".

Balinese Traditional House tends to offer the concept of comfort, sturdiness, and art. In addition, it is adjusted to the owner's wishes. For this concept, it is based on experience and reading books. To maintain harmony in the house, the design uses *Asta Kosala Kosali*, while ornaments that are in great demand are *bun, wayang*, a combination of circle and square. In this process, the concept of symmetry, shift, and rotation is often used. In making this ornament, it can use patterns or without patterns. Using patterns is especially for design ornaments that are rather complicated and long. Patterns are usually photocopied, affixed to timber which is ready to be carved and sculpted. The example of patterns is similar to figure 4 above.

Analysis

The results of this research indicate that Ethnomathematics has grown and developed in Balinese Traditional Houses. The use of *Asta Kosala Kosali* and *Asta Bhumi* concepts in Balinese Traditional Houses still becomes a benchmark. The use of measurements based on body size i.e. *lengkat, nyari, rai* is very dominant in Balinese Traditional House building, especially in making *Saka*. The ratio of *Saka* width and height uses *rai* size in order that the appearance is good looking. The concepts of symmetry, shift, and reflection are widely used in construction and in the ornament shapes of Balinese Carvings. Viewed from formal mathematics, the concepts used in Balinese carving are symmetry, reflection, and translation. The use of body size Ethnomathematics, such as *lengkat, nyari*, and *rai* is considered less practical, so the builders of Balinese Traditional Houses tend to use a meter instrument to measure. To maintain aesthetic proportions is solely by sight, "good" to see. This is supported by the following interview result.

R : What is meant by *rai*?
O : *Rai* is the width of *Saka*. *Saka* height can be 15 times its width. The most important, it is good to see.
S : How about in determining the height of *rai*?
O : No, the meter only.
R : Why do you use a meter?
O : E..e ... It is more common and faster

Ethnomathematics of Balinese Traditional Houses is very interesting for students, as it is related to culture. When Ethnomathematics is brought to class then it can attract students' curiosity. The use of *lengkat, nyari*, and *rai* measurements can be attributed to mathematical material i.e. length measurement. By using these measurements, learning will be more attractive to students because students' *lengkat* are different from each other. The main reason for using Ethnomathematics in mathematics is to reduce the assumption that mathematics has become final and absolute. The followings will describe some of Mathematics learnings that integrate Ethnomathematics.

1) Learning length

Students are introduced or displayed with measurements used by Balinese architectures, namely *lengkat, nyari*, and *rai*. Furthermore, students are required to measure the length of the bench by using these measurements. Some students are asked to report the results of their measurement, and other students give comments. Next, students' bench is measured using a ruler/meter. Students are asked to change the length of meter and centimeter into *lengkat, nyari*, or *rai*, and vice versa. Through teacher guidance, students are expected to find a relation between unit lengths of meters or centimeters.

2) Reflection Learning

Learning the concept of reflection can be done by integrating Ethnomathematics of Balinese Traditional buildings in learning. First of all, students are told to prepare the carving pattern (simple pattern), or provided by the teacher. During learning, students are given an opportunity to make Balinese carvings on a paper using Balinese carving patterns. By using a technique to reflect certain lines, then it can be obtained certain motives.

Furthermore, students are informed that Balinese carving motives can be made by using the concept of reflection. The concept of reflection has been applied on Balinese carving by reflecting so that it results in Balinese carving shadows. Students discuss the distance of shadow with the original shape and size of motives. The expected conclusion is that students find out that getting a shadow has the same shape and size as the original, the distance to the mirror of original motives and shadow is same. With the same way, students can be taught a concept of congruent.

Based on the description above, the characteristics of Ethnomathematics-oriented learning is by giving problems, phenomena, patterns, images, associated with Ethnomathematics. In this case, it is also possible when students create or display an Ethnomathematical model. Ethnomathematics is used as a learning resource for mathematics. Furthermore, students conduct an investigation individually or in pairs related to mathematical ideas existing in Ethnomathematics. The ideas should be established through class discussions or interactions. With teacher guidance, through a process of meaning negotiation that gives students an opportunity to build mathematical knowledge.

4. Conclusion

Mathematics and culture are closely related. Mathematics evolves from culture. Ethnomathematics is a relation between mathematics and culture. In Balinese Traditional Houses, both in carvings used and in the buildings, Ethnomathematics is found namely, the use of similarity, shift, and reflection concepts. This fits perfectly with the formal mathematical concepts of transformation material. In the construction of Balinese Traditional Houses, in determining the size uses *Asta Kosala Kosali* while in determining the location uses the concept of *Asta Bhumi*. These two concepts are the characteristics of Balinese Traditional House buildings. Balinese Traditional measurements used in Balinese Traditional House buildings are *lengkat, nyari,* and *rai.*

Ethnomathematics can be used in classroom learning, both to foster student motivation and as a learning resource in order that students can learn meaningfully. The application of Ethnomathematics in learning provides various benefits, namely (1) to reduce the assumption that mathematics is final, absolute (exact), (2) to illustrate the intellectual development of various cultures, professions, gender, etc., and (3) to help students developing the ability to formulate, apply and interpret various contexts, as well as social and emotional attitudes. Thus, it is recommended (1) for other researchers to explore other forms of Ethnomathematics, and (2) for teachers in order to integrate Ethnomathematics into mathematics learning in the classroom.

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Statement of authorship
The author(s) have a responsibility for the conception and design of the study. The author(s) have approved the final article.

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References

Abiam, P. O., Abonyi, O. S., Ugama, J. O., & Okafor, G. (2015). Effects of Ethnomathematics-based Instructional Approach on Primary School Pupils' Achievement in Geometry. *Journal of Scientific Research & Reports*, *9*(2), 1-15.

Balamurugan, M. (2015). Ethnomathematics; An Approach For Learning Mathematics From Multicultural Perspectives. *International Journal Of Modern Research And Reviews*, 716-720.

Balitbang Puskar. (2010). *Development of Cultural Education and Nation Character.* Jakarta: Kemdiknas

d'Ambrosio, U. (1985). Ethnomathematics and its place in the history and pedagogy of mathematics. *For the learning of Mathematics*, *5*(1), 44-48.

François, K. (2009, January). The role of ethnomathematics within mathematics education. In *Proceedings of CERME* (Vol. 6, pp. 1518-1526).

Harding-DeKam, J. L. (2007). Foundations in ethnomathematics for prospective elementary teachers. *Journal of Mathematics and Culture*, *1*(2).

Iluno, C., & Taylor, J. I. (2013). Ethnomathematics: The key to optimizing learning and teaching of mathematics. *IOSR Journal of Research & Method in Education (IOSR-JRME)*, *3*(1), 53-57.

Pulasari, J. M., Widaryana, J. M. S., Santy, J. M. S., & Artana, J. M. N. (2008). Cakepan Asta Kosala-Kosali lan Asta Bumi.

Rosa, M., & Orey, D. (2011). Ethnomathematics: the cultural aspects of mathematics. *Revista Latinoamericana de Etnomatemática: Perspectivas Socioculturales de la Educación Matemática*, *4*(2), 32-54.

Santoso, I. (2015). Modification of Strapdown Inertial Navigation System Algorithm for Rocket Flight Test. *Journal of Theoretical and Applied Information Technology*, *72*(2).

Unodiaku, S. S. (2013). Effect of ethno-mathematics teaching materials on students' achievement in mathematics in Enugu State. *Journal of Education and Practice*, *4*(23), 70-77.

Widana, I. B. G., & Winarti, N. N. S. (2011). *Dharmaning hasta kosali: arsitektur tradisional Bali*. Dharma Pura.

Yusuf, M. W., Ibrahim Saidu, I., & Halliru, A. (2010). Ethnomathematics (A Mathematical Game in Hausa Culture). *International Journal of Mathematical Science Education*, *3*(1), 36-42.

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