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Ethnophysics: Reconstruction Indigenous Knowledge into Scientific Knowledge in The Brick Making Process

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Abstract

Ethnophysics is a branch of ethnoscience that studies indigenous knowledge to be reconstructed into physical concepts. Indigenous knowledge about the brick-making process was obtained based on experience passed down from generation to generation. This study aims to reconstruct the indigenous knowledge about the brick-making process into scientific knowledge (physics). This study was a descriptive qualitative using an ethnography approach. The subject of this research was three brick craftsmen. The research was conducted in Setiti Village, Muaro Jambi Regency. Observations were carried out to collect data about tools and materials as well as the stages of the brick-making process. Interviews were conducted with brick craftsmen to collect data about the indigenous knowledge of the brick-making process. Indigenous knowledge about making-brick process was analyzed and reconstructed into scientific concepts. The brick-making process consisted of mixing clay, molding, drying in the sun, and burning at high temperatures. The identified physics concepts were a simple machine, pressure, soil, measurement, circular motion, work and energy, temperature, and heat. Indigenous knowledge about making-brick process can be integrated into physics learning at school.

1. INTRODUCTION

Indonesia is a country that has cultural diversity. One of the cultures in Indonesia is the brick-making process (Nuroso et al., 2018). Indigenous knowledge about the brick-making process is obtained based on experience passed down from generation to generation. Evidence that our ancestors know about brick-making is the existence of the Muaro Jambi temple. It is estimated to have been built in 7-12 AD. This temple building made of bricks is called Menapo. Another temple is also found in Pematang Jering Village

Muaro Jambi Regency, which is also made of bricks. The bricks used for building the temple are of very good quality and can last for thousands of years. This shows that the people of Jambi have long been able to master the technique of making bricks.

Bricks are the basic building construction materials made of clay with or without additives through several processes. The process includes mixing clay, molding, drying in the sun, and burning at high temperatures (Fernanda et al., 2012; S. Handayani, 2010). Bricks are widely used for civil engineering applications, such as wall buildings, fences, channels, and foundations (Siska & Teza, 2012). The brick standard in SNI 15-2094-2000 covers several aspects, such as visibility, size and tolerance, compressive strength, harm, density, and water absorption (Fernanda et al., 2012). The brick must have quality requirements, including water absorption, hardness, shape and size, sound, and salt content (Mulyati et al., 2017). Referring to SNI 15 2094-2000, standard sizes for bricks in Indonesia range in length (19-25 cm), width (9-13 cm), and height (5-8 cm). The size of bricks produced mostly in Indonesia is 22 cm x 11 cm x 5 cm. Meanwhile, in Muaro Jambi Regency, the bricks have dimensions of 16.5 x 8.3 x 8.3 cm. It has four holes on the right and left (Suhendra et al., 2015). The brick-making process in Muaro Jambi Regency is different from the existing bricks in ancient times. This difference can be observed in the use of machines in mixing raw materials and molding bricks. However, the process of drying and burning is still fairly traditional. Indigenous knowledge about the making brick process can be part of technoscientific studies.

Ethnoscience is a study that connects local wisdom and scientific concepts (Parmin & Fibriana, 2019). Ethnoscience is divided into ethnophysics, ethnochemistry, ethnobiology, ethnomathematics, and ethnomedicine (Harefa & Renostini, 2017; Lia et al., 2016). The process of making bricks is included in ethnophysics because it involves the concepts, principles, and laws of physics.

The ethnoscience approach is a strategy for creating a learning environment and learning experiences that integrate culture as part of learning science (R. D. Handayani et al., 2018). Learning will also be more meaningful if it is associated with local knowledge and the daily life of students (Khoiri & Sunarno, 2018). Research on local wisdom-based learning has been widely carried out. (Najib, 2018) explains that the process of making roof tiles can be reconstructed into scientific knowledge, which is used as additional teaching material for Integrated Science lessons. (Jufrida et al., 2018) examined the local wisdom of the Merangin geopark which has the potential to be used as a source for learning science at the junior high school level. (Nailiyah et al., 2016) explaine the development of a thematic science module based on the ethnoscience of Jember Regency on the theme of tobacco plant cultivation in junior high school.

Based on the results of previous research, indigenous knowledge about the process of making bricks can also be reconstructed into scientific knowledge that can be used as a source of learning physics and an alternative activity to add insight and knowledge for teachers and students. However, in reality, many teachers still have not utilized local culture as teaching materials in learning physics. Some contributing factors are the difficulty of time in creating teaching materials, the cost of making teaching materials, determining learning materials that are relevant to local culture, and the lack of understanding of teachers about local culture. Even though in its presentation the teaching materials used, students have not used illustrations of the surrounding environment, such as regional culture or local wisdom.

Based on these problems, the solution that can be carried out is an ethnophysics analysis of the brick-making process in Muaro Jambi Regency. This study aims to analyze the physics concepts contained in the brick-making process. The results of this study hopefully can assist teachers in analyzing the science content contained in the brick-making process to serve as the basis for designing local wisdom-based science learning in schools.

2. METHOD

This research was qualitative through ethnography studies. This study was conducted to analyze indigenous knowledge in the process of making bricks and reconstructing it into scientific knowledge in physics. The reconstruction focused on activism and tools used in the manufacturing of bricks. The subjects of this study were three brick craftsmen. The research was conducted at a brick production house in Setiti Village, Muaro Jambi Regency. The criteria of key informants are people who understand the brick-making process in the Muaro Jambi Regency. Data were collected through in-depth interviews, observation, and documentation. Data were analyzed descriptively using the Miles and Huberman model (data collection, reduction, display, and verification). The data analysis process was carried out from the beginning to the end of the study. The data obtained was then verified and reconstructed into a science. Data interpretation was carried out through discussions with competent experts in ethnophysics. The validity test of the data used was the credibility test. The data credibility test was conducted using triangulation through observation, interviews, and documentation on the same object.

3. RESULTS AND DISCUSSION

Brick is an element used in the construction of buildings, such as walls, fences, conduits, and foundations. It is made from clay mixed with sand or other materials, then fired at high temperatures to produce compact and strong bricks (S. Handayani, 2010; Siska & Teza, 2012). The brick strength depends on the density level, mixing ratio, and percentage of water content (Nagathan et al., 2012). The bricks produced in Muaro Jambi have different shapes and sizes compared to other regions. Figure 1 shows the Muaro Jambi bricks with a size of 16.5 x 8.3 x 8.3 cm and has 4 holes. Figure 2 shows bricks produced in other areas with a size of 20 x 10 x 5 cm. It is made using a pressure molding machine to produce solid bricks.

Figure 1. Brick in Muaro Jambi

Figure 2. Brick in other areas

Mixing and molding process

The raw materials for making bricks in Muaro Jambi Regency are soil (clay), water, and sand. According to brick craftsmen, the primary raw materials are clay, water, and sand, which is about 10%. If a large amount of sand mixture is used, it will make the bricks less strong or break easily. However, if it is not mixed with sand, it will shrink in size after being burned. Sandy soils are more profitable because they reduce shrinkage during drying and burning. Clay that is too plastic can cause a lot of shrinkage and deformation (Herlina et al., 2015). The mixing and molding process of bricks in the district of Muara Jambi can be done using machines, as in Figure 3.

Figure 3. Brick Making Processing Machinery

This machine is driven by diesel connected to the V-belt. Raw materials are processed in a cylinder containing a spiral shaft. This spiral shaft functions to grind the raw materials and press the soil into the dispensing funnel so that the machine will continue to rotate (as in Figure 3). The rotation of the machine applies the concept of circular motion. The physical quantities of circular motion include period (*T*), frequency (*f*), angular velocity (ω), angle of travel (θ), and centripetal acceleration (***a***). Circular motion is divided into two parts, Regular Circular Motion and Regularly Changing Circular Motion. Regular circular motion occurs when a moving object has a constant angular velocity (ω). As displayed in Figure 3, the machine has two wheels connected by a rope, as illustrated in Figure 4 and Figure 5. It includes examples of applying regular circular motion.

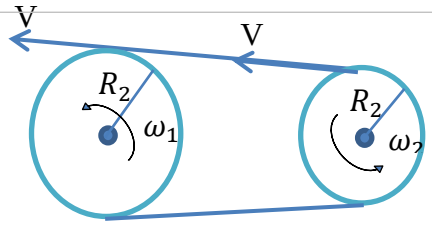

Figure 4. Connect the wheels in circular motion

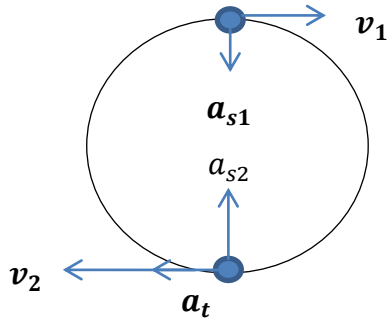

Figure 5. Circular Motion

Meanwhile, regular changing circular motion usually begins with an accelerated regular changing circular motion and ends with slowed circular motion changing regularly. The process of rotating the molen machine in raw material processing includes the application of a circular motion that changes regularly because the rotation rate is not constant.

The process of molding bricks is carried out after the clay is mixed in a continuous rotating molding machine. The dough will then come out of the molding machine in a rectangular shape and four holes. Next, the bricks are cut into pieces with dimensions of 16.5 x 8.3 x 8.3 cm. In this brick molding process, if the same size, volume, and relative

mass are produced, the bricks will be of high value. Scientifically, this local wisdom can be implemented in the physics concepts and the concept of measuring length. In the past, brick-making did not use standard measuring tools and units. It produced bricks of different sizes. This type of brick can be found in the Muaro Jambi temple, which has different sizes. Currently, the molding process is carried out with a machine that has been set to a certain size so that the bricks produced have the same size. The cutting process uses a simple machine made of a wire, as shown in Figure 6. The use of this machine is considered to be more effective and efficient in terms of time.

Figure 6. Brick Cutting

Scientifically, the process of cutting bricks applies the concept of pressure. Pressure is the magnitude of the force acting on an object per unit area. Mathematically it is expressed in equation 1. The cutting tool made of wire is intended so that the applied force can generate higher pressure to cut the clay to produce neat cuts.

$$P = \frac{F}{A} \quad (1)$$

In addition, this cutting tool also applies a simple machine about levers. This tool includes the second type of lever, as illustrated in Figure 7.

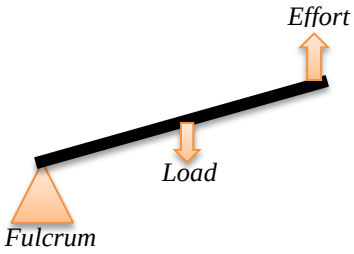

Figure 7. The second type of lever

In levers, the mechanical advantage (MA) can be calculated by comparing the force arm and the load arm. Mathematically expressed by equation 2.

$$MA = \frac{le}{lr} = \frac{w}{F} \quad (2)$$

Le = Arm effort (m)
Lr = Load effort (m)
w = load (N)
F = Force (N)

The printed bricks are transported to the drying area. The process of moving bricks using a handmade lorry is shown in Figure 8. The lorry is an example of a simple machine (second type lever). The process of moving bricks applies the work concept (W). Work is the product of force and displacement. Mathematically expressed by equation 3.

$$W = F \, . \, s \qquad (3)$$

Figure 8. The transporting of bricks

Drying process

According to information from a brick craftsman in Muaro Jambi Regency, the bricks are dried for 2-3 weeks in the sun (Figure 9). Brick drying will be better if it takes place gradually. When it rains, the bricks will be covered using a black tarpaulin so that the bricks do not absorb rainwater. This tarpaulin cover is also used when the sun is too hot, with temperatures > 33°C, because drying bricks at too high a temperature will cause cracks in the bricks. Usually, the craftsmen close the tarpaulin at 11.00-12.00 AM and reopen at 01.00-05.00 PM. The dry bricks have a whitish-brown color and a mass of 2/3 of the weight of the wet bricks.

According to (Mawlood & Abo, 2010), the process of drying bricks is a process of reducing the moisture content in bricks to produce bricks that are ready to be burned. There are two stages: 1) water evaporates on the surface of the brick. The rate of water transport to the brick surface (evaporation) depends on the intensity of the air during drying moving around the brick. The more water evaporates, the faster the water is transported from inside the brick to the surface of the brick. This process is also accompanied by a significant discoloration due to reduced moisture content in the bricks; and 2) second drying, the clay has reached CMC (Critical Moisture Content), which is the lowest water content point where the rate of free water movement from inside the brick to the brick surface with a maximum water evaporation rate from the brick surface. At this stage, the craftsmen must cover the bricks with a tarpaulin to prevent cracking the bricks from direct sunlight, exposure to different heat sources, wind, and anything that causes unbalanced drying.

Figure 9. Brick Drying

Scientifically, the brick drying process involves the concepts of heat transfer and water evaporation. Drying is useful for reducing humidity because of the water content in the brick. However, the shrinkage from this drying process should not exceed 10%. A higher percentage of shrinkage results in cracks at the end of the drying process (Nuroso et al., 2018). The heat from the sun can reach the Earth through a vacuum without an intermediate substance (medium). Heat can be transferred through a vacuum due to heat energy being carried in the form of electromagnetic waves. In general, heat transfer by radiation can be formulated as follows (equation 4):

$$q_{rad} = \sigma e A \, (T_1^4 - T_2^4) \qquad (4)$$

where σ is the Stefan-Boltzmann constant 5,669x10-8 W/m^2, e is the emissivity of the object, A is the surface area, and T is the temperature.

One of the characteristics of dry bricks is by looking at the physical condition of the bricks by changing the color to a whiter and lighter as shown in Figure 10.

Figure 10. Difference between wet brick and dry brick

From the picture above, the bricks at the top of the arrangement have changed color to become whiter. Meanwhile, the lower part of the bricks is still dark, indicating that the bricks are not completely dry. Scientifically, the color of dried clay is influenced by chemically bonded substances/materials in landfills. While the color of clay is affected by substances that contaminate it, namely gray to black color containing charcoal and plant residues, and the red color is caused by iron oxide (Fe) (Zuraida, 2012)(Zuraida, 2012).

Burning process

The burning process is carried out by arranging the bricks to resemble a furnace, as shown in Figure 11. The burning process is carried out for 48 h with the coals always burning. The fuel used is forest wood. Burning is conducted until the bricks are reddish orange. After firing, the bricks are cooled for several days.

Figure 11. Burning process

During the burning process, the bricks are heated with fire. The flame affects the amount of heat received by the brick. The bigger the flame, the greater the heat given by the fire to the bricks. This will result in a greater temperature increase in the brick in the same time interval, so there is a relationship between the heat provided by Q and an increase in temperature ΔT. When the bricks are burned, they are in direct contact with the fire so that the heat transfer process occurs on a conduction basis. Conduction heat transfer, in general, is a process by which heat flows from an area of higher temperature to an area of lower temperature in a medium (solid, liquid, or gas), as shown in Figure 12. In addition, during the burning process, the bricks emit smoke. The movement of smoke is an example of heat transfer by convection. Convection occurs because of differences in fluid velocity when the temperature is different, which will result in differences in density (Tipler, 2004).

The amount of heat flux that moves is directly proportional to the temperature gradient of the object. Mathematically expressed as:

$$\frac{q}{A} \infty \frac{\partial T}{\partial x} \tag{5}$$

By entering the equation constant known as thermal conductivity, the following equation is obtained which is also called Fourier's law regarding heat conduction.

$$q = -kA \frac{\partial T}{\partial x} \tag{6}$$

The minus sign (-) indicates the direction of heat transfer from high temperature to low temperature.

Conduction on flat walls:

If the equation is $q = -kA \frac{\partial T}{\partial x}$ integrated:

$$\int q \partial x = \int kA \partial T \tag{7}$$

will be found:

$$q = -\frac{kA}{\Delta x} (T_2 - T_1) \tag{8}$$

If in a system there is more than one type of material, for example, multi-layered walls (as shown in Figure 12), then the heat flow can be described as follows:

$$q = -\frac{k_1}{\Delta x_1} A\left((T_2 - T_1) = -\frac{k_2}{\Delta x_2} A\left((T_3 - T_2) = -\frac{k_3}{\Delta x_3} A\left((T_4 - T_3\right)\right.\right. \quad (9)$$

$$q = \frac{T_1 - T_4}{\frac{\Delta x_1}{k_1} A + \frac{\Delta x_2}{k_2} A + \frac{\Delta x_3}{k_3} A} \quad (10)$$

The results of the analysis of the physics concepts contained in the brick-making process in Muaro Jambi Regency can be carried out by mapping the basic competencies. The mapping of basic competencies and science content in the brick-making process in Muaro Jambi Regency is shown in Table 1.

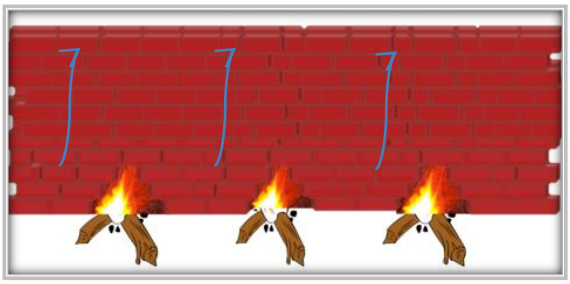

Figure 12. Brick Burning Scheme

Source: Personal Doc

Table 1. Mapping of Basic Competencies and Science Content for Junior High Schools

Basic competencies	Science Content
3.3 Explaining the concept of work, simple machines, and its application in everyday life, including the work of muscles in the human skeletal structure.	Explain the concept of work and simple machines in the process of cutting and transporting bricks using a lorry
3.8 Describe substance pressure and its application in everyday life, including blood pressure, osmosis, and capillarity of transport tissues in plants	Explain the pressure of solids on cutting bricks

Table 2. Mapping of Basic Competencies and Physics Content for Senior High School

Basic competencies	Science Content
3.2 Applying the principles of measuring physical quantities, accuracy, precision, and important figures, as well as scientific notation	Applying the principles of measuring physical quantities, accuracy, precision, important figures, and scientific notation related to the brick sizes
3.3 Analyzing physical quantities of a circular motion at a constant rate (fixed) and its application in everyday life	Analyzing physical quantities in a circular motion at a constant (fixed) rate and its application in brick-making raw material processing machines
3.5 Analyzing the effect of heat and heat transfer which includes the thermal	Analyzing the effect of heat and heat transfer that occurs in the drying

characteristics of a material, capacity, and heat conductivity in everyday life	and burning process of bricks.
3 .9 Analyzing the concept of energy, work, relations work and changes in energy, the law of conservation of energy, and its application in everyday events	Analyzing the business concept of moving bricks using brick-carrying lorries.

Indigenous knowledge about the brick-making process in Muaro Jambi Regency can be reconstructed into scientific knowledge related to physics. The identified physics concepts are simple planes, the pressure of matter, soil and life, measurement, circular motion, effort (work) and energy, temperature, and heat. The results of the reconstruction of public knowledge about the process of making bricks in Muaro Jambi Regency can be integrated into physics science learning.

4. CONCLUSION

Indigenous knowledge about the brick-making process in Muaro Jambi Regency is the knowledge that has been passed down from generation to generation. The bricks in Muaro Jambi have different sizes, namely 16.5 x 8.3 x 8.3 cm, with four holes on the left and right. The process of making bricks consists of mixing clay, molding, drying in the sun, and burning at high temperatures. The mixing and molding processes are carried out using a mixer and pressure molds to produce solid bricks. The drying process in the sun is carried out for 2-3 weeks. The burning process is carried out using a large stove for 24 h. Indigenous knowledge about the brick-making process can be reconstructed into scientific knowledge related to the concept of physics. The physics concepts are identified as simple machines, pressure, soil, measurement, circular motion, work and energy, temperature, and heat. Further researchers are expected to study the development of teaching materials and learning media based on ethnophysics in the brick-making process in Muaro Jambi Regency.

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