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Internalization of Magelang' Local Wisdom in STEM Learning: Analysis of Pottery Making as a Science Learning Resource

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Abstract: The context in science learning needs to be linked contextually and be interdisciplinary so that learning becomes more meaningful. This research aims to analyze the local wisdom of the people of Magelang Regency in making pottery as a science learning resource containing STEM (Science, Technology, Engineering and Mathematics) on temperature and heat. The subjects of this study were pottery artisans in Kragilan, Donorojo, Mertoyudan, Magelang, Central Java. The research design used is descriptive qualitative with data collection techniques in literature and field studies (interviews and documentation). The data in the research is qualitative, namely the results of interviews and identification of local wisdom in making pottery in Magelang Regency, which can be used as a science learning resource with STEM content. In addition, qualitative data analyses local wisdom in making pottery in science learning resources with STEM content on science material. This research shows that local wisdom in making Magelang pottery, especially roof tiles and braziers, is appropriate to the science learning context. The process of making pottery can be internalized in science learning as a science learning resource containing STEM (Science, Technology, Engineering, and Mathematics) for teaching Temperature and Heat material.

Keywords: Pottery; Science learning resource; STEM learning; Temperature and heat material

Introduction

Education is vital to prepare students to face the real world. Therefore, learning must integrate various disciplines, like problems in a complex society. Integrating various concepts in science learning uses a transdisciplinary approach where the boundaries of scientific disciplines no longer appear firmly and clearly because the concepts of scientific disciplines blend and are related to the problems found in their surroundings. These conditions facilitate science learning to be contextual learning. Contextual science learning requires students to know the relationship between learning experiences at school and real life (Wisudawati et al., 2016). Apart from that, learning based on surrounding phenomena can increase student literacy, especially environmental literacy (Kadarisman et al., 2023).

The science learning process emphasizes interaction between students and learning objects directly, so the concept in this learning process is called holistic learning. Many science learning processes, especially at Universitas Tidar, still need to utilize the natural environment as a learning resource, especially the potential learning resources in the surrounding area. Using locally based learning materials and media is still limited to the campus environment and has yet to utilize local potential (Susilo, 2018). Meanwhile, if we refer to Universitas Tidar's vision, namely "To Become a Superior University in the Field of Entrepreneurship Based on Local Resources and Wisdom", then local content learning is study material that contains learning content and processes about local potential and uniqueness which is intended to form students' understanding of excellence and wisdom, especially in Magelang Regency, Central Java.

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In science, contextual learning can be found in the environment around students. The surrounding environment can be used as a science learning resource, because science learning resources can be in the form of textbooks, data, images, the surrounding environment and people which contain information that can be used as a vehicle for students in carrying out the process of changing behavior (Majid, 2012). Natural science learning resources will be meaningful if designed and packaged attractively to make it easier for students and educators to use them (Jalinus et al., 2016). Learning resources are anything that can make it easier for students to obtain information, knowledge, skills and experience in the learning process (Warsita, 2008).

Using the environment as a natural science learning resource can support the learning process in the classroom and is expected to improve the quality of learning in the learning process (Rosita, 2017). In implementing science learning resources, they can be combined using a STEM approach, where the STEM approach can improve student learning outcomes (Chercules et al., 2023; Mailana et al., 2023; Oktavia, 2018). In addition, STEM learning can improve science process skills and motivation to learn science (Maulana et al., 2023), critical thinking skills (Gusman et al., 2023; Lafifa et al., 2023; Putri et al., 2023), and students' generic science skills and creativity (Ratnasari et al., 2023). STEM learning combines mastery of academic and real-world concepts applied in everyday life, where students can become logical thinkers and master technology (Hermansyah, 2020). STEM-based learning can train students to apply their knowledge to create designs as a form of solving environmental problems by utilizing technology (Permanasari, 2016).

STEM learning has been effectively implemented in developed countries but is still relatively new in Indonesia as a developing country (Sari, 2017). The application of the STEM approach by teaching staff has begun to use STEM-based learning resources where these learning resources integrate the values of science, technology, engineering and mathematics (Hidayati et al., 2019). The general aim of learning with a STEM approach is to apply and practice the primary content of STEM in the situations they encounter in life to become STEM literate (Bybee, 2010). STEM learning can be done by applying knowledge in everyday life so that STEM cannot be separated from local values and culture; thus, learning must balance scientific knowledge and the cultivation of scientific values and local wisdom of the community (Almuharomah et al., 2019).

In STEM learning, the process of getting the concepts and substance of the material is science. The use of tools and their simplification is technology and engineering. Meanwhile, the data obtained is analyzed mathematically and obtains mathematical relationships from the concepts studied. Therefore, the technology applied in science learning can be used as a media and resource for science learning, while engineering can be used as an application. Mathematics analyses data to obtain concepts from the science material studied (Sarwanto, 2017).

To meet the needs of students in the 21st century, orientation is needed, and there must be teaching materials that are integrated with local wisdom (Siami et al., 2023). Local wisdom is culture that is made part of knowledge by ancestors. This knowledge is introduced and passed on from generation to generation to adapt to their living environment. Apart from that, local wisdom is also the potential of an area and the result of human thought and human work, which contains wise values and is passed down from generation to generation so that it becomes a characteristic of that area (Khusna et al., 2018). In the education sector, there is a need to integrate local wisdom in learning to make learning more meaningful. Additionally, integrating local wisdom values in learning makes it easier for students to develop ideas and add meaning because they present contextual problems (Parmin et al., 2017). Science educators should be able to utilize local wisdom for science learning to make it more meaningful for students. Utilization of local wisdom helps students understand the learning process through direct observation activities on learning objects (Ilhami et al., 2018). Research on the local wisdom of Yogyakarta's written batik, which contains STEAM aspects in manufacturing, is used as science learning material in junior high schools (Setianingrum et al., 2023).

The local wisdom in Magelang Regency, Central Java Province, is diverse, but only a little local wisdom is still applied and preserved today. The existence of diverse local wisdom in Magelang Regency needs to be explored and utilized in science learning integrated with STEM. Integrating STEM learning resources based on local wisdom can improve conceptual understanding of preservice teacher (Utami et al., 2020).

Based on preliminary studies conducted through interviews with lecturers of the Science Education Study Program at Tidar University, several lecturers have carried out the process of integrating local wisdom into the learning process. Some of the study materials are linked to local wisdom in Magelang Regency. However, integrating local wisdom is only seen from the scientific concepts accompanying it. It causes the understanding of existing local wisdom to be incomplete. This is because educators already know about the STEM approach but have never applied it in the learning process. Educators' awareness of the importance of local wisdom as a source of learning science is also low, so educators still need to link learning resources with local wisdom. On the other hand, most teachers (82%) and students (86%) have yet to use worksheets containing activities to improve Creative Problem Solving skills (Rabbani et al., 2023).

Based on the description of the problems above, namely regarding local wisdom as a learning resource that educators have not applied for science learning, the lack of educators' understanding of local wisdom and its use in science learning, and the lack of introduction and application of STEM in the science learning process. Therefore, it is necessary to overcome existing problems, so research on the analysis of pottery making as study material in STEM learning is carried out. The development of STEM-based PjBL shows extraordinary potential in shaping students' character while improving their academic abilities (Budiarti et al., 2023).

Method

The approach used in this research is qualitative. According to Moleong (2012), qualitative research attempts to present the social world and its perspectives on the world in terms of concepts, behaviour, perceptions and issues about the human being studied. In line with that. Qualitative research intends to understand the phenomenon in a descriptive or general description of what is experienced by research subjects, for example, behaviour, perceptions, motivations, actions and others. In this case, this research will research the process of making pottery in Magelang Regency, which is analyzed based on STEM elements.

The type of this research is descriptive. According to Sugiyono (2012), descriptive research attempts to describe solutions to current problems based on data by meeting face-to-face and interacting directly in the field with the person concerned. What is described in this research is the existence of manual pottery craftsmen in Kragilan, Donorojo, Mertoyudan, Magelang Regency, Central Java. The researcher chose this location because this location is the centre for making pottery in Magelang Regency, and some craftsmen still produce pottery, which is also a data source in this research. The research subject is the party that is the sample or the object the researcher aims to study. At the same time, the object of this research is the existence of pottery crafts in the form of tiles and braziers manually. Data collection techniques in this study were observation, interviews and documentation, with the researcher acting as the key.

Observation and Documentation

Observations and documentation are carried out to support research where only some things can be known just by interviews. Observations were carried out to observe the process of making pottery directly. Meanwhile, documentation is carried out to capture an accurate picture of the pottery-making activity.

Interviews

Interviews were conducted to obtain data directly from pottery artisans. Data obtained about artisans's knowledge in the process of making pottery. The interview instrument is shown in Table 1.

Tabel 1. Instrument for Interviews

No	Questions
1	What materials are used to make pottery? Are there any criteria for these materials?
2	How is pottery made in this village?
3	What products are produced from making this pottery?
4	Is making pottery related to science (physics, chemistry, and biology)?
5	Do you use any special tools when making this pottery?
6	How do you make pottery using these tools?
7	Are there any measurements or calculations carried out when making pottery?

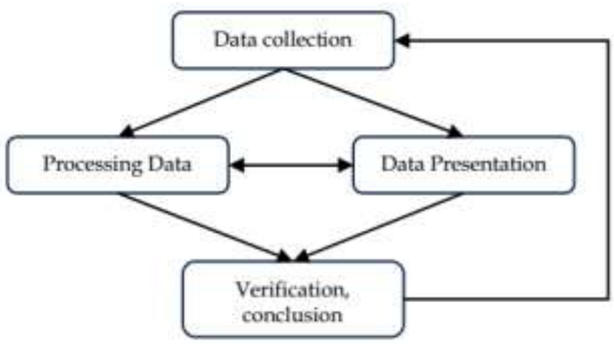

Figure 1. Research flow

Result and Discussion

The results obtained from this study are a study of making pottery in the form of roof tiles and braziers in Mertoyudan District, Magelang Regency. The manufacture of roof tiles and braziers in this district still uses manual presses, which are rotated with human power. In the grinding process, a machine called a selepan is used to smooth the clay mixture so that there are no lumps.

Analysis of the process of making pottery in the form of roof tiles and braziers is as follows. Materials used in making roof tiles and braziers. The materials used in making roof tiles are clay, Javanese soil (topsoil), and peanut oil for greasing the press. The materials used in making the brazier are clay, Javanese soil (topsoil), and water.

Manufacturing process of roof tiles is as follows. The first step is taking clay and Javanese soil from the garden. The clay is mixed with Javanese soil, which is then ground using a *selepan* to become a dough called *jenang bata*. The ground dough is cut into small pieces and then flattened with a beater smeared with peanut oil. The dough is pressed using a press that prints tile shapes. The following print is aerated on the rack. Raw tile is dried in the sun until light brown for one day if it is the dry season or 2 to 3 days if it is the rainy season. The tile is then scraped off the edges to make it look neat. Tiles are fired for 12 hours to burn around 10,000 tiles or 10 hours to burn around 6,000 tiles. Roof tiles are ready to be distributed.

The process of making a brazier is slightly different, as follows. The first step are taking clay and Javanese soil from the garden. The clay is mixed with Javanese soil, which is then ground using a selepan to become a dough called jenang bata. Next, prepare perbot and form the bottom of the circular brazier. Place the moulded bucket on top of the circle shape and forming clay on the side surface of the bucket. Form a brazier in such a way that a brazier has a furnace. The surface is smoothed using a wet cloth during forming. Make a hole in the side surface using a sickle and the mould is then aired. The half-dry brazier is perforated on the top and then scraped to remove the mushrooms so that it looks neat. Raw brazier is dried in the sun until light brown for one day if it is dry season or 2 to 3 days if it is rainy season. The brazier is burned for one day and the brazier is ready to be distributed.

Pottery making is generally still done manually. However, this process keeps the quality of the product produced. Research results show that in both types of handmade or mechanical pottery, it was found that the higher the water content and density, the higher the thermal conductivity value of the pottery (Cabeza-Prieto et al., 2022). The process of making the pottery above, from the preparation to the distribution process, can be analyzed using the following STEM elements.

Science Elements

In the materials used in making roof tiles and braziers, there is a ratio between clay and Javanese soil, namely 1:1. This composition is used so that roof tiles and braziers do not crack when burned or when dried in the sun, which will affect the mechanical properties of the product. This composition is by the results of mechanical testing using hardness and fracture strength tests; the 1:1:1 composition mixture is better due to the homogeneity of each mixed ingredient, so during sintering, a better diffusion process occurs (Sazali, 2011).

In addition, in drying tiles and braziers, which depend on the season, there is a concept of phase changes from the raw materials used. During the hot or dry season, drying is done for one day, while in the rainy season, deep drying takes 2-3 days until the roof tiles and braziers change colour to light brown evenly, which indicates they are dry. In the drying process, there is a change in the phase of the substance, namely from the liquid phase to the gas phase, which is indicated by the process of evaporating the water content in the roof tiles and braziers until they dry out.

The combustion process between tiles and brazier manufacture is slightly different. The burning of tiles depends on the number of tiles to be burned. Burning 10,000 roof tiles takes around 12 hours with a stable fire. Meanwhile, 6000 roof tiles take around 10 hours. Meanwhile, burning the brazier takes one day. The burning duration is related to the mass of the object being burned. The greater the mass of the object being burned, the greater the amount of heat required (Giancoli, 2001). The greater the heat required is indicated by the longer burning time. Apart from that, an open thermodynamic system includes the process of burning roof tiles and braziers. No real boundary separates the system and the environment so that they can interact freely. The heat transfer occurs from the fire at a high temperature to the roof tiles and brazier at a low temperature.

Technological Elements

The technological elements used in making roof tiles and braziers are related to the facilities used to simplify the process of making pottery manually. The technological elements in making roof tiles are as follows.

Tile Press Tool

The working principle of this tool is to apply firm pressure to the raw material so that the cross-section is compressed and produces a roof tile shape according to the installed mould. The technology is based on the load used to assist the roof tile printing process.

Figure 2. Tile press tool

Selepan

The working principle of this tool is to grind and smooth the soil mixture, so there are no lumps. This tool is used both in making roof tiles and making braziers.

The technological element in making a brazier beside the selepan is Perbot. The working principle of this tool is to control and shape raw materials from all directions. The research results show that technology is indeed the root of the sustainability of pottery (Haron et al., 2013).

Figure 3. Selepan

Figure 4. Perbot

Engineering Elements

The resulting design of the tile and brazier can be used as an engineering element studied in the STEM aspect. The design of the resulting pottery is shown in Figure 5.

Figure 5. Pottery produced by Magelang Regency (left: tile, right: brazier)

Roof tiles are made according to the most common shape, namely rectangular. Roof tiles must be made waterproof because they protect the building from rain. Therefore, when making roof tiles in Magelang Regency, they are coated with peanut oil so that the quality of the tiles is good.

Meanwhile, the design of the brazier creates a space at the bottom to accommodate the ash remaining from burning fuel (charcoal). At the top of the brazier is a protrusion for placing a pot, steamer or pan. The brazier can also be used as a burning tool so that a stove is placed at the top.

Mathematical Elements

The mathematical elements involved in making roof tiles and braziers are as follows. Calculate the ratio between Javanese soil and clay in making roof tiles and braziers so that they do not crack when burned or dried in the sun. The ratio between clay and Javanese soil is 1:1. The drying process is carried out depending on the season. During the hot or dry season, drying is done for one day, while in the rainy season, deep drying takes 2-3 days until the roof tiles and braziers change colour to light brown evenly, which indicates they are dry. The tile-burning process depends on the number of tiles to be burned. Burning 10,000 tiles takes about 12 hours with a steady fire. Whereas for 6000 tiles, it takes about 10 hours. In contrast, the brazier burning process takes one day. This time can be converted as a ratio of the heat required during the combustion process.

In the process of firing pottery, the energy involved includes the heat energy required to heat the tiles and braziers, the chemical energy contained in the fuel used, and the thermal energy transferred between the pottery, the fuel and the surrounding environment.

In order to optimize temperature, time, and energy requirements, using mathematical formulas and methods is very important. We can analyze the earthenware firing system in more detail through mathematical modelling. For example, the heat transfer equation can calculate the heat transfer rate between the earthenware and the surrounding air. This formula involves temperature, surface area, heat transfer coefficient, and the temperature difference between the earthenware and the air.

$$Q = m.c.\Delta t \quad (1)$$

If m is bigger, then Q is also more significant; if t is bigger, Q is getting bigger, and if c is getting bigger, Q is also getting bigger. In these equations, they are directly proportional to each other. The more pottery burned, the greater the energy required is also more significant, so more wood is also needed. This is based on de la Ochoa et al. (2023) research, which states that the results must be proportional to the number of calories transferred to the combustion chamber.

The firing time for pottery can be affected by various factors, including firing temperature, humidity, size and thickness of the pottery, and the type of fuel used. The higher the firing temperature, the faster the water in the pottery will evaporate, and the pottery will be cooked. However, a burning temperature that is too high can cause the pottery to break or crack. Therefore, setting the right temperature and burning time is necessary to achieve optimal results.

The analysis of the process of making pottery in the form of roof tiles and braziers in the STEM study above can be used as study material in science learning. The concept corresponding to the manufacturing process relates to temperature and heat.

Conclusion

The research results show that local wisdom in the process of making Magelang pottery, especially roof tiles and braziers, is appropriate to the science learning context. The process of making pottery can be internalized in science learning as a science learning resource containing STEM (Science, Technology, Engineering, and Mathematics) for teaching Temperature and Heat material.

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Author Contributions

Conceptualization, E.T.; methodology, E.T.; validation, B.S., S.,W.; formal analysis, E.T.; investigation, E.T.; resources, B.S, E.T., S., W.; data curation, W.; writing-original draft preparation, E.T.; writing-review and editing, B.S., W.; visualization, E.T. All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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