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Exploring the Geometric Principles of Javanese Tajug Houses: Enhancing Mathematics Education through Indonesian Cultural Heritage

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ABSTRACT

Many ethnomathematical studies focus on Indonesian culture, particularly traditional dwellings, although research into the mathematical notions of the Tajug House is sparse. There has been no previous research that examines the Tajug House form the aspect of geometry. Tajug houses are becoming increasingly rare. Nowadays students are less familiar with traditional house types. As a result, this study investigates the mathematical principles found in traditional Tajug houses in Java, and how these notions might be integrated into educational curriculum to conserve cultural heritage while also improving mathematics learning. This study used an ethnographic approach, to investigates the Tajug House's design through a literature review, expert interviews, and observations. The data obtained were analyzed based on mathematical and Tajug House knowledge by author to see the existence of mathematical concepts in the tajug house. The findings reveal significant geometric concepts, including plane geometry (square, triangle, trapezoid), solid geometry (cuboid), and geometric transformations (reflection). Square found in the base of the house, triangle found in the side of the roof, and trapezoid found in the base of pillar. Cuboid found in the pillar. Reflection found in the base of the house. These results suggest that Tajug Houses can effectively become one of the learning media to geometry subject in schools, demonstrating practical ethnomathematics applications. The learning process can utilize the GeoGebra application. By linking cultural heritage with mathematical education, this research promotes a deeper understanding of both subjects. Future studies should evaluate the effectiveness of Tajug House-based learning in improving students' math comprehension and cultural appreciation.

Keywords: *cultural heritage, ethnomathematics, geometric concepts, Tajug House, traditional Javanese architecture*

ABSTRAK

Banyak studi etnomatematika yang membahas budaya Indonesia, terutama rumah tradisional, meskipun penelitian tentang konsep matematika Rumah Tajug masih terbatas. Keberadaan Rumah Tajug semakin jarang ditemui. Siswa kurang mengenal jenis-jenis rumah tradisional. Oleh karena itu, studi ini menyelidiki prinsip-prinsip matematika dalam rumah tradisional Tajug di Jawa, serta mengintegrasikan konsep-konsep ke dalam kurikulum pendidikan untuk melestarikan warisan budaya sekaligus meningkatkan pembelajaran matematika. Menggunakan pendekatan etnografi, penelitian ini mengeksplorasi desain Rumah Tajug melalui tinjauan literatur, wawancara dengan pakar, dan observasi. Data yang diperoleh dianalisis berdasarkan pengetahuan matematika dan Rumah Tajug oleh penulis untuk melihat keberadaan konsep matematika di rumah tajug. Temuan tersebut mengungkap konsep geometri yang signifikan, termasuk geometri bidang (persegi, segitiga, trapesium), geometri ruang (balok), dan transformasi geometri (refleksi). Bentuk persegi dapat ditemukan pada lantai dasar rumah, bentuk segitiga dapat ditemukan pada sisi atap rumah, dan bentuk trapesium dapat ditemukan pada sisi alas tiang penyangga rumah. Bentuk balok dapat ditemukan pada tiang rumah. Refleksi dapat ditemukan pada bentuk lantai rumah. Hasil ini menunjukkan bahwa Rumah Tajug secara efektif dapat menjadi salah satu media pembelajaran untuk mata pelajaran geometri di sekolah, yang menunjukkan aplikasi etnomatematika yang praktis. Proses pembelajaran dapat memanfaatkan aplikasi geogebra. Dengan menghubungkan warisan budaya dengan pendidikan matematika, penelitian ini mendorong pemahaman yang lebih dalam tentang kedua subyek tersebut. Penelitian di masa mendatang sebaiknya mengevaluasi efektivitas pembelajaran berbasis Rumah Tajug dalam meningkatkan pemahaman matematika dan apresiasi budaya siswa.

Kata Kunci: warisan budaya, etnomatematika, konsep geometris, rumah Tajug, arsitektur tradisional Jawa

INTRODUCTION

Indonesia is home to 37 varieties of traditional houses which representing 1,340 tribes in the country (Indonesian Government, 2017; Oey, 2022). Among them, the Javanese tribe stands out for its distinctive traditional house styles where one of which is Tajug House (Wijaya & Purwanto, 2017; Yuningsih et al., 2021). The Tajug House, a rare traditional building in Java, stands out for its sacredness, which is expressed in the vertical lines on its roof (Pitana, 2024). These lines represent the heavenly realm, virtue, and majesty (Yuliyani, 2023). Compared to other traditional house designs, the Tajug House has the strongest vertical axis (Ilham & Sotyan, 2012). Given the importance of the design of Tajug House as the identity of the Indonesian nation, and the erosion of the value of cultural literacy for young people today (Manurung et al., 2022), then The Tajug House's design must be preserved, and one method to do so is to make it available to the public as soon as possible (Sardjono, 2022).

Understanding of traditional houses can be introduced to students through mathematics learning activities. The structure, shape, and components of traditional houses can be used as relevant learning media, especially in geometry material in schools. For example, students can learn concepts such as symmetry, spatial shapes, and measurement by observing or analyzing parts of traditional houses. In addition, the integration of traditional houses in mathematics learning can also introduce local cultural values, increase students' awareness of Indonesia's cultural richness, and make learning more contextual and meaningful (Liaupati et al., 2022; Wangsa et al., 2024).

During the hegemony of residential dwellings in Indonesia, which has been significantly impacted by Western culture, the Tajug House (see Figure 1) was one of the forms of Javanese houses that are now rarely utilized by Indonesians (Cahyono et al., 2017; Yusran et al., 2019). Several prior research results suggest that architecturally, the Tajug home style offers significant functions such as earthquake protection, effective air circulation, energy efficiency, and simple adaptation to the weather, especially in the Java Island region (Al-Amin, 2021). It is equally important to recognize that the Tajug House form is a symbol of Indonesian culture, particularly the Javanese people, and should be maintained. As a result, attempts to conserve the culture of the Tajug House model must be combined with efforts to ensure the sustainability of Indonesian traditional house design culture and to increase the cultural literacy of the Indonesian generation. One of the efforts that may be done to maintain the sustainability of Tajug House design culture is through the realm of education, where the design can be introduced as early as feasible at the school level (Ishartono & Ningtyas, 2021).

Figure 1. Tajug House
(Source: https://buku.kompas.com/read/3294/5-macam-rumah-adat-jawa-tengah-yang-unik-dan-kaya-akan-makna#google_vignette)

When looking closely at the design of Tajug House in Figure 1, the geometric feature stands out the most. As a result, mathematics may be utilized as the foundation for imparting Tajug House's design culture, with geometry being one of the disciplines covered. However, based on the authors' observations of mathematics textbooks used by primary and high school levels in Java, Indonesia, have not used Tajug House's context to illustrate geometry ideas. To support this aim, learning tools or modules based on the context of Tajug House are required. For this reason, it is vital to investigate the mathematical factors in the design of Tajug House. As a result, it is critical to investigate mathematical issues in the design of Tajug House. The ethnomathematical research paradigm enables extensive and in-depth inquiry, which may then be used to construct these learning tools.

D'Ambrosio, a prominent Brazilian mathematician, is credited with introducing the concept of ethnomathematics. This term encompasses the diverse ways in which different cultures comprehend, develop, and apply mathematical concepts in their everyday lives (Shinta Mifta Repiyan, Isnaeni Umi Machromah, Nuqthy Faiziyah, 2023). D'Ambrosio emphasizes that ethnomathematics extends beyond traditional calculations or measurements, encompassing art, architecture, games, and navigation, all of which incorporate mathematical elements. This approach seeks to acknowledge and celebrate the variety of mathematical thinking and practices worldwide,

highlighting the fact that mathematics is an intrinsic part of human culture (Umbara et al., 2021). D'Ambrosio asserts that ethnomathematics provides a more comprehensive and inclusive perspective for understanding and teaching mathematics, recognizing the wealth of mathematical knowledge stemming from various ethnic and cultural groups (Ishartono & Ningtyas, 2021).

Several previous studies have delved into the mathematical principles present in traditional house designs. For instance, (Faiziyah et al., 2024) explored the mathematical aspects of traditional joglo houses, while (Sri Wahyuni et al., 2023) focused on the traditional Tongkonan Houses of Tana Toraja, Indonesia. Additionally, (Sari et al., 2022) introduced the concept of geometry in traditional tanean-houses in Madura, and (Nurhasanah & Puspitasari, 2022) discussed the application of geometry in Kampung Pulo traditional houses in Garut, Indonesia. However, no attempts have been made to investigate mathematical topics at Tajug House. This investigation is necessary because the traditional value inherent in the House must be conserved, and the findings of this study may assist Indonesian mathematics teachers in contextualizing the notion of geometry during the mathematics teaching-learning process. Therefore, the primary objective of this research is to investigate Javanese traditional houses, particularly Tajug Houses, and to outline the mathematical principles inherent in these structures.

METHOD

In this research, an ethnographic approach is utilized, drawing on the ethnographic study design. This design is founded on four fundamental questions, namely: where do I start looking?, how do I find it?, how do I recognize that it has found something significant?, and how to understand what is it? (Dosinaeng et al., 2020; Prahmana et al., 2021; Prahmana & D'Ambrosio, 2020). The scheme can be observed in Table 1.

Table 1. The scheme of ethnomathematics study

Principal Question	Initial Answer	Specific Point	Specific Activity
where do I start looking?	Analyzing the Tajug house of Central Java	Culture	Study the books and articles about traditional architecture of Central Java and perform interviews with people who know about Tajug house of Central Java
how do I find it?	Investigating the design of Tajug House	Alternative thinking	Analyzing the design of Tajug House Determining what mathematical concepts are contained in the design of Tajug House
how do I recognize that it has found something significant?	Evidence (result) think alternatives are processed beforehand	Mathematical philosophy	Identify what mathematical concepts are contained in the design of Tajug House Design of Tajug House, there is a mathematical concept in it
how to understand what is it?	It is essential for culture, and it is crucial for math	Anthropological Methodology	Describes the connectedness that occurs between the two system of knowledge (culture and mathematics)

Principal Question	Initial Answer	Specific Point	Specific Activity
			Describing mathematical concepts in Tajug House design

The data collection process was conducted from March 16 to May 23, 2024 in 25 articles, five books, and two source persons. The source persons are Mrs. RR Fitri Ardani Titisari, the descendant of Sultan Hadiwijaya from Mangkunegaran Palace Surakarta and Mr. Purwanto, S.Pd, history teacher and also serves as *abdi dalem Kasunanan* Palace Surakarta. The object in this study is the mathematical concept contained in Tajug House. The concepts studied are based on four prominent mathematics branches: geometry, algebra, arithmetic, and statistics. In addition, the subject of this study was Tajug House.

The type of data in this study is qualitative data consisting of observation data, interview data, and documentation data. To obtain the data, the data collection technique is observation technique to observe mathematical forms/concepts in Tajug House, semi-stuctured interview techniques used to strengthen observation data, and documentation techniques to document both the interview process and tajug house design observed.

The semi-structured interview draft consisting of two points, which are (1) the existence of mathematical concepts in Tajug House Design and (2) the possibility of whether Tajug House can be used as a context to teach mathematics (geometry, algebra, arithmetics, and statistics). The instrument was conducted a validity test using Aiken's Value validity test (Ishartono & Ningtyas, 2021). The tes was conducted by Mrs. Isnaeni Umi Machromah, M.Pd, the lecturer of Mathematics department of Universitas Muhammadiyah Surakarta. The content validity index (CVI) obtained an average value of all instrument items was 0,82 or classified as high to be used in this study.

RESULT AND DISCUSSION

RESULT

Where do I start looking?

The research began with an in-depth examination of traditional Central Javanese houses. Although numerous references discussed these houses, none specifically focused on the Tajug House. The research included interviews with history teachers, descendants of the Mangkunegaran Palace, and mathematic lecture. Based on the result of the interviews, the Tajug House's esteemed status among traditional Central Javanese houses, noting that due to its sanctity, the Tajug roof model is reserved for places of worship rather than dwellings.

Tajug House

Omah is a term used by Javanese people to refer to their place of residence (Bayu Hermawan & Yulianto P. Prihatmaji, 2019; Fajarwati, 2018; Prijotomo, 1999). When building a house, Javanese people often construct special houses for specific purposes. A Javanese house typically serves as a residence, a space for ceremonies, a repository for heirlooms and historical items, a place for daily activities, and a space for meditation and spiritual experiences that strengthen the connection with

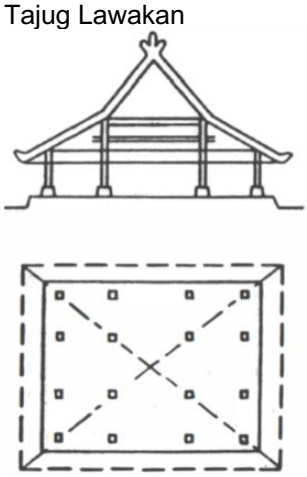
the divine (Setiprayanti & Prijotomo, 2010). Javanese housing can be categorized into five main forms: Panggangpe, Kampung, Limasan, Joglo, and Tajug, each distinguished by the shape of its roof (Sardjono, 2022). The Tajug's design serves as the basis for other house shapes, with the other forms evolving from the original Tajug form (Susilo, 2015).

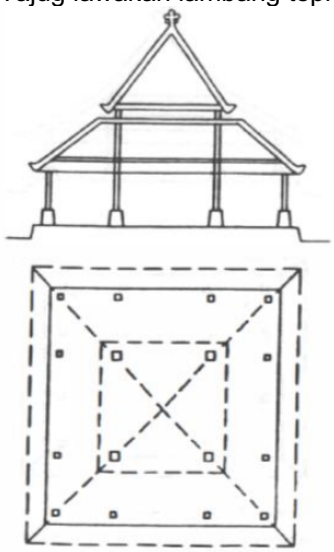
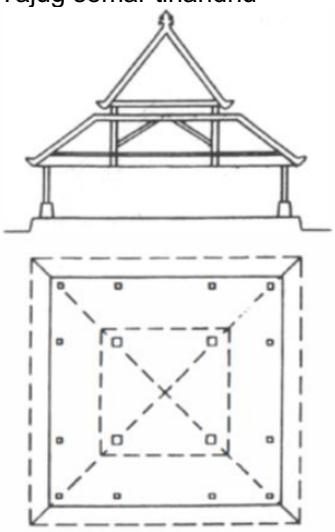
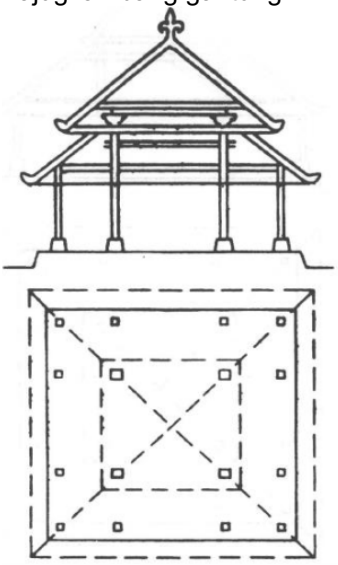
The tapered Tajug roof architecture has been documented in Javanese history since the eighth century AD (Dewi et al., 2019; Sardjono, 2022). This architectural style symbolizes the oneness and eternity of God and is also associated with the interpretation of mountains (Bayu Hermawan & Yulianto P. Prihatmaji, 2019; Dewi et al., 2019). Tajug Houses, known for their distinctive roofs, are traditionally considered too sacred for human habitation. They are commonly used in the construction of mosques and tomb cupolas, which are believed to house ancestral spirits (Sardjono, 2022). The Tajug House has a square design, four pillars called saka guru, and a pointed apex, resulting in four roof sections that connect at the top (see Figure 2) (Yunus, 1985).

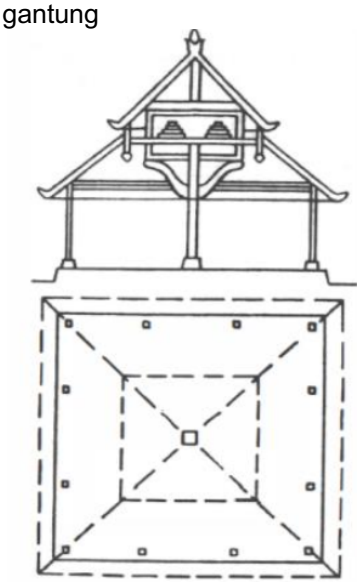
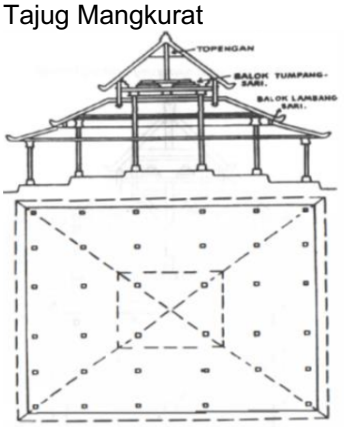
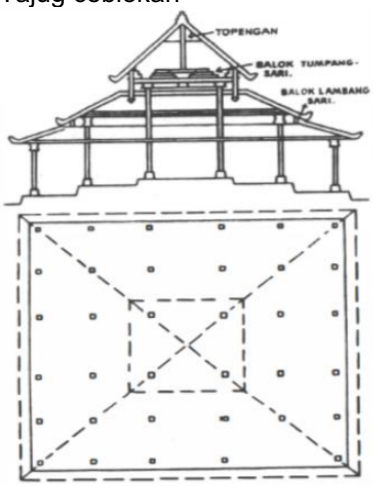
Figure 2. The shape of the main Tajug House

From the basic shape of the main Tajug building, development occurred in the form of expansion in four directions by adding a sloping roof. The development of the Tajug building can be seen in table 2.

Table 2. Development of the Tajug House

No	Figure	Characteristics
1	Tajug Lawakan 	The building is designed as a central structure with an extension created by surrounding it with an overhang. It is a square shape supported by 16 pillars or saka, with a four-sided roof arranged in two sections.

No	Figure	Characteristics
2	Tajug lawakan lambang teplok 	The shape is similar to the Tajug lawakan, the difference lies in the penanggap roof which is attached directly to the saka guru or main pillar. So that there is a distance between the brunjung roof and the penanggap roof. Using 16 saka, 4 (four) as saka guru located in the middle of the building. Example of a building: The Great Mosque (masjid agung) in Yogyakarta, the main building has a Tajug lawakan lambang teplok roof with a three-tiered roof and the overhang has a two-tiered Limasan lawakan roof.
3	Tajug semar tinandhu 	The structure resembles the shape of the Tajug lambang Teplok. The key distinction is the absence of saka guru, with the saka or pillars supporting the brunjung not directly connected to the ground or base of the building, but instead hang on beams or blandar. It features 12 saka or pillars encircling the building and has a roof with 4 sides arranged at distance.
4	Tajug lambang gantung 	The defining feature of this building's architecture is the use of the saka benthung, which serves as a support for the penanggap roof. This architectural style, known as lambang gantung, incorporates an extended overhang around the building. The building typically has a square or rectangular shape and is supported by 16 pillars, with 4 central pillars known as saka guru. The roof is four-sided with three layers: brunjung at the top, penanggap in the middle, and penitih at the bottom. The penanggap roof is supported by the saka benthung, while the overhang at the bottom of the brunjung and penitih roofs is attached to the penanggap roof and the saka benthung pillars.

No	Figure	Characteristics
5	Tajug Semar Sinongsong lambang gantung 	The distinctive feature of this building lies in the use of a single pillar, known as saka tunggal, which acts as the main support. This architectural style is referred to as "semar sinongsong." The penanggap roof is affixed to the lower end of the brunjung roof, creating what is known as the lambang gantung. The brunjung roof is upheld by the saka brunjung, with additional support from the blandar, which in turn is supported by the saka tunggal. To provide balance, there is reinforcement in the form of a bahu danyang or kerbil to support the blandar. Another distinctive aspect is the use of 21 sakas, with one in the middle serving as the saka guru. The roof is comprised of four sides arranged in three sections. Additionally, there is a gap between the brunjung and penanggap roofs, with the lambangsari serving as a connector between penanggap roof and penitih roof.
6	Tajug Mangkurat 	The architectural structure in question shares similarities in roof design with the Tajug semar sinongsong lambang gantung. However, it differs in the presence of four pillars known as saka guru. In total, the structure incorporates 36 pillars.
7	Tajug ceblokan 	The term "Ceblok" refers to dropping to the ground, which is fitting since the primary feature of this structure is its location on a saka that is embedded in the ground. The penanggap roof is directly connected to the saka guru, and the saka penopang or penanggap is also directly linked to the penitih roof, with a lambangsari serving as a connection between the penitih roof and the paningrat or pangapit roof. This structural system is known as the lambang teplok. Another distinctive feature of this type of building is the 48 saka, with the roof comprising 16 sides arranged in 4 sections.

How do I find it?

To uncover the mathematical concepts embedded in the Tajug House, the author examined its architectural elements, observing the relationship between these parts and specific mathematical concepts. Subsequently, the author analyzed how these architectural features corresponded with predetermined mathematical principles. A summary of these observations is provided in Table 3.

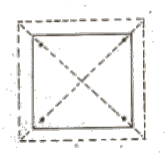
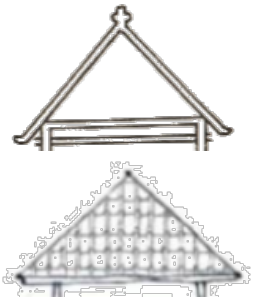
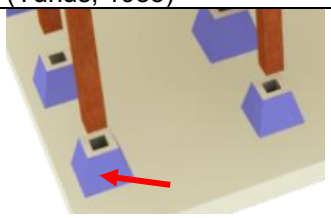
Table 3. The Geometrical Concept Analysis

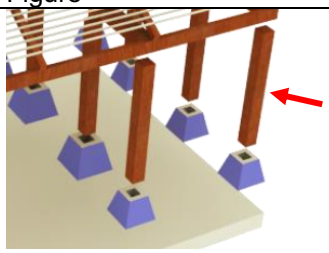
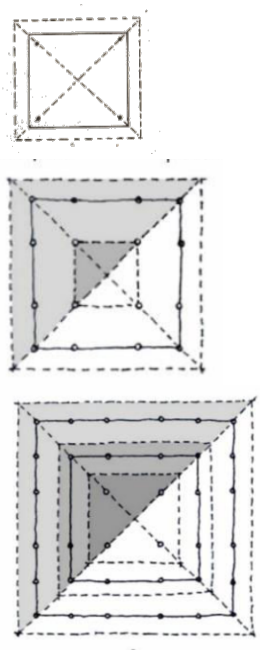
Concept	Concept existence	Sub-concepts	Topic
Geometry	Yes	Geometry Transformation	Reflection
		Plane geometry	Square
			Triangle
			Trapezoid
		Solid geometry	cuboid

How do I recognize that it has found something significant?

Based on the authors' initial analysis of mathematical concepts, as shown in Table 2, only the concept of Geometry was identified among the four studied concepts. The authors discovered three sub-concepts within Geometry: geometric transformation (including reflection), plane geometry (encompassing squares, triangles, and trapezoids), and solid geometry (comprising cuboids). The details of the geometry concept, according to the authors' analysis, are presented in Table 4.

Table 4. the concept of geometry in Tajug House

Geometrical Concept	Figure	Information
Plane geometry: square	 (Yunus, 1985)	the base of the house
Plane geometry: triangle	 (Yunus, 1985)	The side of the roof
Plane geometry: trapezoid	 (Dewi et al., 2019)	The side of umpak. Umpak (pedestal or Plinth) is a support at the bottom of the pillar

Geometrical Concept	Figure	Information
Solid geometry: cuboid	 (Dewi et al., 2019)	The pillar
Geometry transformation reflection	 (Yunus, 1985)	The base of the house

How to understand what it is?

The confirmed concept is geometry, which was verified by consulting a mathematical expert. The expert corroborated the sub-concepts identified by the authors, namely geometric transformations, plane geometry, and solid geometry. She emphasized that the Tajug House could serve as a vital context for comprehensive mathematics instruction. According to her, teachers can utilize GeoGebra—a dynamic geometry software—to visualize mathematical objects during lessons on geometric transformations, by sketching parts of the Tajug House in GeoGebra. Further research is necessary to explore the application of Tajug House-based mathematics learning and its effectiveness. This would not only enhance students' mathematical understanding but also promote the cultural significance of traditional houses, particularly the Tajug House.

DISCUSSION

The objective of this study is to investigate the geometric principles embedded in the architectural design of the Tajug House. The analysis revealed that the structure incorporates at least three major geometric domains: planar geometry, solid geometry, and geometric transformations. These findings align with earlier research, which highlighted the significant potential of traditional

architecture as a contextualized medium for teaching and learning geometric concepts (Hariastuti, 2018; Pratami et al., 2018). Diverse geometric shapes, such as trapezoids, square, and triangles, found on the roofs, walls, columns, and ornaments of Tajug houses, are in line with the research of (Pitaloka & Susanti, 2022) which identified various fundamental aspects of mathematics in Tumiyono Joglo. Next is the concept of solid geometry which this study found that the form of pillars in the House shaped like a cuboid. This finding is also in line with the results of research from (Faiziyah et al., 2024) who study mathematical concepts in Joglo's traditional house. They found that inside the Joglo House there was also a pillar that resembled a cuboid. The shape of the pillars found in traditional houses, especially in the Central Java and East Java (Indonesia) regions, tends to be cuboid because structurally the cuboid shape has better stability compared to other forms (Ariyanti & Malasari, 2023). In addition, esthetically, the cuboid shape of pillars in traditional Javanese houses reflects their cosmological, aesthetic, and cultural symbolic meanings (Kusuma & Damai, 2020).

The last concept found in this study is the concept of geometric transformation—reflection—contained in the floor design of Tajug House. The researcher used virtual lines to describe the concept of reflection on the floor design of Tajug House as seen in Table 4. These findings support previous research that also found that (Fijayanti & Wahidin, 2023) that studied Saung Ranggon House in West Java, Indonesia. The study found geometric transformations, such as reflections, in the design of a traditional Saung Ranggon House. In addition, research from (Lembang & Ba'ru, 2021) that found Toraja Tongkonan house carvings contain the concept of geometric transformation, specifically reflection in the base of the house. The concept of reflection in traditional house architecture is often used because it reflects local wisdom and adaptation to the environment (Carina & Imam3, 2023). In addition, the reflection concepts in the traditional house is responsive to natural conditions such as earthquakes (Minor & Sahibil, 2024).

Teachers can use the findings of this study to contextualize geometry ideas during the mathematics learning process. One example is to create Tajug House-based problem using the HOTS approach as follows:

> "Tajug House is one of the traditional Javanese houses that has an isosceles triangle-shaped roof. Suppose you are an architect who is designing a replica of the Tajug House with an isosceles triangle roof. The length of the roofing base is 12 meters. The height of the roof from the base to the top is 8 meters. Evaluate whether the roof design with this area is effective in protecting the house from heavy rain, considering that the roof must have an area of at least 50 square meters for optimal protection. Explain your reasons."

The problem was using Tajug House to make it more understandable by the students as meaningful learning is a learning process that engage students' prior knowledge (Ausubel & Fitzgerald, 1961). Previous studies also suggest the same benefit of using traditional houses to make mathematics learning become more meaningful and understandable (Kusuma & Damai, 2020; Lembang & Ba'ru, 2021; Usnul et al., 2019). In addition to the context of learning, this finding is also

expected to introduce Indonesian culture to the student level, so that it will enrich students' literacy about Indonesian culture.

Beyond those benefits of the research findings, some parts of the present study can be elaborated more. On of the example is this study only focusses on the geometrical concepts, hence further research may explore from other mathematical concepts such as statistics, numbers, algebraic, and sets.

CONCLUSION

To conserve the Tajug House through mathematics learning, researchers must identify the mathematical concepts embedded within it via ethnomathematics studies. This research employed an ethnographic approach, answering four key questions: where to start looking, how to find the concepts, how to recognize significant findings, and how to understand them. The study began with literature on traditional houses in Central Java to select samples, specifically the Tajug House. The mathematical aspects were then analyzed and confirmed by experts for triangulation and deeper understanding. Among the four explored mathematical concepts—geometry, algebra, statistics, and arithmetic—only geometry was found in the Tajug House and verified by a mathematical expert. The identified sub-concepts include geometric transformations like reflection, plane geometry such as squares, triangles, and trapezoids, and solid geometry like cuboids.

The are some limitations of this study. The first limitation is that the time available for this research was limited, so the depth of analysis of the tajug house was limited. The second limitation is dealing with the mathematical concept. This research has uncovered the mathematical concepts within the Tajug House. However, this study has not tested the application of these concepts in mathematics learning or their impact on students' understanding. It is suggested that these findings can enhance mathematics learning from elementary to secondary education levels, thereby optimizing conservation efforts. Future research could expand on the effectiveness of Tajug House-based learning in improving students' mathematical understanding.

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