Journal of Ecohumanism
2024
Volume: 3, No: 6, pp. 1872 – 1882
ISSN: 2752-6798 (Print) | ISSN 2752-6801 (Online)
https://ecohumanism.co.uk/joe/ecohumanism
DOI: https://doi.org/10.62754/joe.v3i6.4143

Exploring Ethnomathematics in the Traditional House of Suku Tengger: Bridging Structures and Classrooms

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Abstract

This ethnomathematics study explores the interplay of mathematical principles and cultural practices in the Suku Tengger society, focusing on traditional housing construction. The data of this study were based on the interview session with the traditional leader who comprehend the structural aspect of the traditional house and cultural tradition involved in constructing the house, and the blue-print of the structural architecture of the house. Thematic analysis was conducted to analyze the data aiming to identify the integration of the mathematical principles and potential contexts and activities that can be integrated in the mathematical classroom. Our findings show that there are several mathematical principles integrated in the structural element of the house namely the concept of tangent, arithmetic modulo (mod(5)), and measurement and geometry. Our results suggest learning sequences that are notably well-organized and integrate reflective approaches, digital simulations, and practical activities. Specifically, this study posits that emerging technologies like augmented reality could further democratize and enrich the educational experience, providing a window into the cultural dimensions of mathematics for a diverse student body. Additional research is required to fully understand the effects of cultural context on geometric abilities, including spatial abilities, and how to improve accessibility and inclusivity by utilizing augmented reality technology and other types of software geometry.

Keywords: *Ethnomathematics, Traditional Architecture, Ethnomathematics Instructions, Tenggerese Housing.*

Introduction

The abstract character of mathematical objects itself is one of the obstacles that students and teachers alike encounter when it comes to studying mathematics (Hazzan & Zazkis, 2005; Sa'Dijah et al., 2018; Susiswo et al., 2021). This is also a challenge that teachers confront when teaching mathematics. Therefore, in order to make mathematics more understandable to pupils, it is necessary to employ methodologies that are appropriate for the subject. When it comes to teaching concepts and assisting students in the construction of these concepts, one technique that may be utilized is the utilization of real-world settings (Anwar et al., 2012; Sembiring et al., 2008). One of the contexts that can be incorporated into the learning of mathematics is the cultural context. This context is not only recognized and experienced by the students in their environment, but it is also abundant with positive messages that can assist the development of the learners' character and a positive attitude (d'Entremont, 2015; Fran & Kerkhove, 2010; Harding, 2021; Yan et al., 2022).

However, in order for students to be able to observe and appreciate the existence of mathematical concepts inside that culture as well as the function that they play within that society, the employment of cultural context must be felt in a genuine manner. This is necessary in order for students to get the most out of their educational experience. Consequently, it is of utmost significance to conduct a comprehensive study on the application of mathematical concepts in cultural settings and to also conduct an in-depth investigation of the potential of contexts that can be included in the learning process (D'Ambrosio & Rosa, 2017; Ostwald, 2020; Rosa et al., 2016; Venetis, 2020; Witt, 2022). In the context of education, ethnomathematics provides students with a learning experience that is not only exciting and relevant but

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DOI: https://doi.org/10.62754/joe.v3i6.4143

also easily accessible. This is accomplished by combining learning with the students' cultural context (Mania & Alam, 2021).

This ethnomathematics research aims to explore how mathematical concepts are embedded within cultural practices and how these concepts can be effectively incorporated into the educational process (Bussi & Mariotti, 2002) Specifically, this study focuses on the architectural design of the traditional houses inhabited by the Tenggerese tribe in East Java. This research not only highlights mathematical principles present in a cultural context but also offers a distinctive approach to integrating these cultural insights into mathematics education (D'ambrosio, 1985; Hariastuti et al., 2022; Wildfeuer, 2022). By focusing on the architectural structures of Tenggerese traditional homes, this study provides a practical and culturally relevant way to bring ethnomathematical knowledge into classroom instruction.

It is essential to carry out this research since it not only contributes to the growth of theory but also to the practical side of the situation. Based on the findings of this research, an innovative approach to teaching mathematics is presented (D'Ambrosio, 2016; Machaba & Dhlamini, 2021; Naresh & Kasmer, 2018; Rosa & Gavarrete, 2017; Rosa & Orey, 2016). This approach involves incorporating mathematical concepts into an architectural setting that is already recognizable to students. As a result, students' comprehension and interest in the subject matter are enhanced. The study, in a theoretical sense, presents a new perspective in terms of understanding how mathematical concepts are integrated into traditional architecture. It also provides new insights into the relationship between mathematics and culture.

Method

Research Designs

This ethnomathematics study employs a qualitative research method aiming to investigate and understand the integration of mathematical ideas in the construction of Tengger traditional house (D'Ambrosio, 2016). Research team conducted anthropological approach on local Tengger community to understand comprehensively their knowledge system and original practice underpinning the construction of their traditional house. Through ethnography, researchers observed the local cultural context of the Tengger ethnic community related to their values, beliefs, and traditions. Interview with a local leader who understand comprehensively structural aspect of the house and cultural philosophy complement the data aiming to collect their insight and perspective about mathematical concept involved in the construction of the traditional house.

Subjects of the Research

The participant of this study was a village head who also serves as the chief of the indigenous council, possessing a profound understanding not only of governance and administrative systems but also of the culture of the Tengger community, including traditional houses and customs. He has comprehensive knowledge of traditional house construction and the cultural activities related to the construction process. Researchers selected the participants, through a purposive sampling, based on the recommendation from the local community. The information related to the criteria of the participants was well-informed that the person understands and comprehends the integration of mathematical principles and accompanying cultural aspects.

Data Collection

There are two stages employed in collecting the data, namely, semi-structured interviews with participant who has comprehensive knowledge related to the structural component of the traditional house as well as the cultural aspects and comprehensive investigation of the blueprint of the architecture. The interview plays an essential role in collecting information about the integration of mathematical principles in the construction of the traditional house. During the interview session, the researcher posed open questions to encourage a deep discussion about their perspective, experiences, and beliefs about mathematical principles integrated into the construction of the traditional house. In the second stage, researchers examined the

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architectural blueprints and procedures related to the construction procedure of the traditional house. This investigation aims to identify various design concepts, proportional elements, and geometric considerations that were important in the construction process. These data are valuable information to enhance understanding of the intricate architectural details and the importance of mathematics in constructing the house.

Data Analysis

The thematic analysis was performed to evaluate the obtained data aiming to identify recurrent themes that were associated with the integration of mathematical principles in the construction of the traditional house (Korstjens & Moser, 2018; Saldaña, 2013). Firstly, the researcher transcribed the interview recordings and read line-by-line the transcription together with the field notes to look for the patterns and connections between the responses of the participants. This current study aims to identify the mathematical principles, spatial organization, and numerical meaning that were integrated into the construction and also the ceremonial and cultural activities accompanying the construction process. This study also employed an analytical review of the architectural blueprint and procedures.

The research acknowledges that it has limits that are associated with subjectivity and generalizations, which are characteristics that are typical of all qualitative methods of investigation. There is a possibility that the findings cannot be immediately transferred to the architectural practices of other indigenous people because of the fact that the Tengger culture is situated in a special environment. However, an emphasis on understanding the inclusion of mathematical ideas in the traditional building methods of the Tengger Tribe provides vital insight into the junction of culture and mathematics (also known as the intersection of culture and mathematics).

Results and Discussion

Our investigation into Tenggerese traditional architecture discovered three mathematical concepts that correspond to the structural and cultural characteristics of the Suku Tengger community. Several critical points are included in these thoughts. First, the roofs of the structures have angles ranging from 45 to 60 degrees, which provides architectural appeal while also mitigating environmental hazards such as volcanic ashfall (Figure 1). Second, mod(5) is incorporated into the ritualistic framework to aid in the selection of auspicious building days. Geometric concepts are embodied in the Saka Guru (major pillars) and Cagak Pinggir (connected pillars), which are used to measure and shape. The eight Cagak Pinggir in an octagonal arrangement represent the eight cardinal directions and their spatial importance, whereas the Saka Guru has four pieces and resembles squares or rectangles. The roofing structures created by Tenggerese artists demonstrate their perfection. Their precise measuring from point to point and line to line demonstrates their geometric measurement abilities. In the next sections, we'll look at how each concept fits into Tenggerese architecture. We will also look at how to successfully incorporate these culturally embedded mathematical concepts into learning activities.

Figure 1. Tenggerese Traditional House

The Concept of Tangent

Based on observations and interview results, researchers identified several mathematical concepts applied in the construction of roofs of traditional Tengger tribe houses which have a distinctive slope, one of which is the concept of geometry and slope, see transcript 1. The accurate identification of the inclination angles of Tenggerese roofs is an outstanding and tangible opportunity to impart knowledge of applied trigonometry and geometry within the context of an educational environment. Roof inclinations, which typically vary from 45 to 60 degrees, are a good example of the tangent function in trigonometry in practice. This function links roof inclination to vertical rise to horizontal run. This instructional method teaches trigonometric functions and lets students see them in architectural design (Ngu & Phan, 2020).

Transcript 1

Researcher: Regarding the shape of the traditional house roof, why is it designed that way?

Participant: The roof of the traditional house is designed with this shape and a slope of about 45 degrees for reasons of durability and sturdiness. This is because the traditional houses are located near Mount Bromo, which is an active volcano, and it frequently emits ash and dust that are carried by the wind to the residents' houses. With this shape and slope, the dust will quickly slide off and not accumulate on the roof, which could otherwise weaken it and cause it to collapse.

Implementation in The Mathematical Classroom. The involvement and participation of students can be increased by the use of project-based activities, as indicated by a number of studies (Almulla, 2020; Kokotsaki et al., 2016; Warden & Woodcock, 2005). The assignment for the students is to make models of Tenggerese roofs. These kinds of activities are referred to as "project-based" activities. Students may be required to do project-based assignments that teach them how to calculate the tangent of an angle. After gaining this information, they may then apply it to calculate the rise-to-run ratio in order to achieve the highest possible roof inclination. Raise the height of the roof is the goal of this project. Through the construction of cardboard or wood models of Tenggerese homes, students have the opportunity to get an understanding of Tenggerese architecture. Student learning is improved as a result of this since it encourages active participation. toddlers are able to learn through touch as a result of this.

When digital technology, especially computer-aided design (CAD) software, is used, these ways of learning can be made much better. Students use computer-aided design (CAD) tools to make copies of different roof slopes. By trying out different angles, they can get a better sense of how these angles affect the flow of water and ash off the roof. Based on the findings of this study, architectural plans should be changed to fit the limitations set by the surroundings. They agree with what (Li & Gong, 2021) found about this improvement. It is helpful to do a study of how well different roof angles work. For this reason, students can get a better understanding of the steps that go into sustainable design. One of the main goals of this educational practice is to look into Tenggerese building styles.This study suggests a new way to teach geometry and trigonometry: using real-life examples (Ostwald, 2020; Venetis, 2020).

Introducing mathematical principles into educational practice will enable you to commence with a firm foundation. It is crucial to realize that this method prioritizes the significant roles that these concepts play in calculating angles and distances. For students to grasp the mathematical principles behind structural inclinations like roof slopes, they must possess a framework (Stewart & Tall, 2015; Verner & Maor, 2007). The most important step is the construction of a foundational stage since it gives a framework for students to acquire this understanding. Paper materials are utilized to make exact replicas of Tenggerese roofs, and children are invited to participate in hands-on activities that involve the creation of these duplicates. These exercises will take place immediately after the theoretical presentation has been provided. The study's

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authors (Cumino et al., 2021) underline that visualizing mathematics through architecture makes it easier to imagine how these concepts are implemented in practical architectural contexts. Mathematics can be perceived by visualizing it through architecture.

The next phase in education is for students to go digital. At this stage, students use CAD software to generate comprehensive roof designs. This stage is critical because it connects mathematics theory to practice. According to (Pielsticker et al., 2021), it allows students to experiment with angles and dimensions in a digital environment. Following the digital design process, students utilize cardboard or wood to build real-world models to practice their skills. At the completion of the project, a session will be held to review and discuss student suggestions. Students can evaluate the effectiveness of their environmental solutions. Students are encouraged to consider sustainable and adaptive design in this exercise (VanWynsberghe, 2022). According to (Salomone & Kling, 2017), group presentations allow students to demonstrate their work while also communicating mathematical concepts. This technique helps people learn from one another and promotes communication.

Through the provision of a more in-depth comprehension of the practical application of trigonometry and geometry in contemporary architectural design, the module is enhanced through the participation of a guest speaker session led by an experienced architect or engineer. Last but not least, the purpose of this session is to enhance the module. By integrating these two concepts, this integration successfully bridges the gap between theoretical classroom education and the tangible effects that it has in the real world. Students acquire significant insights into the real-world applications of the mathematical principles they are studying as a result of their involvement in the activity. There is a connection between the utilization of a structured educational system and the enhancement of students' understanding of mathematical principles, as well as the cultivation of students' creativity and the promotion of a connection during the learning process to applications that are relevant to the real world. Students will be equipped with the abilities necessary to engage in critical and imaginative thinking in a variety of settings as a result of this presentation, which will focus on the pragmatic application of mathematical principles in the fields of architecture and sustainable environmental adaptation.

The Concept Modulation System

While investigating the traditional homes of the Suku Tengger, we encountered a fascinating instance of the Suku Tengger people incorporating modular arithmetic into their cultural practices. The generation of propitious dates for the construction of the houses served as a notably evident illustration of this occurrence, see transcript 2. The Tenggerese calendar shows the principles of modular system through the use of five-day cycles, namely Legi, Pahing, Pon, Wage, and Kliwon. This calendar system is a good example of the implementation of the concept of modular arithmetic mod(5) in reality. The properties of the cycles show the similarity with the mathematical notion of reminders used in division and congruence. This special case is comprehensively addressed in modern mathematical classroom.

Transcript 2

Researcher: In the process of building a house, are there any special rituals performed by the Tengger people?

Participant: Usually, when a resident plans to build a house, they consult the traditional leader, known as Romo Pandita, to find out the auspicious day. In the Tengger tradition, there are specific good days for certain activities, such as building a house, getting married, and so on. In the Tengger calendar, there are five days in a week: Legi, Pahing, Pon, Wage, and Kliwon. We also combine these with the Gregorian calendar, which has seven days, as well as monthly, yearly, and five-year cycles. In one year, there are months when we are prohibited from any activities, such as the "Kapitu" month and

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> the "Kasanga" month. "Kapitu" refers to the seventh month in the Javanese calendar, and "Kasanga" is the ninth month, both according to the Javanese Tengger count. During these months, we cannot build houses. There is also a prohibition during the five-year cycle. The purpose is to allow nature to rest. Our ancestors established such calculations to ensure peace and harmony for their descendants.

The use of the context of Tenggerese calendar in determining the good day to start the construction process was embedded in their cultural practice, so it can show an example of the practical integration of abstract mathematical concepts like modular arithmetic mod(5) in their daily life. The integration of cultural components into mathematics classrooms can significantly enhance the students' learning experience in general. (Atweh, 2013) indicated that it is necessary to incorporate cultural context into mathematics education as a means of increasing the accessibility and engagement of abstract concepts. This is in accordance with what (Atweh, 2013) suggested. Using a calendar context in determining good days through simulation activities can not only increase understanding of mathematical principles but can also emphasize significance in the context of everyday life (Bishop, 2013; Karjanto & Beauducel, 2021).

Implementation in the Mathematical Classroom. In order to teach the concept of modulo arithmetic within the local cultural context of the Tengger tribe, learning activities may consist of the following: an introduction to the Tengger tribe's calendar system and traditions associated with it; games that utilize the modulo system to represent Tengger tribe characteristics; and simulations of traditional event planning within the Tengger tribe.

Commence learning activities by delivering a concise exposition of the Javanese calendar system and its cultural significance within the Tengger tribe, specifically in regards to the determination of auspicious days, as suggested by (Karjanto & Beauducel, 2021). Elucidate on the recurring five-day cycle of the Tenggerese calendar, which comprises the following days: Pahing, Pon, Wage, Kliwon, and Manis. This elucidation may incorporate visual images or animation. By establishing a connection between the concept of modulo and the previously covered notion of division with remainder, one can provide an introductory overview of the latter. The child is then instructed to utilize their comprehension of the relationship between a remainder of five and a quotient in relation to the Tengger tribal calendar. In order to enhance student engagement and enthusiasm, instructional materials such as visual aids (e.g., videos and photos) may be selected to depict Tengger tribe customs and events associated with the construction of traditional dwellings (Shaffer & Kaput, 1998).

Assign students the following learning endeavor: construct a basic Tenggerese calendar showcasing a five-day cycle. They can be created with either paper or computer software. By engaging in this exercise, pupils will enhance their comprehension of the Javanese calendar's 5-day cycle concept. This is due to the fact that they will be obligated to learn the method of day counting within a cycle as well as its practical application. Students can further cultivate their creative abilities by engaging in this endeavor and crafting Javanese calendars. They are free to consider various descriptions of the five-day cycle. Students may also put into practice the concept of modulus 5 through this activity. They must determine how to organize their calendar's days to correspond with a five-day cycle.

Measurement and Geometrical Shape

We were able to identify numerous aspects of Tenggere's architecture by analyzing the structure of traditional houses and conducting interviews with participant. During interview, participant confirmed that there are four main pillars in the center of the house which called Saka Guru, see transcript 3. Beside the main pillars, there are connecting pillars called as Cagak Pinggir. Look at Figure 2 to see how the layout of Saka Guru, which is made up of four different components, corresponds to a square or rectangular structure. While this is going on, the elements of Cagak Pinggir have been determined to be eight Cagak Pinggir, which are responsible for supporting the traditional house. The concept of the eight primary cardinal directions and the geometric consequences of those directions is reflected in this edge structure, which exhibits a link with the octagonal shape.

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Transcript 3

Researcher: Regarding the house construction, I noticed there is a wooden structure in the middle of the house that supports the roof?

Participant: Inside, there is what we call "soko guru" or "saka guru," which are pillars supporting the roof trusses. There are four "saka guru" inside and four "saka guru" on the outside. So, there are a total of eight "saka guru," and these represent the eight cardinal directions.

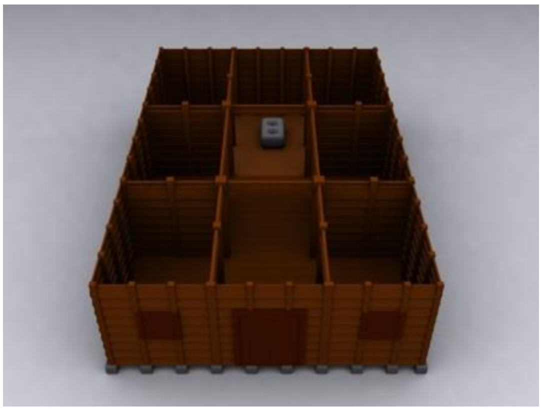

Figure 2. Architectural Elemen of Traditional of Tengger: Saka Guru (Main Pillar) Dan Cagak Pinggir (Connecting Pillar)

Traditional Tenggerese structures appear to have a natural comprehension of two-dimensional figures and a pragmatic application of geometric concepts in the field of construction, as evidenced by their architectural structure. In their work published in 2023, (Spindola & Miranda, 2023) present an account of the assimilation of intricate geometric knowledge into the architectural techniques of indigenous civilizations. It is possible to observe this in the meticulous measurements and precise shapes that are characteristic of Tenggerese building. When it comes to the construction of their roof support systems, the Tenggerese demonstrate an incredible level of ability by employing precise measurements of the distances between points and lines. This serves as an illustration of how arithmetic and geometric measurement skills can be applied in real-world situations. Taking into consideration the findings of (Zhang & Seah, 2021), which stated that the original building techniques placed an emphasis on measuring and geometry, this activity is in agreement with those findings. These components are necessary for the creation of buildings that not only fulfill the function for which they were designed, but also have aesthetic appeal and cultural significance.

Implementation in Mathematical Classroom. It is possible to initiate the incorporation of cultural context in relation to the idea of measurement and geometric shapes that are incorporated into building structures through the use of straightforward activities. These activities may include the introduction of fundamental geometric shapes that students can directly observe in traditional house building structures. Students are able to observe simple flat plane shapes such as squares, rectangles, octagonal shapes, parallelism, intersections of lines with lines and planes, and other similar shapes. The presentation of these fundamental ideas is of utmost significance for pupils because it serves as a foundation upon which they can build a full understanding of more complex ideas or subjects. Students have the ability to see geometric things through the use of several forms of media, including films, photos, and three-dimensional shapes created with

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architectural software like Sketch Cup. Augmented reality is another option for students to have access to. Following this, students are encouraged to concentrate not only on the structure of the building, but also on the environment surrounding the Tengger house, as well as the manner in which the Tengger tribal community takes into consideration environmental factors when planning the construction of a traditional house, as well as the manner in which cultural values are also taken into consideration when building the traditional house. According to the concept (d'Entremont, 2015; Shore et al., 2023) that learning should incorporate cultural background into learning material, the incorporation of cultural aspects into learning is consistent with this approach.

The next learning activity involves involving students in project assignments in the form of creating building designs or building models of the Tengger traditional house. This is done so that learning activities not only support the process of concept construction, but also have the potential to support students' creative abilities, which are skills that are required for the 21st century (Handayani et al., 2020; Purnomo et al., 2022). When participating in this project, students are urged to actively participate in planning by applying their knowledge of measurement and scale, as well as their creativity in selecting inexpensive materials that are sturdy and cutting procedures that may yet guarantee the efficiency of the resources that are utilized.

However, activities that include the use of hand-on materials have limits because of the fact that they involve inaccurate measurement activities, such as imprecise construction procedures. As a result of these less-than-ideal circumstances, the mathematical concepts that pupils are supposed to observe will either fail to be successful or possibly give birth to misconceptions. Therefore, it is imperative that the process of mentoring, as well as strengthening and putting an emphasis on issues of correctness, is always communicated.

It is necessary for additional action to entail the utilization of digital simulation media such as computer-aided design (CAD) or augmented reality (AR) in order to predict faults and issues that may emerge. One benefit of using this digital geometry software is that its geometry model accepts geometric principles. This CAD or AR learning activity involves examining and modeling a standard house's roof slope. This slope affects a traditional house's roof's ability to endure precipitation and volcanic dust. CAD and AR allow students to interact with three-dimensional objects from the traditional Tengger tribal house in real time (Shore et al., 2023). This shows pupils how slope affects roof strength in retaining precipitation and dust, as well as volcanic eruptions. The immersive and interactive augmented reality element lets students experience real-life scenarios that demonstrate how theoretical principles apply in the real world (Anwar et al., 2022; Chang et al., 2022; Haleem et al., 2022).

Conclusion

The current ethnomathematics study demonstrates how mathematical principles are incorporated into cultural aspects, particularly in the traditional houses of Tengger Tribes. Our finding show that there are a number of mathematical principles that are included into the structural design and cultural activities (the Tengerese calendar system), such as geometry, measuring, and the modular arithmetic system. The results of our research suggest that there are a few possible cultural contexts that may be incorporated into the activities that take place in the classroom. This will not only help students better understand the mathematical concepts, but also how they might use such concepts in their everyday lives. This present work in the field of ethnomathematics proposes learning sequences that are significantly well-organized and incorporate reflective methodologies, digital simulations, and practical exercises.

Through the introduction of how the Tenggeres community uses the geometry principle in computing the inclination of the rooftop of their house and through the engagement of students in the design of the rooftops model of the traditional house, students are provided with a genuine opportunity to actively participate in and comprehend the fundamentals of the mathematical principles. In addition, the utilization of dynamic geometry systems and augmented reality in the simulation of the measurement of the angle of the rooftops and the effects on the durability of the roof to resist rains and dust from volcanic eruptions offers assistance for their comprehension of the concept and its application. By integrating cultural aspects regarding how members of the Tenggeres community interact with one another, we will be able to demonstrate the significance of collaborative learning in terms of the exchange of information and the resolution of issues. Students are able to acquire a full understanding of the subject matter by actively participating in the Tenggerese calendar system and by examining the ways in which mathematical concepts are incorporated into a variety of cultural traditions.

This current ethnomathematics study provides evidence of the strong relationship that exists between mathematical concepts and cultural contexts, as well as the ways in which these contexts can be included in educational activities. It is necessary to conduct additional research in order to determine the extent to which the potential for learning activities in a variety of creative and unconventional situations, as detailed in the research, can have an effect on the mathematical abilities of students. In the subject of mathematics education, there is a need for more in-depth study to be conducted on the topic of how to incorporate cultural context through the utilization of augmented reality technology and other forms of software geometry on geometric abilities such as spatial abilities, as well as boosting accessibility and inclusivity.

Acknowledgments

This research was supported by the Riset Kolaborasi Indonesia, Skema A, Indonesia Collaboration Research Schema A, PTNBH, and Universitas Negeri Malang with contract No. 10.5.74/UN32.20.1/LT/2023.

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