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Ethnomathematics studies: Mapping and construction of culture-based teaching materials

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Abstract. Mathematical ideas are often found in community activities and culture. Researchers have paid much attention to ethnomathematical studies describing mathematical ideas in culture. However, the mapping and construction of Makassar culture-based mathematics teaching materials have not been widely explored. This study aims to map and construct culture-based mathematics teaching materials through ethnomathematical studies. This type of research is a qualitative study with an ethnographic approach. The subject of this research is the Jeneponto community with Makassar ethnic background. The research instrument used observation sheets, interview guides, voice recorders, and field notes. Observation of cultural objects focuses on salting methods, fishing methods, time systems, forms of craft, and the use of horses. The results show that mathematical ideas are used in various activities and cultures of society. Mathematical concepts are connected with various cultural objects: numerical systems, lines and angles, plane figures, spatial figures, statistics, sequences and series, social arithmetic, and algebra. Activity-based task sheets, project assignments, modules, and field observation reports are forms of culture-based teaching materials in harmony with the ethnomathematical model as a learning innovation. The findings in this study propose integrating culture-based teaching materials in the ethnomathematical learning model.

Key words: ethnomathematics, culture, teaching materials, mapping, curriculum.

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INTRODUCTION

The study of ethnomathematics has received much attention in various parts of the world in recent decades. Many researchers have studied culture as a framework for understanding student diversity, social behavior, and values that grow in society through the development of learning designs (Young, 2008). Culture-based learning is a means to establish meaningful educational and social relationships between communities and increase the values of local wisdom (Julita et al., 2019). Ethnomathematics through cultural internalization in mathematics learning is a means of displaying mathematical concepts in a humanistic, interesting, fun, and meaningful way (Kurniawan & Hidayati, 2020; Pathuddin et al., 2021; Utami et al., 2019). Many essential findings that link culture with mathematical concepts include; the use of non-formal units, games with mathematical rules, and geometric patterns in the Sundanese people (Muhtadi et al., 2017). The concept of measurement, design, and geometric shapes in the architecture of the Sasak traditional house (Supiyati et al., 2019). Numerical concepts are used uniquely by Javanese Primbon (Utami et al., 2019). The Javanese number system, basic geometry, and fractal geometry appear in the architecture of Borobudur Temple (Kurniawan & Hidayati, 2020).

There is more information that shows that mathematics exists and develops in culture. Furthermore, traditional food forms (Pathuddin et al., 2021), buying and selling activities, and various forms of handicrafts (Laurens et al., 2019) are equivalent to mathematical concepts. However, there is still little that provides information about the mapping and construction of culture-based mathematics teaching materials, especially in Makassar culture.

The ethnomathematics paradigm has evolved from simply promoting cultural values to an effort to develop a curriculum related to multicultural ideas (Agustin et al., 2018). Ethnomathematics has both challenges and opportunities through the design of innovative culture-based teaching materials. However, the mapping and construction of culture-based teaching materials require consideration of curriculum content and other standard components to position ethnomathematics as a model of learning innovation (Laurens et al., 2019). Teachers need the availability of information, adequacy of materials, and activity instructions that can provide them with knowledge related to the application of ethnomathematics in the classroom (Ergene et al., 2020). Furthermore, limited cultural information can lead to bias and misperceptions, so learning designers must be sensitive to recognizing students' learning needs (Young, 2008). The efforts needed to strengthen ethnomathematics in the curriculum are through the construction of culturally nuanced learning tools in the form of lesson plans and worksheets (Agustin et al., 2018), the creation of cultural context questions (Utami et al., 2019), and mathematics modules based on local wisdom (Yuliani & Irham, 2022).

The ethnomathematical approach can be designed through activities that involve relevant cultural elements so that they become an inseparable part of the learning objectives (Ergene et al., 2020). The teacher applies ethnomathematics in the classroom by developing student-centered inquiry. Learning activities focus on exploring cultural contexts and discussing and promoting the applied values of mathematics in everyday life through project assignments (Naresh, 2015). Assignments should provide opportunities for students to make mathematical connections in various contexts. Ultimately, a framework is needed to reflect on ethnomathematics as an integrated approach that has implications for mathematics academically, socially, and culturally (Baba & Iwasaki, 2001). Culture has the potential to develop in line with the objectives of the curriculum. Therefore, the mapping and construction of culture-based teaching materials are needed to make it easier for teachers to apply an ethnomathematical approach in the classroom. In line with this description, the research questions are: (1) how to map culture-based mathematics teaching materials? and (2) how to construct culture-based mathematics teaching materials? This study aims to map and construct culture-based mathematics teaching materials through ethnomathematical studies.

METHODS

This qualitative study uses an ethnographic approach that captures the community's cultural activities. The research focuses on ethnomathematics mapping with academic mathematics and constructing culture-based mathematics teaching materials. The research subject is the Makassar tribe in Jeneponto Regency. The Makassar tribe inhabits the southern region of South Sulawesi Province and is called pa'rasanganna tau mangkasara (the land of the Makassar people), including the Jeneponto community (Mattulada, 2011). The research instrument uses an observation sheet of cultural objects representing mathematical characteristics in the form of structures, processes, tools, techniques, or interactions. The culture in this study is limited to the community's knowledge system related to salting methods, fishing methods, time systems, traditional crafts, and the use of horses. Each object of observation is analyzed into a universal mathematical activity (Bishop, 1988): counting, locating, measuring, designing, playing, and explaining. Observations were continued through interviews to explore mathematical concepts that appeared in various cultural objects and community activities. The interviews were semi-structured with open-ended questions so that the respondent's information could be analyzed more flexibly. The collected data is grouped by theme or sub-competency in the academic mathematics curriculum. The findings of this study are then mapped in the form of a matrix that connects each cultural domain with the topic of academic mathematics teaching materials. Furthermore, the results of the mapping are constructed to describe the form of relevant activities or tasks in the form of culture-based mathematics teaching materials.

RESULTS AND DISCUSSION

Ethnomathematical Mapping

Salting method

The traditional salting method is a community knowledge system passed down from generation to generation. The salting process depends on the season and weather, requiring salt farmers to estimate the best time to start work. The location of salting is called *tonrang,* which is divided into several plots as a place for salt crystallization. The salting method dramatically determines the quality of the salt produced through a particular work cycle. The steps for salting are as follows: First, clean the moss from the *tonrang* and insert water. Second, repairing bunds called *tingkasa'.* Third, compacting the plot surface using a tool called *pa'dengka.* Fourth, make a grid on the surface. Salting plots using a device called *salaga.* Five, inserting water through a gap in the cold water reservoir using a windmill called *padete'* to experience heating for one week. Six, flowing hot water through a gap made on the edge of the salting plot. Salt plots ready to flow with hot water will crystallize for two days (if the weather is sunny). Salt grains are collected using a tool called *pakkai'*. Salt grains are collected on the edge of the salting plot using *panyorong*. The salting cycle continues until the entire plot produces salt. The flow of traditional salt-making is shown in Figure 1.

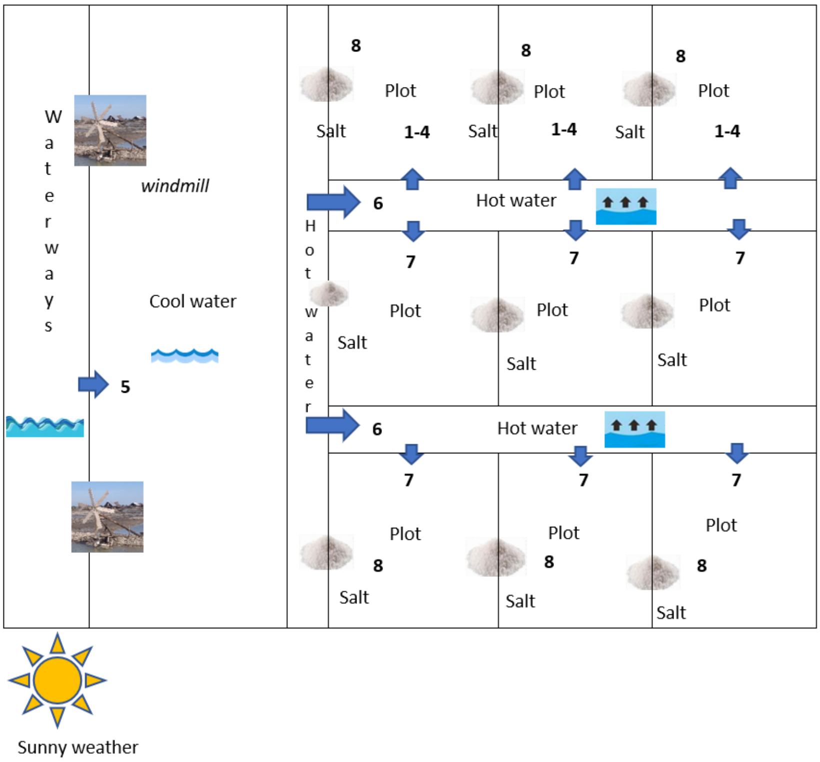
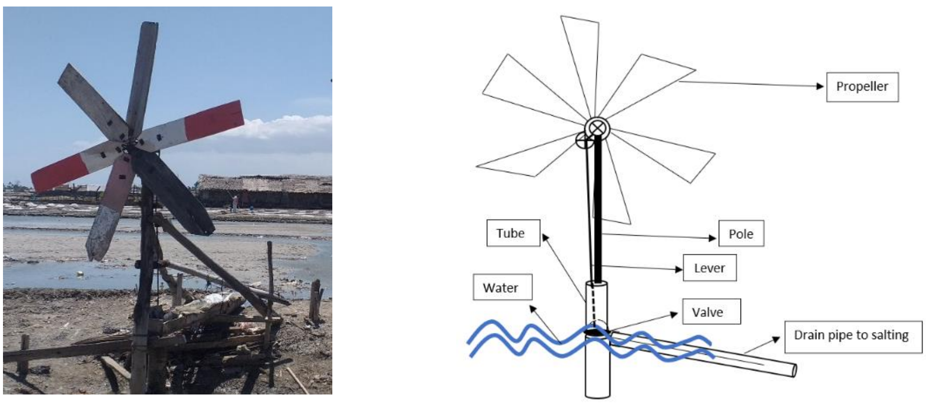


Figure 1. Salt working flow

Tidal and low tide conditions greatly determine the water discharge in salting. Therefore, a windmill must pump water from the channel into the salting machine. The windmill comprises wooden propellers totaling six blades that stand on a pole. At the center of the propeller is a rotating wheel that moves the lever. The lever functions as a pump lever that flows water into the salt. At the bottom of the lever, there is a valve that functions to suck water so it can no longer come out of the pipe.



(a) (b)

Figure 2. (a) Windmill for salting (*padete'*), (b) *Padete'* sketch

Salt farmers collect their crops in warehouses called *lontang*. Salt ready for sale has several rules; for example, salt farmers only get 2 out of 3 shares while the rest become *tonrang* owners.

The *lontang* shape resembles a combination of a triangular prism and a rectangular prism. *Lontang* size depends on the available land area. *Lontang* walls are made of coconut leaf sheaths and woven bamboo called *gamacca*, which block rainwater.

Figure 3. Salt storage warehouse (*lontang*)

The salting method has a long path and involves many mathematical ideas (Hanik et al., 2022). Salt farmers must measure the area of *tonrang* and divide it into several plots. The flow of water from the main channel must be calculated as well as possible so that the entire plot gets water. The concept of a quadrilateral and its elements is vital in the salting plan. The regulation of water is related to complex elements involving time, wind speed, tidal height, and the opening and closing of the water flow in each plot. Many mathematical concepts can emerge from the salting process, such as; arithmetic operations of integers, percentages, least common multiples, most significant common factors, volumes, and comparisons. Units of length, units of area, and units of volume can also be found in the measurement activities of Sundanese people (Muhtadi et al., 2017). The windmill (*padete'*) plays an essential role in salting because it is a functional water pump. The blades of a windmill can be used as context for introducing lines, angles, and circumferences of circles. A salt storage warehouse (*lontang*) is a spatial concept for designing and measuring activities. Although the technique of making *lontang* looks simple, it has a measurement concept and design function in line with traditional buildings like the Sasak people in designing storage buildings (Supiyati et al., 2019).

Fishing Method

Two methods are used to catch fish: netting using a small motorized boat called *katingting* and netting using a trap called *bagang*. The fishing process relies on natural phenomena such as tides, lunar periods, wind direction, and weather. Fishermen must have precise calculations with these various phenomena to maximize their catch—the calculation method to estimate the best time to catch fish using the Arabic calendar. The high and low tides are highest during the full moon and crescent periods. The period beyond that date is called *konda*, i.e., the condition of the seawater is not low tide but not high tide. *Konda* is divided into two types: large *konda* with changing tides and low tides every 6 hours, while small ones change for 12 hours. Estimates of the time of high and low tides are significant for coastal communities to determine the location for fishing, determine the time to exchange pond water and add water to salting, and collect shellfish, crabs, and shrimp on the beach.

Catching fish by setting a trap is done by making a building called a *bagang* at a specific location and depth of six meters. The *bagang* building consists of bamboo tied together and strengthens each other. At the top of the *bagang* are a small house and a large net prepared to catch fish. Fishermen use the Arabic calendar to estimate the right time to set traps. The crescent period is the best time for fishermen to catch fish in shallow waters and around the *bagang*.

On the other hand, during the full moon, the fish move away from the *bagang*, so it is not the right time to catch fish. Fishermen will prepare a block-shaped container as a place to store fish catches. Furthermore, the fish will be grouped on rattan ties called *toddo'*. Grouping various types of fish in one *toddo'* makes it easier for fishermen to sell all the fish they catch.

Figure 4. *Bagang*

Time System

Determination of time using the *bilang-bilang mangkasara* (determination of auspicious days in Makassar Culture). *Bilang-bilang mangkasara* is based on the Arabic calendar, divided into four days. The first day represents the nature of the earth, the second day represents the nature of water, the third day represents the nature of wind, and the fourth day represents the nature of fire. For the next date, it is repeated according to the first day and so on until the month changes. Makassar culture only recognizes the turn of the month, the number of days, and the division of the quality of time in a day. There are five divisions of time in a day, namely; *bari'basa* (06.00-08.00), *kanaik-naikanna alloa* (08.00-11.00), *tangnga allo* (11.00-12.00), *lohoro* (12.00-15.00), and *asara* (15.00-18.00). Each time division has its quality, as shown in Table 1.

Table 1. The time quality of the week

Day	Time				
	06.00-08.00	08.00-11.00	11.00-12.00	12.00-15.00	15.00-18.00
Friday	○	🯅	+	=	▣
Saturday	▣	○	=	+	🯅
Sunday	=	+	🯅	▣	○
Monday	○	🯅	▣	=	+
Tuesday	=	○	+	🯅	▣
Wednesday	+	🯅	▣	○	=
Thursday	=	○	+	🯅	▣

Information:

○	:	Empty
🯅	:	Death
+	:	Live
=	:	Break even
▣	:	Contain

A good time to start an activity is to combine the *bilang-bilang mangkasara* with the time quality of the week. So, a good day must represent the nature of earth or water, then be paired with the best quality time of the day, representing the nature of life and contain. The use of good time is often done to build houses and traditional parties (weddings), as well as start work such as farming, fishing, and salting. The mathematical idea contained in calculating auspicious days is to count and explain. The quality of the day in Makassar culture has its explanation, although philosophical values are more dominant than rationality. The *bilang-bilang mangkasara* are in line with the knowledge system of the Javanese people who know *primbon* as a time quality calculation system that contains various numerical concepts (Utami et al., 2019).

Traditional Crafts

The Jeneponto people have traditional woven motifs with unique geometric patterns. *Gamacca* is a house wall in the form of woven bamboo in a geometric pattern (Saing, 2010). Weaving using palm leaves produces a variety of very functional household crafts such as *bakulu'* (a food place), *pusa* (a place for incubating chickens), *tappere* (a mat), and *songkolang* (a place for cooking rice). The mathematical ideas contained in various forms of crafts have geometric patterns. In line with the woven pattern of the Maluku people, which has equivalents with the concepts of fractions and geometry (Laurens et al., 2019). Similar concepts are also found in various batik motifs related to flat shapes and transformation geometry (Sianturi et al., 2022).

At the wedding, woven bamboo ornaments called *lasuji* decorate the house's walls, while at the gate, there are woven bamboo ornaments called *panca*. Furthermore, there is *sira'*, an ornament that adorns the *tongko' sila*. *Sira'* are pieces of wood that form geometric objects and are used to cover essential parts of the *tongko'sila*. The number of *tongko' sila* has a symbolic meaning to the status and position of the owner of the house in the community order (Saing, 2010). One-window for the messenger (*ata*), two-window for ordinary people (*tau samara*), three-windowed for people who have an essential role in society (*tau bajik*), and four-windowed for the descendants of nobility (*ana' karaeng*).

(a) (b)

Figure 5. (a) *panca*, (b*) gamacca*

The Use of Horses

Horses are remarkable animals in the culture of the Jeneponto people (Sahajuddin et al., 2020). There is even the only horse market in South Sulawesi Province that connects buyers and sellers from various regions. The horse market operates only on Saturdays. The price of each horse depends on its posture, age, grooming, and use. *Counting activity* is a mathematical idea found in the horse market. Sellers and buyers make bargains based on the factors determining a horse's selling price. Buying and selling in the horse market also involve a third party ready to help the seller find a buyer at the price he wants. The price offered is, of course, more expensive than the price determined by the seller, but the horse will sell more efficiently by using the services of a third party. Mathematical concepts related to buying and selling activities in the horse market, including; social arithmetic, and proportionality.

(a) (b) (c) (d)

Figure 6. (a) horserace, (b) horse market, (c) *coto*, (d) *pabendi*

People use horses as a means of transportation called *bendi*. *Bendi* is traditional transportation still preserved by the community amid hectic motorized vehicles. *Bendi* has a model similar to a wagon: a cart pulled by a horse. The cart has been equipped with circular tires to facilitate the movement of the bendi on the road. *Bendi* is controlled by a person called *pabendi*. A *pabendi* needs to estimate the capacity of passengers or goods, transportation weight, distance traveled, and the ability of the horse to pull the load in a specific time. The cost of maintaining horses and wagons is a determining factor for passenger or freight rates. Mathematical ideas that appear in the activities of *pabendi* include; count, and explaining. Passengers who take advantage of the *bendi* service will receive a fare based on the distance traveled and the amount of load. Therefore, *pabendi* activities are related to the concept of comparison and algebra.

Farmers use horses to plow fields and gardens. Many traditional foods are made from horse meat in Jeneponto, such as *coto* and *gantala*. The price of *coto* and *gantala* is highly dependent on the selling price of horse meat. Horses are a cultural symbol, especially at various traditional events. Processed horse meat becomes the main dish for every party, showing prestige and social status. Therefore, the price of horses is very dynamic in line with the level of demand at a particular time. For example, during holidays and party season. Horse meat processing activities are related to the concept of function, set, and social arithmetic.

Furthermore, the Jeneponto people have popular traditional sports, namely, *paklumbang jarang* (horserace). Horses that can enter the race must meet several conditions, such as; posture, age, and type. Race horses are special horses that have fantastic prices, especially if they win the race. Therefore, the rearing of racehorses is different from that of ordinary horses. Racehorse owners generally entrust their maintenance to other people who are experts. In addition, horse riders, called jockeys, are people who can communicate and have an emotional bond with horses. The horse owner has the responsibility to provide for the maintenance and running costs of the race. When horserace, a jockey has a hand in preparing the horse's emotional state to be stable and spurring the horse during the race. Horserace activities have extensive dimensions and involve mathematical ideas in the form of; count, explaining, and playing. Mathematical concepts that can be connected with horserace, including; function, comparison, and perimeter.

The relationship between cultural objects and mathematical concepts is analyzed using teaching material mapping. The ethnomathematics mapping and development potential in mathematics learning can be seen in Table 2.

Table 2. Ethnomathematical mapping

Cultural object	Dimension	Mathematical activity	Related mathematics concepts
Salting method	Salting plan	Designing, measure	Rectangle, parallel lines, right angles, perimeter
	Windmill	Measure	Angle, circumference of circle, debit
	Salting workflow	Count, play	Numbers, social arithmetic, comparison
	Tide	Count, explaining	Numbers
	Warehouse (*lontang*)	Designing, measure	Geometry, proportionality
Fishing method	Catch	Count, locating	Function, numbers, social arithmetic
	Bagang	Designing, measure, locating	Lines and angles, algebra
	Month period	Explaining	Numbers, statistics
	How to sell fish	Count	Algebra, sosial arithmetic, set
Time system	Auspicious days	Count, explaining	Numbers, set, modulo
	Quality time of the week	Count	Sequence and series
Traditional craft	Woven pattern	Designing	Geometry, function, sequence and series
	Sira'	Designing, measure	Geometry
The use of horses	Horse market	Count	Social arithmetic, proportionality
	Pabendi	Count, explaining	Comparison, algebra
	Coto dan *gantala*	Count	Set, function, social arithmetic
	Horserace	Explaining, play	Function, comparison, perimeter

Construction of culture-based mathematics teaching materials

Teachers need guidance to integrate culture into mathematics learning (Gavarrete & Albanese, 2021). Ethnomathematical mapping has contributed to the development of the design of teaching materials that are compatible with the academic mathematics curriculum. Ethnomathematics is a form of non-formal mathematics that is generally practical, predictive, estimates, predicts, and has philosophical values that the community believes. Unlike the case of the rules of academic mathematics, which are theoretical, logical, deductive, and systematic. However, the content of ethnomathematics requires various standardizations to develop as teaching materials.

The preparation of culture-based mathematics teaching materials can be started by analyzing the curriculum by studying the syllabus and lesson plans. The development of syllabi and lesson plans is essential for integrating culture into mathematics learning (Agustin et al., 2018). The teacher maps the cultural context and dimensions corresponding to the mathematical content. Learning steps that support cultural integration need to be developed. Integrating culture in learning mathematics means that mathematization activities occur in the classroom. Accordingly, various approaches have been used to integrate Sundanese culture into the curriculum (Lidinillah et al., 2022).

Therefore, teaching materials need to facilitate activities that are relevant to the cultural context as a means of discovering mathematical concepts. Teaching materials in the form of activity sheets by inserting cultural activities in learning have the potential to bridge ethnomathematics and academic mathematics. Students recall mathematical concepts through activities as a form of reflective thinking at a higher level (Baba & Iwasaki, 2001). In line with that, teaching materials with the RME model effectively improve students' mathematical literacy skills (Agusdianita et al., 2021). Students follow the flow of concept discovery that is more realistic and readily accepted by using the cultural context. Two advantages can be obtained, namely, (1) students have a belief in the importance of learning mathematics because it is connected to their cultural thinking, and (2) students realize that mathematics develops in cultural activities. Teachers can design learning through project assignments, direct observation, and performance. The teacher becomes the designer of learning instead of being the orator in the classroom. Students have a more prominent role in finding concepts through teacher guidance. In line with that, the design of student worksheets with a cultural context also has the potential to be developed (Sholihah et al., 2022). Likewise, teaching materials based on technology applications are an effective means for teachers to integrate culture into mathematics learning (Johnson et al., 2022; Nuryadi et al., 2022). Teachers use traditional food context media as a means of integrating culture into mathematics learning (Mania & Alam, 2021).

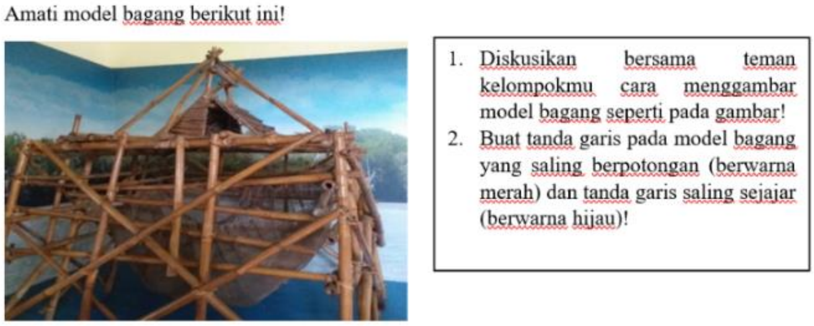


Figure 7. Cultural activity-based mathematics learning

Assignments are a critical element in supporting student learning success. However, instructional guidance is still needed so that students understand the relationship between mathematical concepts in culture. A module is a tool that can guide students to learn culture-based mathematics. Modules have advantages over books provided by the curriculum. The module is developed according to the characteristics of students. The substance of the material is focused on specific units so that it is easier for students to understand the content. The module has a specific learning development goal, including integrating culture into learning. The module has a tutorial nature so that students can learn independently. This opinion is in line with the Sumbawa culture-based mathematics module, which is equivalent to the introductory concepts of algebra and geometry (Yuliani & Irham, 2022).

CONCLUSION

Mathematical ideas can be found in various community activities and cultures, such as; count, playing, measuring, locating, designing, and explaining. The integration of ethnomathematics in learning has various levels. Ethnomathematics requires teaching materials that synergize with cultural values to apply in the classroom quickly. Teachers can design syllabi and lesson plans that become signs of culture-based learning in the classroom. Furthermore, teaching materials in the form of cultural-based activity sheets, cultural project-based task sheets, and modules are needed in the ethnomathematical integration process. This study recommended that the influence and contribution of culture-based teaching materials in mathematics learning can be explored further.

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