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ETHNOMATHEMATICS IN TEN INDONESIAN TRADITIONAL MUSICAL INSTRUMENTS

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Abstract: This article aimed to describe the results of the ethnomathematical exploration of traditional musical instruments that can be used as mathematics teaching materials. The research method chosen in this study was the Systematic Literature Review (SLR) method. The SLR method is used to identify, review, evaluate, and interpret available research with areas and topics of interest. Data collection is done by documenting and reviewing all articles related to ethnomathematics on traditional musical instruments, selecting only those using Indonesian traditional instruments, and publishing them in Indonesian national journals. It was found that 10 articles matched these criteria. The results showed that ethnomathematics-based mathematics learning on traditional musical instruments can be used in the learning process and can be used as a learning resource, a means of introducing mathematics through culture, implemented in mathematics learning, and as teaching materials in learning mathematics. The uses in learning can be the shapes of the instruments as well as how to play the instruments that yield number patterns.

Keywords: exploration, ethnomathematics, Indonesia, traditional musical instruments

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INTRODUCTION

Culture and education are two elements that are interrelated in daily life since culture is a complete comprehensive unit that applies in both society and education and is a basic need for every individual. Culture may change in accordance with the development of people's mindsets. Mathematics is part of a culture and is implemented and used to conduct an innovative analysis (Wulandari & Puspadewi, 2016).

Mathematics does not only manifest itself in culture but also exists all around us, who naturally use mathematics in art and all activities in general (Boaler, 2016). In addition, the National Council of Teachers of Mathematics (NCTM) has long highlighted the importance of building relationships between mathematics and the culture existing around students' environment (NCTM, 1991).

Cultural integration in learning mathematics that plays a very important role in mathematics teaching-learning practices should be suited to students' needs, especially for practical, aesthetical, and recreational reasons (Wulandari & Puspadewi, 2016). A person's mathematics ability is influenced by cultural background and what he sees and feels. In other words, "*When practical or culturally-based problems are examined in a proper social context, the practical mathematics of social groups is not trivial because they reflect themes that are deeply linked to the daily lives of students*" (Rosa & Orey, 2006).

Culture can be interpreted by how members of certain groups interpret their experiences through languages, symbols, values, norms, social practices, and uses of artifacts (Banks, 2016). Mathematics as an activity (Marsigit, 2016) and concepts implemented by certain cultural groups is known as Ethnomathematics (D'Ambrosio, 1985; D'Ambrosio, 1986). Barton defines Ethnomathematics as a field of study that examines the way a group of people in a particular culture understand, express, and use cultural concepts and practices that are defined by researchers as something mathematical (Turmudi, 2017).

Since it was first coined in 1977, Ethnomathematics has continued to be developed and known by the world through D'Ambrosio's writings and speeches at various conferences (Hidayati & Prahmana, 2022). The rapid development of Ethnomathematics has also occurred in Indonesia. Since 2011-2022, 787 scientific articles have been published and recorded by the Garuda website (https://garuda.kemdikbud.go.id), as accessed on October 21, 2022, at 10.00 a.m using the keyword "ethnomathematics".

There are 358 ethnic groups and 200 sub-tribes in Indonesia (Zubair, 2003). The 2010 Population Census recorded that there were 1,340 ethnic groups in Indonesia (BPS, 2017). One of the cultural artifacts from Indonesia is traditional musical instruments (Depdikbud, 1994). Thus, almost every region in Indonesia has traditional musical instruments.

Traditional musical instruments are an integral part of traditional music and one of Indonesia's cultural heritages as stated in Law Number 5/2017 concerning Culture Promotion (Pemerintah Indonesia, 2017). These traditional musical instruments can be in the form of one or a set of instruments. These musical instruments have various forms and functions, and they can be further explored in the field of education.

Musical instruments have long been known to function as mathematics learning sources, materials, and media. The history of music in the West recorded that Pythagoras succeeded in combining mathematical theory by creating musical scales through various experiments using several bells of different sizes, glasses filled with different amounts of water, and strings stretched in different levels of tension (Depdikbud, 1994). In addition, people commonly do not realize that there is a connection between musical instruments and mathematical concepts.

Effective learning resources and media allow students to easily transform learning messages into learning experiences (Ghufron, Budiningsih, & Hidayati, 2017). Using the right mathematics learning media, students can understand the use of mathematics concepts instead of just memorizing them (Rohaeti, Bernard, & Primandhika, 2019). The use of traditional musical instruments in learning mathematics will help students to master

the mathematical concepts being taught. In addition, teachers can present interesting and meaningful learning.

This study examined how previous studies had revealed ethnomathematics in traditional musical instruments, the relation between traditional musical instruments and mathematical concepts, and the application of ethnomathematics learning. The learning that became the focus of analysis made use of cultural artifacts, namely traditional musical instruments in mathematics classes.

METHOD

The method used in this research is Systematic Literature Review (SLR). It is a qualitative approach that is used to summarize the results of primary research which are descriptive qualitative in nature and to present facts that are more comprehensive and balanced (Siswanto, 2010; Page et al., 2021). There are several stages carried out in this research, namely problem formulation, literature review, literature selection, data presentation, data processing, and conclusion drawing. In the first step, the questions formulated are as follows.

1. What are the traditional musical instruments that have been explored in ethnomathematics research?
2. What are the mathematical concepts existing in traditional musical instruments?
3. Can traditional musical instruments be used in teaching mathematics?

The second step, a literature search, was conducted on Garuda website to find articles published between 2018 and 2021. *Garba Rujukan Digital*, often abbreviated as Garuda is a website providing scientific references from Indonesia and access to scientific works written by Indonesian academics and researchers (Wahyudin, 2010). Currently, there are 2,201,748 articles available, and they can be accessed for free on the website.

The next process was selecting literature to obtain articles relevant to the research objectives. The following are the criteria for selecting the literature:

a. Research articles published in national journals
b. Articles written in the Indonesian language
c. Article available in full papers
d. Article examining and exploring mathematical concepts through traditional musical instruments.

Eleven articles with the same keyword on the titles were obtained from the Garuda website. Meanwhile, based on the abstracts, there were ten papers. Then, only nine papers were selected from them. To support the result of the review, an initial search was carried out using the same keywords on Google Scholar to identify pre-existing reviews (Martín-Martín, Orduna-Malea, & Delgado López-Cózar, 2018; Page et al., 2021). After analysis, one article was obtained from Google Scholar, so the total number of articles analyzed in this study was 10. Furthermore, the researchers conducted data tabulation in a table. We reviewed and described the articles, especially the result section. At last, we compared the results and drew a conclusion.

RESULTS AND DISCUSSION

Ten full papers that met the criteria were then examined. There were two articles published in 2018, four articles published in 2019, one article published in 2020, and three articles published in 2021. Almost all the articles were published by national journals accredited by (Sinta 2-Sinta 5) and there was only one article published in a national journal that had not been accredited at the moment. The results are presented in detail in Table 1.

There were 787 scientific articles that were not published and recorded through the Garuda website. They contained the word "ethnomathematics" and were published from 2011 to 2022. However, there were limited articles that specifically used the context of traditional musical instruments. In other words, the possibility to explore traditional musical instruments in Indonesia through ethnomathematics research was real.

Table 1. The result of Ethnomathematics study through traditional musical instruments

No.	Result	Journal Title	References
1.	The exploration of mathematical concepts on the Gordang Sambilan musical instrument shows that the musical instrument shapes represent the basic concepts of geometry of circles, tubes, cones, and truncated cones. Meanwhile, the size of the radius of the roof and plinth, the diameter of the roof and plinth, the height, circumference, and the cover of *Gordang Sambilan* form an arithmetic sequence pattern where the difference of two terms that are in order is always constant. *Gordang Sambilan* musical instrument is one of the Mandailing tribe music instruments that can be used in learning mathematics. As the shapes of *Gordang Sambilan* resemble a tube and a truncated cone, they may serve as tools to introduce mathematical concepts such as geometry. By doing so, students will understand abstract mathematical concepts more easily. The size of the nine instruments in *Gordang Sambilan* shows an arithmetic series. Exploring culture as a medium for learning, it is expected that students can understand learning materials more easily, develop an attitude of love for culture, and preserve culture from learning at school. The mathematical concepts in *Gordang Sambilan* can make learning mathematics in class more meaningful.	Edumatika : Jurnal Riset Pendidikan Matematika - Sinta 3	Lubis, Mujib, & Siregar (2018)
2.	Mathematical concepts presented by *Angklung Paglak* Banyuwangi include: (1) the concept of two or three-dimensional shapes, such as rectangles, isosceles triangles, right triangles, trapezoids, circles, tubes, rectangular prisms, and triangular prism; (2) the concept of traditional units of measure; (3) the concept of similarity in size; and (4) the concept of combination.	AKSIOMA: Jurnal Program Studi Pendidikan Matematika - Sinta 2	Hidayatulloh & Hariastuti (2018)

No.	Result	Journal Title	References
3.	There is an Ethnomathematics concept presented by Banyuwangi traditional musical instruments. *Kendang*, one of the musical instruments from Banyuwangi, has a mathematical element, namely a two-dimensional shape. *Saron* shows a mathematical element of the arithmetic sequence. In *Bonang*, there are elements of mathematics, namely geometric shapes and congruence. In *Gong*, there is a mathematical element that lies in the shape of the gong that resembles a truncated cone. *Angklung* has a mathematical element of the arithmetic sequence. *Kluncing* represents a mathematical element of two-dimensional shapes. The teaching materials developed in this study are in the form of student worksheets with the topic of ethnomathematics on traditional Banyuwangi musical instruments. The topics included in the worksheets are two-dimensional shapes, geometric shapes, and arithmetic sequences.	KadikmA - Sinta 5	Andarini *et al.* (2019)
4.	Mathematical concepts found in *Marawis* (Arabic percussion) musical instruments are circular geometric shapes, reflection, translation, folding symmetry, rotational symmetry, acute angles, and obtuse angles. The mathematical concepts found can also make it easier for Marawis musical instrument craftsmen to minimize the use of molds in the manufacturing process. The results of this study can be a source of learning mathematics at various levels of education, namely elementary, junior high, and senior high schools.	Jurnal Gantang - Sinta 3	Afriyanty & Izzati (2019)
5.	There is a mathematical concept of cylindrical geometric shapes found in *Lamba/Gendang* and circular two dimensional-shapes found in *Nggo*/*Gong*. Learning mathematics using ethnomathematics objects can expand existing mathematical applications using things around the students. Ethnomathematics can also help students understand abstract mathematics concepts using concrete ethnomathematics objects.	OPTIKA: Jurnal Pendidikan Fisika/Jurnal Dinamika Sains - Sinta 5	Dhiki (2019)
6.	The results of ethnomathematics analysis of Bengkulu Traditional Musical Instruments show that they have the concept of circles, and as a result, they can be used as tools and media to learn mathematics. Students can find and recognize directly the surface forms of these musical instruments based on certain contexts. This will make them more active in class. They can also understand the concept of circles and relate Bengkulu local wisdom with mathematics. The parts or shapes of the traditional Bengkulu musical instruments show the concepts of circles which can be used as media and visual aids in conveying the circle concept.	Jurnal Pendidikan Matematika Raflesia (JRPM) – Sinta 4	Widiarti, Anggreni, & Sari (2019)

No.	Result	Journal Title	References
7.	Toba Batak traditional musical instruments have various mathematical concepts such as the concept of two-dimensional shapes and geometrical concepts. Based on the results of the analysis of *Pangora* shape, there is a geometric concept of a circle. The shape of *Sarune Bolon* represents the geometric concept of an isosceles triangle. The shape of *Garatung* also represents a geometric concept of a rectangle and trapezoid. The shape of *Taganing* represents a geometric concept of a tube. Then, *Sarune Bolon* resembles a cone. Musical instruments can be concrete and innovative learning resources. They can help improve students' thinking processes and make learning more meaningful.	Jurnal PEKA (Pendidikan Matematika)	Sitanggang (2020)
8.	The mathematical concepts shown by Javanese Gamelan musical instruments include one-dimensional geometry (lines, parallel lines, and right angles); two-dimensional geometry (squares, rectangles, circles, trapezoids, and triangles); and three-dimensional geometry (tubes, spheres, and truncated cones). Mathematical concepts in Javanese gamelan musical instruments allow mathematics learning media to be designed using Javanese gamelan so that mathematics is able to preserve national culture.	Math Educa Journal – Sinta 5	Supriyono, Purwaningsih, & Saputra (2021)
9.	The mathematical concepts in musical instruments used in *Reyog* Ponorogo are geometry, transformation, and geometric sequences. The geometric concepts include circles, truncated cones, trapezoids, tubes, and ellipses. The concepts of transformation are reflection and translation. Thus, Reyog Ponorogo musical instruments can be used as alternative learning media that can improve students' mathematical literacy.	Jurnal Pendidikan Matematika - Sinta 4	Damaningrum & Budiarto (2021)
10.	Tambourine contains mathematical concepts, especially those related to three-dimensional geometry, namely tubes and cones. The *Hadroh* Bass shows the concept of a tube. Moreover, *Terbangan* and *Tung Tam Keprak* also present the same mathematics concept of tubes. Although it looks slightly different from the shape of a cone, if people pay closer attention, *Darbuka* is a combination of two cones. Tambourine is more suitable to be used with the cooperative learning model to teach geometry.	Jurnal Pendidikan Matematika (Kudus) - Sinta 4	Mu'asaroh & Noor (2021)

Figure 1 shows the number of citations of the ten articles reviewed. The highest number of citations was from articles published in 2019. The number of citations of articles published before (2018–2019) and during the COVID-19 pandemic (2020–2022) showed a big difference. Social restrictions are suspected to be the main factor for the low level of research on traditional musical instruments or other cultural artifacts because this type of research requires researchers to come in person and not many cultural artifacts can be accessed virtually.

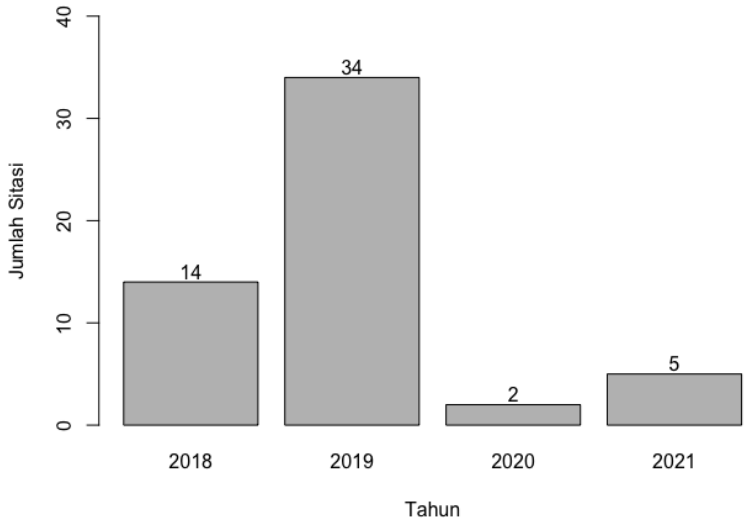

Figure 1. The number of citations from articles about Ethnomathematics in traditional musical instruments

Traditional Musical Instrument Exploration

The reviewed ethnomathematics papers discuss quite a variety of traditional musical instruments. These musical instruments come from various provinces in Indonesia, such as North Sumatra, East Java, Riau Islands, East Nusa Tenggara, Bengkulu, D.I. Yogyakarta, and Central Java. In total, it is still less than 20% of the current total of 34 provinces. The complete results are shown in Table 2.

Table 2. Traditional musical instruments explored in ethnomathematics studies

No.	Musical Instrument	Area of Origin
1.	*Gordang Sambilan*	Mandailing Natal, Sumatra Utara
2.	*Angklung Paglak*	Banyuwangi, Jawa Timur
3.	*Kendang*, *Saron*, *Bonang*, *Gong*, *Angklung*, dan *Kluncing*	Banyuwangi, Jawa Timur
4.	Marawis: *Hajir*, *Marwas*, dan *Darbuka*	Kota Tanjung Pinang, Kepulauan Riau
5.	*Lamba*/*Gendang* dan *Nggo*/*Gong*	Ende, Nusa Tenggara Timur
6.	*Dol*, *Redap*, *Kulintang*, dan *Tassa*	Kota Bengkulu, Bengkulu
7.	*Sarune Bolon*, *Panggora*, *Garatung*, *Taganing*, *Hapetan*, *Gondang*, *Ihutan*, *Sarune Bulu* dan *Sulim*	Toba, Sumatra Utara
8.	Gamelan Jawa: *Saron*, *Bonang*, *Siter*, *Rebab*, *Kenong*, *Gong*, *Ketuk*, dan *Kendang*	Kulonprogro, D.I. Yogyakarta
9.	Reyog Ponorogo: *Gong*, *Gayor*, *Kedhang*, *Ketipung*, *Angklung*, dan Terompet	Ponorogo, Jawa Timur
10.	*Bass Hadroh* dan *Rabuka*	Demak, Jawa Tengah

The results of the study show that several musical instruments have the same name, for example, *Gong*. However, ethnomathematically there are differences in how people in East Java, East Nusa Tenggara, and D.I. Yogyakarta understand, express, and

use the concepts of the traditional musical instrument. In East Java, Banyuwangi, and Ponorogo, *Gongs* are made of different materials, have different sound characteristics, and present different mathematical concepts (Andarini et al., 2019; Damaningrum & Budiarto, 2021).

Mathematical Concepts in Traditional Musical Instruments

The concept of geometry is the most frequently explored mathematical concept in ethnomathematics research on traditional musical instruments. It is in line with previous studies that found that more than half of ethnomathematics research includes geometric content (Hidayati & Prahmana, 2022). Geometry concepts in traditional musical instruments such as two-dimensional shapes (rectangles, isosceles triangles, right triangles, trapezoids, and circles) and three-dimensional shapes (cylinders, rectangular prisms, triangular prisms, and cones).

Meanwhile, the less discussed concepts are reflection, translation, folding symmetry, rotational symmetry, acute angle, and obtuse angle. Besides, the mathematical concepts in traditional musical instruments are related to number patterns such as arithmetic sequences, traditional units of measurement, similarity in size, combinations, sequence, and congruence. Table 3 shows the mathematical concepts from the exploration of each traditional musical instrument.

Table 3. The mathematical concepts of traditional musical instruments

No.	Name of Musical Instrument	Mathematical Concept
1.	*Gordang Sambilan*	Arithmetic and geometric sequences
2.	*Angklung Paglak*	Two or three-dimensional geometric shapes such as rectangles, isosceles triangles, right triangles, trapezoids, circles, and other geometric shapes such as cylinders, rectangular prisms, triangular prisms, traditional units of measurement, same size, and combination
3.	*Kendang*, *Saron*, *Bonang*, *Gong*, *Angklung*, and *Kluncing*	Two-dimensional shapes, arithmetic sequences, space and congruence shapes
4.	Marawis: *Hajir*, *Marwas*, and *Darbuka*	Geometric shapes of circles, the concepts of reflection, translation, folding symmetry, rotational symmetry, acute angles, and obtuse angles
5.	*Lamba*/*Gendang* and *Nggo*/*Gong*	Tubes and circles
6.	*Dol*, *Redap*, *Kulintang*, and *Tassa*	Circles
7.	*Sarune Bolon*, *Panggora*, *Garatung*, *Taganing*, *Hapetan*, *Gondang*, *Ihutan*, *Sarune Bulu*, and *Sulim*	Geometry of two-dimensional shapes and three-dimensional shapes
8.	Gamelan Jawa: *Saron*, *Bonang*, *Siter*, *Rebab*, *Kenong*, *Gong*, *Ketuk*, and *Kendang*	One-dimensional geometry (lines, parallel lines, and right angles); two-dimensional geometry (square, rectangle, circle, trapezoid, and triangle); and three-dimensional geometries (tubes, spheres, and truncated cones)

No.	Name of Musical Instrument	Mathematical Concept
9.	Reyog Ponorogo: *Gong*, *Gayor*, *Kedhang*, *Ketipung*, *Angklung*, and Terompet	Geometry (circles, truncated cones, trapezoids, cylinders, and ellipses), transformations (reflections and translations), and geometric sequences
10.	*Bass Hadroh* and *Rabuka*	The three-dimensional (cylinders and cones)

Implementation of Traditional Musical Instruments in Mathematics Learning

Based on the results of the analysis, traditional musical instruments as cultural artifacts can be used by students to learn mathematics (Andarini et al., 2019; Damaningrum & Budiarto, 2021; Mu'asaroh & Noor, 2021). In addition, Ethnomathematics research on traditional musical instruments can be used as a learning resource (Afriyanty & Izzati, 2019; Dhiki, 2019; Sitanggang, 2020). It also serves as a means of introducing mathematics through local cultures (Lubis, Mujib, & Siregar, 2018), developing learning designs (Hidayatulloh & Hariastuti, 2018), designing realistic mathematics learning, and conducting outside classroom learning (Widiarti, Anggreni, & Sari, 2019). The traditional musical instruments contribute to national culture preservation (Supriyono, Purwaningsih, & Saputra, 2021).

Ethnomathematics uses cultural artifacts (traditional musical instruments) to study mathematics. Ethnomathematics which is integrated into the curriculum and carried out in class experiments is able to increase students' self-perception and motivation, and it has a social impact of changing students' positive attitudes towards their culture and ancestors (Amit & Abu Qouder, 2017). Therefore, the study of mathematics based on local cultures is important because introducing local wisdom can build student character (Turmudi, 2017). In addition, providing problems with an ethnomathematics context is proven to help students understand the problems presented to assist students in conducting further analysis and reasoning processes from the data obtained (Ramadhani, Saragih, & Napitupulu, 2022).

The results of this review show that traditional musical instruments are theoretically feasible to be used as a source of learning mathematics, but they still need to be proven empirically. It is also necessary to pay attention to possible culture-based mathematics learning or ethnomathematics problems that are related to 1) students' mindsets and interests, 2) students' ability to use learning resources and innovation; and 3) practical obstacles (Peni, 2019).

CONCLUSION

The results of this review show that ethnomathematics based on traditional musical instruments can be used in the learning process as a learning resource. It also serves as a means of introducing mathematics through culture and implementing mathematics learning. Moreover, it functions as a mathematics learning material. The shapes and how to play the instruments can be further analyzed to teach number patterns.

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