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Exploring Ethnomathematics in Batak Toba Carvings for Locally-based Mathematics Teaching Material

Candra Ditasona[1*]

[1] Mathematics Education, Universitas Kristen Indonesia, Jakarta, Indonesia

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ABSTRAK

Sebagai salah satu ornamen adat suku Batak Toba, "gorga" memiliki makna filosofis dan berfungsi untuk memperindah dekorasi rumah adat. Motif gorga memiliki ciri khas tersendiri, dengan pola yang tersusun rapat dan desain yang simetris. Hal ini menunjukkan adanya aspek matematis dalam pola ukiran gorga tersebut. Penelitian ini bertujuan untuk menganalisis kesimetrian yang terdapat pada motif gorga yang dapat dimanfaatkan sebagai bahan ajar matematika berbasis lokal. Kajian dilakukan dengan mengeksplorasi berbagai motif gorga dan menganalisis jenis simetrinya. Penelitian ini menggunakan pendekatan penelitian etnografi. Pengumpulan data dilakukan dengan mengamati bangunan yang berhiaskan motif gorga, mempelajari literatur, dan melakukan wawancara dengan pemahat gorga. Analisis data kualitatif dapat dimulai dengan reduksi data, penyajian data, penarikan kesimpulan dan verifikasi. Hasil penelitian mengungkapkan adanya tujuh jenis simetri yang diperoleh dari semua motif gorga. Jenis-jenis simetri ini meliputi simetri translasi, simetri luncuran refleksi, simetri vertikal, simetri rotasi 180°, simetri vertikal dan rotasi 180°, simetri horizontal, dan simetri vertikal dan horizontal.

ABSTRACT

As one of the traditional ornaments of the Batak Toba tribe, "gorga" carries philosophical meaning and serves to embellish the decoration of traditional houses. The gorga motif has its own distinctive characteristics, with closely arranged patterns and symmetrical designs. This indicates the presence of mathematical aspects within these carved gorga patterns. This research aims to analyze the symmetries embedded in the gorga motifs that can be utilized as locally-based mathematics teaching material. The study is conducted by exploring various gorga motifs and analyzing their types of symmetry. The research is employing an ethnographic research approach. Data is collected through observing buildings adorned with gorga motifs, studying literature, and conducting interviews with gorga carvers. Qualitative data analysis can be started with data reduction, data presentation, drawing conclusions and verification. The research findings reveal the existence of seven types of symmetry obtained from all gorga motifs. These symmetry types include translation symmetry, glide reflect symmetry, vertical symmetry, rotation 180° symmetry, vertical and rotation 180° symmetry, horizontal symmetry, and vertical and horizontal symmetry.

1. INTRODUCTION

Academically mathematics consists of knowledge of facts, algorithms, axioms and theorems as well as symbols and provisions that have been mutually agreed upon and apply universally. The teaching of mathematics that has been carried out so far has made mathematics more general in nature (Gupta et al., 2022; Lahdenperä et al., 2022). This makes mathematics acceptable and understood by anyone in various countries, as a science that is culturally free. Mathematics is always taught in schools as a culture-free subject which is a universal learning with the aim that its concepts and contents can be accepted and used by anyone (Booth et al., 2017; Winiarsih et al., 2021). But in its development it makes mathematics difficult for students to understand because it is abstract. Therefore, presenting mathematics that is related to the context of everyday life and the cultural context of students can be a solution to this gap. Mathematics has actually integrated with culture and become part of people's lives so that there is no point in teaching mathematics as an abstract concept without integrating culture into it (Abroriy, 2020; Febriyanti et al., 2019).

The use of cultural context in mathematics education has several highly relevant benefits. Understanding mathematics in a cultural context can make the learning material more relevant for students. This helps students see how mathematical concepts can be applied in their everyday lives and in various cultural contexts (Colliver, 2018; Prahmana & D'Ambrosio, 2020). Moreover, incorporating cultural context in mathematics education can also aid students in better comprehending mathematical concepts. Concepts

*Corresponding author.
E-mail addresses: candraditasona@gmail.com (Candra Ditasona)

that may be abstract or challenging to grasp become more concrete and tangible when illustrated with culturally relevant real-life cases (Hidayat et al., 2020; Simanjunntak & Imelda, 2018).

In the Indonesian curriculum document, namely the 2013 curriculum, the philosophical foundation contains the role of culture in education. One of the statements on the philosophical basis of the curriculum is that education is rooted in national culture to build the present and future life of the nation. If you observe the philosophical basis, the 2013 curriculum has provided space to be able to integrate cultural elements into learning (Morrar et al., 2017; Tholani, 2013). In culture-based learning, students use culture as a way to transform their observations into more creative forms of understanding. One such learning is ethnomathematics. The term ethnomathematics (ethnomathematics) is used to express the relationship between culture and mathematics. Ethnomatematics examines various ideas, ideas, methods, mathematical practices developed by people from various cultures (Maryati & Prahmana, 2018; Rosa et al., 2016; Rosa & Orey, 2011b). One of the main goals of ethnomathematics is to build a civilization that respects differences and is free from discrimination. Ethnomathematics offers students the chance to recognize and appreciate the unique contributions that various ethnic groups have made to the advancement of mathematics (Rosa et al., 2017; Sirate, 2011; Wahyuni et al., 2021). As a result, students can develop a greater understanding and appreciation for diversity, which can lead to positive outcomes such as increased appreciation for differences among individuals.

Indonesia is a multicultural country. Consists of thousands of tribes with diverse cultures. This has contributed to the increasing study of ethnomathematics in Indonesia. The study of ethnomathematics can include traditional house buildings, dances, counting methods, traditional games, weaving, and various aspects of traditional culture. For example, ethnomathematics studies on Batak culture have greatly increased in recent years. Ethno-mathematical research related to the Batak ethnicity includes studying ulos weaving, music instrument, and traditional house (C. Ditasona, 2018; Hidayat et al., 2020; Marta & Simorangkir, 2023; Rahmadani & Reflina, 2023).

One part of Batak culture which is very rich in mathematical concepts and is interesting to study is *gorga* carving. *Gorga* is one type of ornament that is owned by the Batak people. In general, *gorga* carvings have a very distinctive shape with pattern characteristics that tend to be tightly packed. The use of colors in *gorga* carvings only consists of three colors, namely red, white and black. Both the colors and the motifs found on the *gorga* reflect the Batak people's philosophy of life. Carved forms like *gorga* are not found in other tribes in the archipelago. With this uniqueness, this *gorga* motif can only be found in North Sumatra. The highest distribution is in the Toba and Samosir regions.

As an ornament, *gorga* also experienced development. Previous study state *gorga* could only be found on the walls of traditional houses, now they can be found in market buildings, government offices, places of worship, tombs, and private houses (Hasudungan et al., 2016). *Gorga* has become an icon that represents the identity of the Batak people. As an identity, of course *gorga* has its own philosophy for the Batak people. In addition to beautifying a building, for the Toba Batak tribe, *gorga* also has a philosophical meaning, religious meaning, and shows the pride of the owner of the building (Hidayat et al., 2020; Simanjuntak et al., 2020).

With the characteristics of the carvings which tend to be close together, and the transformation patterns contained in the *gorga* carvings, precise measurements are needed to make the motifs arranged neatly and beautifully. It takes special skills possessed by the sculptor to make *gorga*. Previous studies have shown that the concepts of transformation geometry and arithmetic sequences are used in making *gorga* (C. Ditasona, 2018; Candra Ditasona et al., 2021). Based on these findings, this study aims to analyze the patterns of symmetry in the various *gorga* motifs.

2. METHODS

This research is a qualitative research. Research that seeks to understand certain phenomena, processes, or meanings behind people's worldviews and experiences usually begins with qualitative investigations. It is based on the belief that qualitative research methods provide a deeper understanding of social phenomena than would be obtained from a purely quantitative approach (Silverman, 2014). Several characteristics of qualitative research, first, the researcher plays a major role in data collection and analysis. Second, the research process is inductive, because each theory developed is based on observations and understanding from the investigation. Third, the product of qualitative inquiry is highly descriptive. Instruments such as drawings and field notes are used to convey what has been learned about the phenomenon investigated, and support research findings.

The characteristics of qualitative research are: (1) conducted in natural conditions, with direct target at the data source, and the researcher is the key tool; (2) this research is more descriptive in nature; (3) the emphasis in qualitative research prioritizes processes rather than products or results. (4) Data

analysis in qualitative research is done inductively; (5) Qualitative research emphasizes the meaning behind the observed data (Bogdan & Biklen, 2007). This type of research is ethnographic research. Ethnography refers to qualitative research involving cultural descriptions. Since ethnomathematics has social and cultural foundations, a useful methodology for the study of ethnomathematics is ethnography. The stages of ethnographic research include: (1) Choose the problems; (2) Review the literature related to the problem; (3) Designing the research; (4) Collect data; (5) Analyzing the data; (6) Interpret findings and make conclusions; (7) Results reporting (Abdullah, 2017; Fouze & Amit, 2018).

This research was conducted in two adjacent districts, namely Toba and Samosir District, North Sumatra Province. The objects observed in this study include buildings, as well as cultural heritage objects that use *gorga* ornaments. This research involved several informants such as traditional leaders, *gorga* sculptors, as well as building owners or traditional houses that have *gorga* ornaments. The selection of resource persons was determined by their understanding of history, the meaning of philosophy, and their direct involvement in the practice of making *gorga* carvings. The role of this resource person is to produce a description of the phenomenon being observed. The educational background of the resource persons was quite varied. Especially for engravers who have educational backgrounds from junior high school graduates to high school graduates. They do not get skills and knowledge about *gorga* carving from school, instead they learn carving knowledge from generation to generation through their parents or ancestors.

The data collected in this study used several instruments including observation, interviews, photographs and video recordings to see the process of making *gorga*. In this study, the researcher chose the Participant as Observer position, where the researcher participated in activities at the location. But still giving the role to the participant is more prominent than the role of the researcher (W.Creswell & N.Poth, 2018). The type of interviews conducted in this study was semi-structured interviews. The purpose of using semi-structured interviews in this study was to collect as much information as possible, because with these interviews the questions asked by the researcher and the answers given by the informants were more open.

Qualitative data analysis can be started with data reduction. Data reduction refers to the process of selecting, focusing, simplifying, abstracting, and/or changing the data that appears in the intact material from written field notes, interview transcripts, documents, and other empirical materials (Miles & Huberman, 2014). The second step of qualitative data analysis is data presentation. Data can be presented in the form of charts, brief descriptions, relationships between categories, or flowcharts. This is intended to display information in a more concise and easy-to-understand form so that researchers can see the overall picture and make it easier to carry out further analysis. The third step is drawing conclusions and verification. Conclusions will be verified in further analysis. Verification can be done by reviewing the data reduction process, presenting data, and drawing initial conclusions. This cycle will always be done every time a new conclusion is found. In testing the validity of the data obtained in this study, researchers used a credibility test by extending the observation period and triangulating data sources. Data triangulation was carried out by collecting and analyzing several types of data and data collection methods such as interview data, observation data, data from video, audio and photo recordings and related literature studies.

3. RESULT AND DISCUSSION

Results

Gorga motifs tend to be complicated and difficult to paint. The complex transformation patterns, tight image details, and the color combinations in the *gorga* make it seem complicated. Based on the results of interviews and direct observations, the researchers found that making *gorga* motifs is not as difficult as we imagine. Every *gorga* motif always has a basic motif called *mal*. *Mal* is used by *pande* (a term for *gorga* carvers) to make it easier to draw *gorga* motifs so that they look neat and beautiful. the process of drawing motifs using malls is carried out like the tracing process to produce a complete *gorga* motif. From one type of *mal* can produce different motifs depending on how to put the *mal* on the board. Some of the techniques used include shifting, rotating the *mal*, flipping the surface of the *mal* and others.

The method of making *gorga* using *mal* allows the formation of motifs with symmetrical patterns. The different ways of translating, rotating and reversing the *mal* will also produce different motives. According to the interview results of all engravers, changes in the position of the *mal* by rotating, flipping, shifting are done so that the resulting motifs are more varied. For example, if we draw all the motifs by simply sliding, the impression will be more monotonous. This variation in the arrangement of the mall gives the impression that the carving looks complicated but still has a pattern. Based on observations of several existing *gorga* motifs, researchers observed that there are seven patterns of symmetry found in the *gorga* motif, including translational symmetry, glide reflect, vertical symmetry, horizontal symmetry, 180° rotational symmetry, vertical and 180° rotational symmetry, vertical and horizontal symmetry. Results are

the main part of scientific articles, containing: final results without data analysis process, hypothesis testing results. Results can be presented with tables or graphs, to clarify the results verbally.

Symmetry Type 1

Symmetry in type 1 is also called translational symmetry. One example of a carving that has translational symmetry is shown in Figure 1.

Figure 1. Gorga Motif's with Translational Symmetry

The motif from Figure 1 generated through the mal contained. The drawing process begins with placing the mal in a position. To draw the next motif, pande then shifts the mal to the right and places it right after the first image is produced. The following drawings, the same method is repeated until the entire area is covered by the motif. Based on the drawing process, if it is illustrated using letters, then the patterns found follow the "pppp…" pattern.

Symmetry Type 2

Symmetry type 2 is glide reflect symmetry. The gorga motif that has a pattern like this the researchers found in the following types of gorga iran-iran as show in Figure 2.

Figure 2. Glide Reflect Symmetry on Gorga Iran-Iran

Base on Figure 2 to produce the iran-iran gorga motif, the first step taken by pande is to place the mal in the initial position. From the position of the first image, the engraver folds the mal to the right (vertical reflection) then proceeds to rotate it 180° and attach it right next to the first motif. For the third motif, the engraver folds the mal horizontally again followed by rotating it 180° then attaches it right after the second motif. This method is repeated until the field is filled with images. This arrangement pattern follows the "qdqd…" pattern.

Symmetry Type 3

This type of symmetry is a mirror that is done vertically. One of the gorga motifs that has a pattern like this can be seen in Figure 3.

Figure 3. Gorga Jenggar

The pattern for making *gorga jenggar* is quite simple. From the mall as shown in Figure 3 the sculptor folds the mall vertically so that a complete motif is obtained. The symmetry pattern follows the "pqpqpq…" pattern.

Symmetry Type 4

This type of symmetry is also called 180° rotational symmetry. One of the gorga motifs whose pattern follows this type of symmetry is as shown in the *gorga simarogung-ogung* motif as show in Figure 4.

Figure 4. Gorga Simarogung-ogung

Base on Figure 4, to get the *gorga* simarogung-ogung motif, *pande* initially placed the mall. For the next image, *pande* will rotate the initial motif by 180° and then paste it right after the initial motif as. This pattern can be best illustrated as "bqbq ..."

Symmetry Type 5

Symmetry type 5 is vertical symmetry and rotation 180°. Researchers find this symmetry pattern in the *gorga si tompi* motif as shown in Figure 5.

Figure 5. Gorga Sitompi

The *gorga* sitompi motif looks solid and tends to be complicated. However, we can take this part of *gorga* sitompi to simplify it as shown in Figure 5. Even though it looks complicated, actually how to draw *gorga* sitompi is very simple. According to *pande*'s explanation, how to draw this motif is done by dividing the drawing area into several lines. If we simplify the shape of the motifs, each line will look like. To draw this motif, *pande* only uses one mall. The first way to do this is to draw using a mall as in the position in Figure 6.

Figure 6. Vertical Symmetry and Rotation 180°

Base on Figure 6 the next process is *pande* folding the mall to the right (mathematically we know this as a vertical reflection) so that an image is produced. To get the next image, from the position then rotate 180° and then attach it right next to the previous image so that it produces. From a position like *pande* folds the mall to the right (vertical reflection) to obtain. The next image will again resemble obtained by

rotating the mall. The mall is rotated 180° and attaches it right after. In this way the motif is drawn repeatedly so that all rows are filled with images.

For other rows, variations are made in drawing them. For example, if the first row starts with a position then the second row will start with a mal position. Based on observations of the entire process of drawing the *gorga* sitompi, it was found that the motif has vertical symmetry and 180° rotation with a drawing pattern that follows the pattern "bdpqbdpq ..."

Symmetry Type 6

Symmetry Type 6 is horizontal symmetry. One of the *gorga* motifs that has a horizontal symmetry pattern is as shown in Figure 7.

Figure 7. Gorga with Horizontal Symmetry Pattern

Base on Figure 7, to make this motif, *pande* will place the mall in its initial position and draw it. To obtain the second image, *pande* will shift the mall to the right (translation) and paste it right after the first image. To draw the motifs at the bottom, the method used by *pande* is based on the position of the mal. From this position, *pande* folds the mall down (horizontal reflection) and attaches the mall. It is the same as the steps for making, with reference to the position of the mall *pande* folds the mall down (horizontal reflection) then pastes is obtained. And so on the method used to draw motifs on the entire surface of the board.

Symmetry Type 7

This last type of symmetry is vertical and horizontal. This symmetry is found in one of the following *gorga* motifs as show in Figure 8.

Figure 8. Gorga with Vertical and Horizontal Symmetry Patterns

Base on Figure 8, the way to draw the motif is to place the mall in the position. Then *pande* will fold the mall to the right (vertical reflection) and attach the mall right after the initial drawing to obtain. *Pande* will use a mall in the position fold the mall down (horizontal reflection) and stick it just below. In the same way using the mall position in *pande* will obtain. This is then done repeatedly until all fields are filled with images. Overall, the symmetrical patterns contained in the *gorga* carvings can be summarized in Table 9.

Tabel 9. Seven Types of Symmetry in the Gorga Motifs

Type of Symmetry	Pattern	Name of Symmetry	*Gorga* Motifs
Type 1	pppp ...	Translation	
Type 2	qdqd ...	Glide reflect symmetry	

Type of Symmetry	Pattern	Name of Symmetry	*Gorga* Motifs
Type 3	pqpq ...	Vertical symmetry	
Type 4	bqbq ...	Rotation 180° symmetry	
Type 5	bdpqbdpq ...	Vertical symmetry and rotation 180°	
Tipe 6	dddd ... qqqq	Horizontal Symmetry	
Tipe 7	bdbd ... pqpq	Vertical and Horizontal Symmetry	

Discussion

Based on the research results, it was found that of all the types of *gorga* motifs observed, there were 7 types of symmetry in these *gorga* motifs. These types of symmetry include translational symmetry, glide reflect symmetry, vertical symmetry, rotation 180° symmetry, vertical symmetry and rotation 180°, horizontal symmetry, vertical and horizontal symmetry. These symmetrical patterns were also found in research on decoration of the Incas. Some of the Inka decorations show the repetition of the same pattern from left to right of the image. Other patterns of symmetry were also found in research on the series of desert paintings, as well as mosaics (Gilsdorf, 2016; Marchis, 2009; Sulaiman et al., 2019).

Furthermore, from the discovery of several mathematical aspects of Batak culture, such as geometric transformations in *gorga* (C. Ditasona, 2018), arithmetic sequences on *gorga* carvings (Candra Ditasona et al., 2021), 2d and 3d geometry concepts in traditional house (Hidayat et al., 2020), fractals on *gorga* motifs (Situngkir, 2012), the concept of flat geometry on ulos (Rahmadani & Reflina, 2023), as well as the integral concept of the taganing musical instrument can be utilized as a learning resource for local students. Thus mathematics is no longer seen as something abstract and foreign to students. Mathematics will be easier to understand because it is very closely related to daily activities and student culture (Fauzi et al., 2023; Rosa & Orey, 2011a). Students can use these mathematical concepts in solving problems related to their lives (Dudu & Vhurumuku, 2012; Prahmana & D'Ambrosio, 2020). In the end the use of these mathematical concepts will also contribute to the development of their own culture.

These findings show how mathematical ideas and practices develop in local cultures. As a multicultural country, findings from ethnomathematics research from various ethnicities in Indonesia will certainly be a very abundant source of learning for students. The use of cultural contexts in learning mathematics fosters a new awareness for students, in the end students will realize that cultural diversity is a wealth. Thus they will learn to respect differences and will create an atmosphere free of discrimination and intolerance. The results of this study can be used to enrich students' mathematics learning resources based on Batak culture. Integrating the findings of this research into learning mathematics is expected to foster students' love for their culture. This method can be done as a step to preserve culture. This research only examines *gorga* motifs in Toba and Samosir districts. One of the obstacles in this study was the

difficulty in finding *gorga* carvers, considering that there were not many *gorga* carvers in the two districts. With the growth of students' love for their culture, it is hoped that this tradition of carving *gorga* will develop in the future.

4. CONCLUSION

This research shows that *gorga* is not just a work of art. Furthermore, there are mathematical aspects contained in the *gorga* motif, one of which is the symmetrical pattern that is formed. Based on the research results, 7 types of symmetry were obtained in the *gorga* carving motifs, including translational symmetry, glide reflect symmetry, vertical symmetry, rotation 180° symmetry, vertical symmetry and rotation 180°, horizontal symmetry, vertical and horizontal symmetry.

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