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Ethnomathematics in Aashtimki: A Study on Tharu's Culture

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Abstract:
Tharu is one of the indigenous communities having their distinctive culture and practices. For doing daily tasks, they have developed their own mathematical conceptions and ideas. Ethnomathematics is the study of mathematical concepts and knowledge that are applied by a specific group of people but are typically not covered in the formal curriculum. This study is intended to explore the mathematical concepts hidden in the *Aashtimki* painting that *Tharu's* people celebrate. This study used the observation and documentation analysis method to collect data for this aim. The painting for *Aashtimki* have established a large degree of local knowledge that is primarily based on intuition, estimation, observation, and practice that has been passed down from generation to generation and is deeply rooted in their local culture. Emic ethnomodeling is used to investigate the mathematical elements embedded into the construction of *Aashtimki* painting in *Tharu's* community. The findings of the study revealed that *Aashtimki* painting have sophisticated mathematical ideas and knowledge and they used the concepts of reflection, rotation, translation and dilation of transformation implicitly.

Keywords: ethnomathematics, indigenous knowledge, *aashtimki,* transformation geometry, symmetry.

1. Introduction

Nepal is a country that is multilingual, culturally and religiously diverse. Geographically, linguistically, caste-wise, ethnically, religiously, and culturally, it is diverse. Each of the 59 indigenous groups has its own culture. *Tharu* is among them. The *Tharu* constitute a significant ethnic group in Nepal, accounting for 6.2 percent of the overall population (Census, 2021). They live in the Terai region, which stretches west from *Kanchanpur* to east from *Jhapa*. *Tharu* people are ethnic, with a blend of ethnic characteristics and daily activities based on ethnomathematical concepts (Chaudhary, Panthi & Bhatta, 2023).

The term ethnomathematics refers to ethno and mathema, with ethno referring to sociocultural contexts (e.g., language, jargon, code of behavior, myths, and symbols) and mathema referring to knowing, understanding, explaining, and performing activities to cipher, measure, classify, order, infer, and model. Finally, the suffix tics has the same root as art and technique (D'Ambrosio,1985). Ethnomathematics emphasizes understanding of the various ways for performing and interpreting mathematics that are influenced by cultural values, traditional concepts and notions, and ethnic environmental conditions (Rosa & Shirley, 2016).

In the Nepalese context, ethnomathematics has been defined as the study of various mathematical notions by indigenous peoples. The ethnomathematical notions of many groups of people, as well as mathematical concepts performed outside of school, have now become part of teaching and learning.

Teachers are currently attempting to integrate cultural and local teaching methods into curricular activities (Pradhan, Sharma, & Sharma, 2021). In Nepalese Tharu people, weaving is a common cultural activity. The cultural values and identities are reflected in the weaving of Dhakiya. The production of the Dhakiya weaving incorporates a variety of mathematical concepts and ways of thinking. When weaving Dhakiya, it was seen that the weaver displayed sophisticated mathematical concepts. At various stages of education, it is suggested that native Dhakiya weaving can be used to teach and learn mathematics. The integration of Dhakiya weavers' ethnomathematical concepts with school mathematics strengthens the complex, relevant linkages between the mathematical concepts of two distinct worlds (home and school), where the children simultaneously live and study. If the concepts presented are based on students' experiences and actions, both the teaching and learning of school mathematics can be improved (Chaudhary, Panthi & Bhatta, 2024). The study explores the cultural context of mathematical concepts, particularly calculus, in *Tharu's* ethnomathematics. It highlights the interconnectedness of formal and informal mathematical concepts in school-based curriculums. The ethnomathematics approach can be applied in various teaching contexts, allowing children from villages to improve their mathematical skills. The findings suggest that integrating ethnomathematics into formal curriculum implementation can enhance students' understanding the concepts of Rolle's theorem in Calculus. The study encourages further research on the practical value of ethnomathematics in educating students about other mathematical ideas in diverse cultural settings (Chaudhary, Panthi & Bhatta, 2023).

According to Bishop (1991), mathematics is a cultural product that has evolved as a result of numerous actions, and counting, locating, measuring, designing, playing, and explaining are all components of that cultural product. Everyday existence is imbued with a culture's knowledge and traditions. Individuals are constantly comparing, classifying, quantifying, measuring, explaining, inferring, generalizing, and assessing utilizing culturally specific material and intellectual tools (D'Ambrosio, 2006). In this study, we looked for hidden traditional mathematics concepts in the *Aashtimki* painting's design.

The main objective of this study was to explore the ethnomathematical concepts embedded in the *Aashtimki* painting celebrated by *Tharu* people in their Nepalese community, with the goal of answering the following research questions: What the *Tharu* people does, why they do it, and how they celebrate Krishna Janmashtami? And How are *Tharu's* hidden mathematical ideas and understandings to be conveyed in their *Aashtimki* festival, with connections to formal mathematical knowledge?

2. Methods And Procedures

The qualitative inquiry aimed to explore ethnomathematical ideas embedded in *Aastimki* of *Tharu* from Dang District in Nepal. The qualitative methods of data collection include interviews and observation were adopted. The observed data was documented through paintings, whereas the interview data was documented by transcripts of the conversation. To understand the concept of transformation included in the *Tharu* people's *Aashtimki* festivities, interview transcripts and paintings were analyzed and established expanded.

Global (etic), local (emic), and glocal (dialogical) actions have aided us in investigating, studying, and discussing issues related to decolonization and culture, while also assisting us in understanding the mathematical ideas, procedures, and practices developed by and useful to members of distinct cultural groups. A local (emic, insider) approach is concerned with how individuals of various cultural groups came to construct mathematical ideas, techniques, and solve mathematical tasks. It honors cultural practices, social understandings, conventions, religion, gender, and beliefs by allowing people to define their culture in their own words. It tries to understand daily happenings through the eyes of members of the culture being researched in order to capture the significance of mathematical daily life activities (Orey, & Rosa,2006). In this study, we discovered about *Aashtimki* paintings, why *Tharu* people make them, why they celebrate the occasion, and what the traditional significance of *Aashtimi* paintings are. After observing the *Aashtimki* paintings mathematically and identifying unique mathematics among them, we explored transformation geometry in this study and apply emic ethnomodeling.

3. Results And Discussions

Figure 1. *Aashtimki* Paintings

The *Ashtimki* painting discussed above has great significance in *Tharu* culture. It is important to note that the *Tharu* people, who are primarily farmers, worship Kanha, a cowherd, whose parents Isaru and Jasu, father and mother respectively, are also farmers. There is a celebration of rustic life in the painting as Kanha is portrayed dancing, plowing, and playing the flute and the *Mandra*, popular musical instruments of the *Tharus*. On the left and the right corners at the top of the painting, there is a moon and a sun suggesting the *Tharu* people's busy farm life from sunrise to moonrise. Similarly, in between the sun and the moon, there are five male figures referred to as five Pandava brothers. There are female figures who are supposed to be Draupadi and/or Radha. The boat, the fish, and the ox in the painting all reflect the life story of Kanha in particular and the *Tharu* people in general. The colour combination of green, blue, yellow and red is typical to *Ashtimki* painting in *Tharu* culture. We discovered hidden transformation geometry in *Aashtimki* in this painting. The process of moving a two-dimensional painting on a plane by mapping the preimage set of points to the image set of points. A transformation is defined as the physical or mental movement of a painting to a different position or orientation on a plane (Boulter & Kirby, 1994). For example, the transformation (T) to the point P (x, y) yields the shadow P'(x, y). The procedure can be expressed as follows: P (x, y)→ P'(x, y). There are two types of transformation: Rigid (Isometric) Transformation and Non-rigid (non-isometric) transformation. From the perspective of researchers, the *Aashtimki* painting resembles the concepts of transformation.

Reflection: A reflection is a type of rigid transformation in which the painting seems to be flipped across an axis or line on a plane; the line can be the x- or y-axis, or a line other than one of the axes. This is known as the line of reflection. The item and its reflection are congruent, but the figures' positions and alignment are reversed. A mental image of the reflection action would be to pull the object out of its plane, flip it over an indicated line, and then place it back on the plane. When a reflection painting is viewed in a mirror, the line of reflection, or the line over which the preimage is reflected, is formed by the mirror edge. This type of change is frequently referred to as "flip" or "flipping" (Bansilal & Naidoo 2012).

For horizontal x-axis reflection, if the point shadow P(x,y) is P'(x,-y), then

P'(x',y')= P'(x,-y),

The matrix form is expressed as follows:

$$x' = 1\times x + 0 \times y$$

$$y' = 0\times x + (-1) \times y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix}$$

It demonstrates that the 2×2 matrix of an object's reflection on the x-axis is $\begin{pmatrix} 1 & 0 \\ 0 & -1 \end{pmatrix}$.

The image below shows a reflection on the x- axis (horizontal axis) of the *Aashtimki* painting:

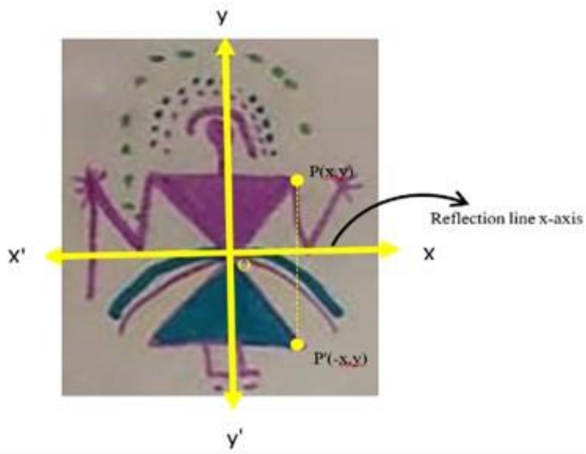

Figure 2. *Aashtimki* painting is reflected on the x-axis.

For vertical y-axis reflection, if the point shadow P(x,y) is P'(-x,y), then P'(x',y')= P'(-x,y), The matrix form is expressed as follows:

$$x' = (-1) \times x + 0 \times y$$

$$y' = 0\times x + 1\times y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix}$$

It demonstrates that the 2×2 matrix of an object's reflection on the y-axis is $\begin{pmatrix} -1 & 0 \\ 0 & 1 \end{pmatrix}$.

The image below shows a reflection on the x- axis (horizontal axis) of the *Aashtimki* painting:

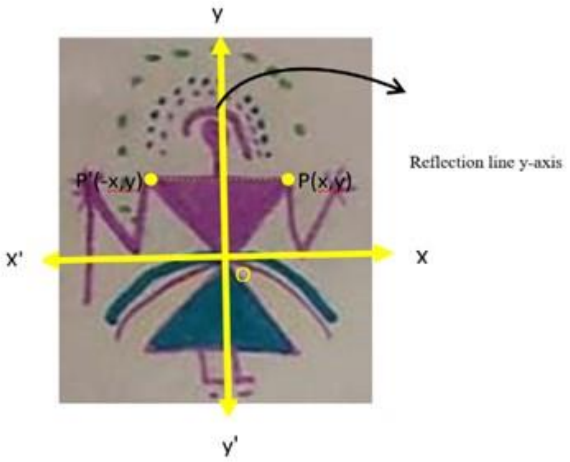

Figure 3. *Aashtimki* painting is reflected on the Y-axis

For reflection in the line y=x, if the point shadow P(x,y) is P'(y,x), then P'(x',y')= P'(y,x), The matrix form is expressed as follows:

$$x' = y = 0\times x + 1 \times y$$

$$y' = x = 1\times x + 0\times y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix}$$

It demonstrates that the 2×2 matrix of an object's reflection on the line y= x is $\begin{pmatrix} 0 & 1 \\ 1 & 0 \end{pmatrix}$.

The image below shows a reflection on the line y=x of the *Aashtimki* painting:

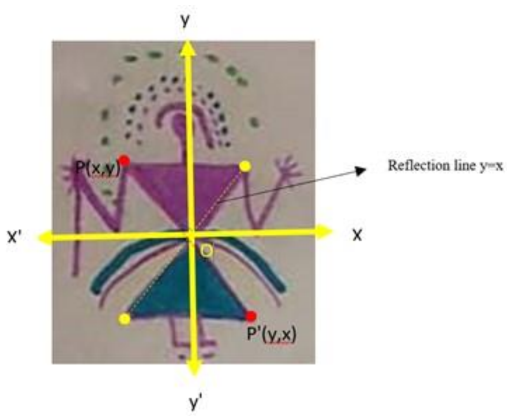

Figure4. *Aashtimki painting is reflected on the y=x.*

For reflection in the line y= - x, if the point shadow P(x,y) is P'(-y, -x), then P'(x',y')= P'(-y,-x), The matrix form is expressed as follows:

$$x' = -y = 0\times x + (-1) \times y$$

$$y' = -x = (-1) \times x + 0 \times y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix}$$

It demonstrates that the 2×2 matrix of an object's reflection on the line y= -x is $\begin{pmatrix} 0 & -1 \\ -1 & 0 \end{pmatrix}$.

The image below shows a reflection on the line y= -x of the *Aashtimki* painting:

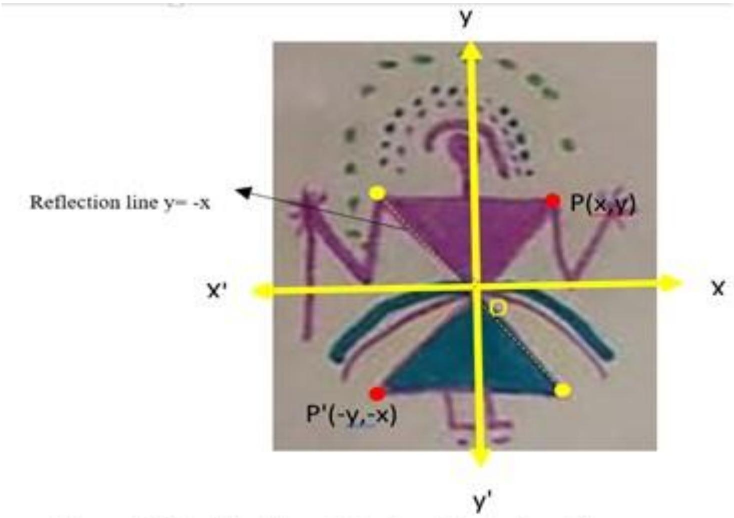

Figure 5. *Aashtimki* painting is reflected on the y= - x.

Rotation: A rotation is a type of rigid transformation in which a two-dimensional figure is turned an angle and direction around a fixed point known as the center of rotation. A rotation is also known as a turn. The rotation rotates the painting and all of its points through a given angle measurement, with the vertex of the angle referred to as the center of rotation. Two pieces of information are required for a description of rotation: the center and angle of rotation, as well as the direction of rotation; the center of rotation is the only location that is not influenced by the rotation (Wesslen & Fernandez, 2005). In rotation, there are two fundamental points: angle and direction. Positive represents anticlockwise and negative represents clockwise, and it can be rotated at any angle.

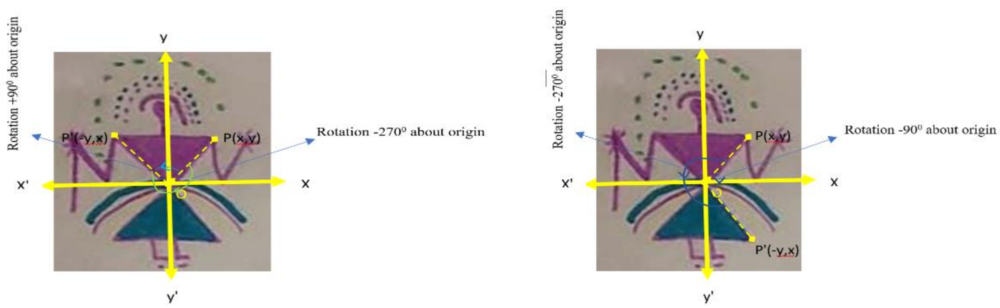

Figure 6. *Aashtimki* painting is rotate +90^0 and -90^0 about origin

For rotation anticlockwise (positive) about 90^0 or clockwise (negative) about 270^0, if the image of a point P(x,y) is P'(-y, x), then P'(x',y')= P'(-y,x). The matrix form is expressed as follows:

$$x' = -y = 0\times x + 1 \times y$$

$$y' = x = 1\times x + 0\times y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix}$$

It demonstrates that the 2×2 matrix of an object's rotation anticlockwise (positive) about 90^0 or clockwise (negative) about 270^0 is $\begin{pmatrix} 0 & -1 \\ 1 & 0 \end{pmatrix}$.

The image below shows a rotation anticlockwise (positive) about 90^0 or clockwise (negative) about 270^0 of the *Aashtimki* painting:

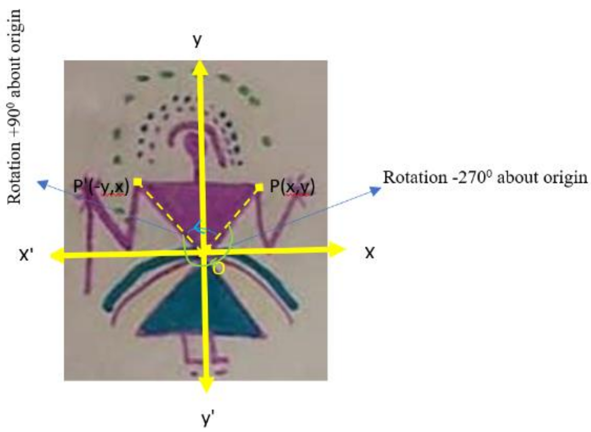

Figure 7**.** *Aashtimki* painting is rotated +90^0 about origin

For rotation clockwise (negative) about 90^0 or anticlockwise (positive) about 270^0, if the image of a point P(x,y) is P'(y,-x), then P'(x',y')= P'(y,-x). The matrix form is expressed as follows:

$$x' = y = 0\times x + 1 \times y$$

$$y' = x = (-1) \times x + 0\times y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix} \cdot \begin{pmatrix} x \\ y \end{pmatrix}$$

It demonstrates that the 2×2 matrix of an object's rotation clockwise (negative) about 90^0 or anticlockwise (positive) about 270^0 is $\begin{pmatrix} 0 & 1 \\ -1 & 0 \end{pmatrix}$.

The image below shows a rotation clockwise (negative) about 90^0 or or anticlockwise (positive) about 270^0 of the *Aashtimki* painting:

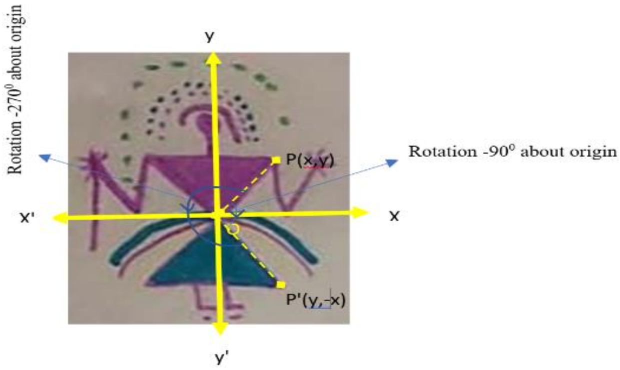

Figure 8. Aashtimki painting is rotated -90⁰ about origin

For rotation clockwise (negative) about 180^0 or rotation anticlockwise (positive) about 180^0, if the image of a point P(x,y) is P'(-x,-y), then P'(x',y')= P'(-x,-y). The matrix form is expressed as follows:

$$x' = -x= (-1) \times x +0\times y$$

$$y' = x = 0 \times x + (-1) \times y$$

$$\begin{pmatrix} x' \\ y' \end{pmatrix} = \begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix} . \begin{pmatrix} x \\ y \end{pmatrix}$$

It demonstrates that the 2×2 matrix of an object's rotation clockwise (negative) about 180^0 or rotation anticlockwise (positive) about 180^0 is $\begin{pmatrix} -1 & 0 \\ 0 & -1 \end{pmatrix}$.

The image below shows a rotation clockwise (negative) about 180^0 or rotation anticlockwise (positive) about 180^0 of the *Aashtimki* painting:

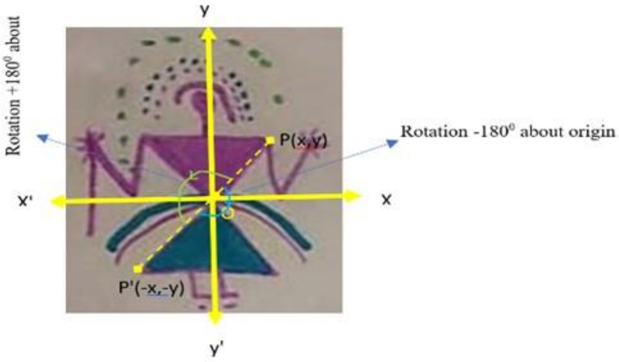

Figure 9. Aashtimki painting is rotated 180⁰ about origin

Translation: A geometric translation is the movement of a point, line, or figure on a two-dimensional surface. Translation is defined as "moving each point of an object the same distance and in the same direction." The translation, often known as a slide or a shift, is the most basic transformation. The symbols for a point translation are A → A′. The arrow denotes that the point A is being relocated to a new location designated A prime (A′). On a graph, an arrow can be drawn to show the direction of an object's movement, and the shaft of the arrow represents the planned distance of the movement.

The image of a point P(x,y) translated by $\binom{a}{b}$ indicates the object moves a unit right or left according to the sign of a and b unit up or down according to the sign of b, and its final image is P'(x +a, y +b). So, a point P(x,y) translated by translation vector $\binom{a}{b}$ is

P'(x +a,y+b).

$$P(x, y) \rightarrow P'(x + a, y + b)$$

The following image is a translation of the *Aashtimki* painting:

Figure 10.1 Aashtimiki Painting is traslated

Dilation: Dilation is a transformation that either decreases or increases the size of a figure. Dilation extends or shrinks the original figure and changes the size of the preimage; thus, it is not rigid because it does not meet the criteria that the image is congruent to the preimage. Dilation is a similarity transformation in which a two-dimensional figure is reduced or extended by a scale factor ($\neq 0$), but the center of dilation remains unchanged. So, if the image is enlarged, it is called enlargement, and if it is reduced, it is called reduction.

The dilation of a point P(x,y) by scale factor ($k \neq 0$) with center (0,0) means that the image is k times larger or smaller than the object and its final image is P'(kx, ky). So, The dilation of a point P(x,y) by scale factor k with center (0,0) is P'(kx, ky).

$$P(x, y) \rightarrow (kx, ky)$$

The following image is a dilation of the *Aashtimki* painting:

Figure 11. Aashtimiki Painting has been enlarged and reduced in size.

4. Conclusion

We find that mathematical concepts and knowledge are used implicitly by the *Tharu* in their actions. *Tharu* culture has a long history of employing transformation geometry. The transformation geometry techniques employed in the development of the *Aashtimki* painting demonstrate this. The *Aashtimki* artwork clearly shows that the purpose used the principle of reflection, rotation, translation, and dilation of transformation, which are all examples of fractals. It's fascinating to see how precise their calculations are utilizing simple equipment of the day, which necessitate a mathematical proficiency sufficient for the painters of the day.

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