Teacher Half-Yearly Journal *17*(1),116-127, 2025

Connecting Cultural Artifacts with Mathematics: An Example from *Rangauli* Mandala

Jaya Bishnu Pradhan
Department of Mathematics Education, Mahendra Ratna Campus, Tahachal, Tribhuvan University.
✉ *jebipradhan@gmail.com*

Submitted: March 8, 2024; Accepted: July 12, 2024; Published: January 31, 2025

Abstract

This paper investigates the integration of cultural artefacts, specifically the Rangauli mandala, into the teaching and learning of school mathematics. Drawing on qualitative research methods, the study explores the mathematical ideas inherent in cultural practices and artifacts, emphasizing their pedagogical implications. Through interviews and observations, the research uncovers sophisticated mathematical concepts embedded in the construction of the Rangauli mandala, such as geometric patterns and spatial reasoning. The findings highlight the importance of connecting mathematics instruction with students' cultural backgrounds, as their familiarity with cultural artefacts can enhance understanding and engagement with mathematical concepts. Despite challenges such as overloaded curricula and time constraints, the study underscores the value of incorporating cultural artifacts and students' ethnomathematical ideas into mathematics education to promote conceptual understanding. Ultimately, the paper advocates for the utilization of ethnomathematics as a pedagogical tool to bridge the gap between students' everyday mathematical practices and formal school mathematics through facilitation to have deeper learning and cultural appreciation in the classroom.

Keywords: Cultural artifacts, Ethnomathematics, Ethnography, Cultural friendly pedagogy.

Introduction

Cultural artifacts are objects, symbols, or expressions created by a particular group of people that provide insights into their cultural beliefs, practices, values, and history. These artifacts can include tangible items such as art, tools, clothing, and architecture, as well as intangible elements like language, rituals, music, and folklore. They serve as tangible evidence of a cultural identity which help to unde the dynamics of societies and their evolution over a time. Gueudet and Trouche (2009) extend this concept by introducing the term resources which encompasses artifacts that facilitate the l g process. From an ethnomathematics perspective, Bonotto (2007) suggests that incorporating cultural artifacts into the school mathematics classroom enhances the relevance and meaning of mathematical concepts. For him, the cultural artefacts introduced into mathematics classroom are concrete materials, which children typically meet in real life situations. These cultural artifacts not only reflect the cultural identity of diverse groups but also provide contexts for exploring mathematical principles within culturally significant settings. Ethnomathematics refers to how different groups of indigenous people use mathematics in their daily lives, helping them maintain their cultural identity (D' Ambrosio, 2006). Each group has its own special way of doing math, tailored to their specific needs and challenges. This type of math, developed by professionals within these communities, is often better at solving their particular problems than the math taught in schools. That's because it's based on their practical knowledge and ways of thinking, which they've refined over many years. Indigenous knowledge, according to Mundy and Compton (1995), comes from experience, has been tested over generations, and fits well with the local culture and environment.

In Nepal, indigenous people have their own unique mathematical methods that they use in their everyday routines. Indigenous knowledge is specific to particular cultures and societies. This knowledge is deeply intertwined with community practices, institutions, relationships, and rituals, evolving within cultural contexts over time. It is often implicit, passed down through generations within cultural practices and understanding. This indigenous knowledge also extends to mathematical understanding embedded within cultural artifacts and practices. Mathematical concepts and techniques are woven into traditional activities such as agriculture, craftsmanship, and rituals. Thus, the preservation and transmission of indigenous knowledge involve not only the safeguarding of cultural artifacts but also the mathematical insights inherent within them. Those cultural artifacts can be the mediated tools to facilitates understanding of abstract mathematical concepts.

Nepal has rich cultural traditions and unique rituals. Creating *Rangauli* mandala is one of cultural tradition observed during the restive celebrations of Tihar (festival of lights). Drawing *Rangauli* mandala is believed to usher in prosperity and blessings for both the family and the community. People make *Rangauli* drawings using colorful rice powder, which also feeds small animals like birds and ants. This shows the importance of sharing and getting along with others, and respecting nature and our relationships with animals. Mostly, it's Hindu women who do this art, passing it down through families. They usually make *Rangauli* during Diwali, using seven colors of rice powder. In this paper, I investigated how we can use cultural artefacts of *Rangauli* mandala to the teaching and learning of school mathematics. Considering these issues, this paper intended to find out what mathematics concepts are hidden in *Rangauli* designs and how teachers can use these designs to teach mathematics classroom.

Method and Procedures

This study is intended to uncover mathematical ideas inherited in the *Rangauli* mandala and investigate its possibilities in teaching and learning in school mathematics. To achieve this objective, I opted for qualitative research methods as I aimed to uncover the intricate realm of mathematical concepts and knowledge embedded within the *Rangauli* mandala found in cultural context of students. Qualitative research relies primarily on gathering qualitative data, cutting across disciplines and subject matters (Denzin & Lincoln, 2005). In my research, I chose a qualitative approach because it allows for a deeper understanding of the intricate relationship between cultural artifacts like the *Rangauli* mandala and mathematical concepts, especially in how they're used to teach math in schools. Quantifying these ideas, perceptions, and knowledge into numbers wouldn't do justice to their complexity. Mathematical concepts intertwined with cultural artifacts, as well as people's feelings, beliefs, and attitudes toward them, cannot be adequately captured through quantitative methods.

Ethnography is a qualitative research methodology. The goal of ethnography is to provide rich and descriptive accounts of specific cultures, document their social interactions, behaviours, beliefs, and practices. Ethnography comprehends human behavior within its natural social context by merging the insights of participants from specific cultures with the expertise of the researcher (D'Andrade, 1981). In essence, ethnographic research combines participant observation with various aspects of nonparticipant observation studies to attain a comprehensive understanding of a specific society, group, institution, setting, or situation. To achieve my research objectives, I utilized in-depth interviews and non-participant observation. I developed interview guidelines and observation protocols for mandala creators and teachers to facilitate data collection in the field (Creswell, 2009). During interviews, respondents were encouraged to express their thoughts freely, and additional questions were posed based on their responses to gather comprehensive information for the study. To avoid disrupting the flow of conversation, I employed a voice recorder to capture all responses from interview participants. Furthermore, I precisely documented all possible conversations using a video camera and recorded field notes whenever feasible. The data obtained from the exploration of out-of-school culture underscore the plenty of ethnomathematical ideas and knowledge.

I collected data from various sources throughout my study. Following Creswell's approach (2009), I reviewed all the gathered data and categorized it into themes that were consistent across all sources. To facilitate analysis, I transcribed conversations and interviews into written manuscripts. Analyzing and interpreting the data was the primary focus of my research. I examined the data and connected it to various theories to derive meaning. By triangulating data from multiple sources and theoretical frameworks, I aimed to provide accurate descriptions. This involved assigning significance to the analysis, identifying patterns, and exploring relationships among different aspects. In my study, I used the concept of pluralism to analyze cultural artifacts within the cultural elements of students' and their understanding of natural phenomena, incorporating their ethnomathematical knowledge. To enhance the validity and reliability of my analysis, I cross-referenced statements from research participants and reviewed the text multiple times during data collection.

Rangauli Mandala and Mathematics

Drawing *Rangauli* needs different shapes and patterns, like circles and symmetrical designs. It's a way of celebrating and connecting with nature and each other. Regarding the ways to drawing of *Rangauli* mandala, I inquired with one of my research participants, P1. She replies:

> *The mental images of the pattern motive to draw a Rangauli mandala. The cognitive map of the mandala is important things for that. We start from a point and draw some concentric circles. Anyone can draw different shapes inside the regions in concentric circles. Some may draw an eight-pointed star or eight petals of a lotus as per their choices.*

From the interview with P1, I came to know that the construction of mandala is a mental map or schema of the creators. The embodied cognition of mandala creators helps them in the execution of their task. They have already formed mental image of the mandala in their mind. However, the various geometrical patterns found in their construction remain largely hidden or obscured from the participants. The technique of creating such cultural arts and artefacts follows a craft model approach (Pradhan, 2017). Thus, the statement of P1 emphasizes the importance of mental imagery in the creation process. This aligns with ethnomathematics, which acknowledges the role of cultural practices and individual cognition in mathematical activities. In this case, the mental images of patterns serve as a cognitive tool, guiding the creation of intricate geometric designs. Furthermore, the concept of a "cognitive map" of the mandala highlights the spatial reasoning involved in its construction. Ethnomathematics recognizes spatial thinking as a fundamental aspect of mathematical cognition across cultures. The cognitive map serves as a mental blueprint, allowing the creator to navigate the geometric space and make informed decisions about the placement of shapes and patterns. The process of starting from a central point and drawing concentric circles reflects geometric principles such as symmetry and radial symmetry. These geometric concepts are not only integral to the aesthetic appeal of the mandala but also demonstrate mathematical reasoning in action. Moreover, the flexibility in choosing shapes to fill the concentric circles reflects mathematical creativity and problem-solving. Ethnomathematics acknowledges diverse mathematical practices and perspectives, emphasizing the importance of cultural context in shaping mathematical activities. In this case, individuals draw upon their cultural knowledge and personal preferences to select shapes such as eight-pointed stars or lotus petals, contributing to the richness and diversity of *Rangauli* designs.

Figure 1: *Rangauli Mandala*

The mandala depicted in the figure 1 was constructed by P1 herself, placed in front of the main doorways of her house. During our interaction, I inquired about her technique for drawing an eight-pointed star, a task she had previously completed. She agreed to demonstrate it again, starting with a rough sketch. Her process involved initially drawing a circle and dividing it into four equal parts by intersecting lines. Subsequently, each quadrant was halved, and concentric circles with increasing radii were drawn. Isosceles triangles were then formed with vertices on the outer circle's circumference and bases on the inner circles. Observing this process, it became evident that sophisticated mathematical concepts were being applied in constructing the mandala. Similarly, when I spoke with another participant, P2, about the knowledge and mathematical ideas behind such intricate artifacts, they shared their insights.

> *I learned to make this artifact by observing the ways my mother drew, much like how these children patiently observe my activities here. First, I draw a sitting place for the goddess Laxmi at the center, as we are going to worship her. Then, I drew a larger circle and eight lotus petals, as we believe that she likes to rest on a lotus flower.*

This narrative encapsulates the intricate dynamics of indigenous knowledge generation and distribution within a cultural context. From the interview of my research participant P2 asserted that the learning from the mother reflects the intergenerational transmission of knowledge, a hallmark of indigenous knowledge systems. Through observation and apprenticeship, knowledge is passed down from one generation to the next, ensuring its continuity and preservation. Furthermore, the analogy drawn between the research participant's observation of her mother's drawings and the children's observation of her own activities underscores the communal aspect of knowledge sharing within indigenous communities. Learning is not confined to formal settings but occurs through everyday interactions and experiences within the community. The central focus on goddess Laxmi and the specific rituals associated with her worship highlights the integration of spiritual beliefs and practices into indigenous knowledge systems. These rituals are deeply rooted in cultural traditions and serve as a means of connecting with ancestral wisdom and spiritual entities. The act of drawing a sitting place for the goddess Laxmi and depicting her preference for resting on a lotus flower reflects the incorporation of ecological knowledge and symbolism into artistic expression. Indigenous knowledge often encompasses a holistic understanding of the natural world, where cultural practices are intertwined with environmental stewardship and reverence for nature.

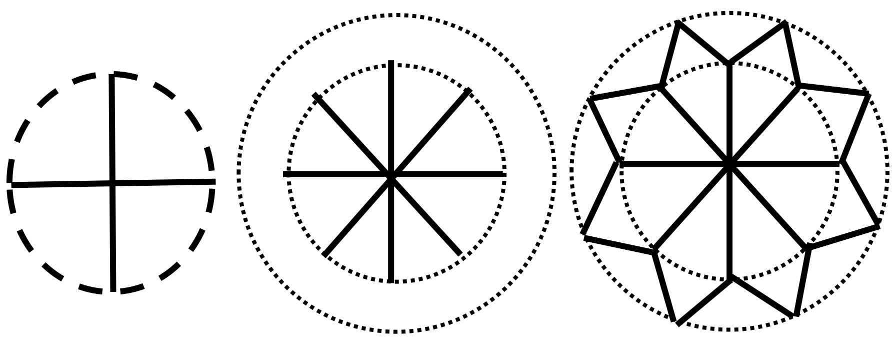

Figure 2: *Process for Construction of Mandala*

Through interviews and observations of indigenous methods of construction as part of their cultural tradition, I have gained insight that they have deep understanding of sophisticated mathematical ideas and concepts such as concentric circles, coordinate axes, and symmetry when creating mandala as part of their cultural tradition. The process often involves the concept of both bilateral and rotational symmetry. Upon close observation, it becomes apparent that many beautiful phenomena in the world exhibit mathematical properties including the golden ratio. Despite lacking formal mathematics education, their work often incorporates mathematical concepts such as ratio and proportion, symmetry, tessellations, reflection. Furthermore, in the indigenous communities, mathematical concepts and techniques are often transmitted through hands-on experiences and apprenticeship-like relationships, rather than formal instruction (Vygotsky, 1978). The act of drawing a sitting place for the goddess Laxmi at the center demonstrates spatial reasoning and geometric understanding. Placing the goddess at the center of the mandala implies a sense of symmetry and balance, which are fundamental principles in geometry and mathematical aesthetics. The subsequent creation of a larger circle and eight lotus petals involves geometric concepts such as symmetry, proportion, and pattern. The division of the circle into eight equal segments to represent the lotus petals requires an understanding of angles and spatial relationships.

Bridging Cultural Artefacts with School Mathematics

Mathematics instruction becomes more interesting and meaningful when it is connected to the everyday activities and experience of students. Students' everyday interactions with their cultural environment provide numerous opportunities to engage with and conceptualize abstract mathematical concepts. The activities and artifacts within students' cultural environments often involve a wealth of mathematical knowledge and ideas. These mathematical ideas, deeply embedded in the students' cultural environment, offer a conducive setting for learning and serve as effective tools for communicating mathematical concepts. Mathematical ideas are intricately woven into every aspect of a group's environmental activities, yet these ideas may remain largely unnoticed. Mathematical anthropology utilizes mathematical models in studies of history, ethnography, and material culture to describe both material and cognitive patterns within specific groups of people (Eglash, 2001). Further, Rosa and Orey (2010) advocate for the use of mathematical modeling as a methodological tool within the ethnomathematical program, emphasizing its potential to reshape cultural identity positively by incorporating a more authentic representation of mathematical practices and problems within students' own communities (D' Ambrosio, 1998, 2006; Zaslavsky, 1996). Across different cultures worldwide, symmetry prevails in the design of textiles, sand paintings, wall paintings, pottery, art, and artifacts. The mathematical ideas practiced within students' environmental contexts can be utilized as cultural metaphors for teaching and learning school mathematics. The informal mathematical concepts applied in daily life serve as a rich source knowledge for understanding abstract mathematical concepts. Therefore, the ethnomathematical system within a cultural group can facilitate a deeper understanding of school mathematics. Regarding the potential integration of cultural artifacts into the teaching of mathematics, one of my research participants, T1 remarked:

> *I believe that mathematics is evolve from the culture. The different group of people are using mathematical ideas implicitly in their profession. Their children are also doing same work what their parents do. Children are also using same kind of mathematics. But the real problem is to connect their mathematics to school mathematics.*

The statement highlights a crucial aspect of ethnomathematics, which recognizes that mathematical ideas and practices are deeply rooted in culture. Ethnomathematics emphasizes the importance of acknowledging and incorporating diverse cultural perspectives and mathematical practices into the teaching and learning of school mathematics. The notion that mathematics evolves from culture aligns with ethnomathematics' core principle that mathematical knowledge is shaped by cultural contexts and societal practices. Different groups of people use mathematical ideas implicitly in their professions, passing down these practices from one generation to the next. Indigenous knowledge, rooted in their cultural context, often employs the craft model approach for generating and disseminating knowledge. This approach emphasizes participatory and cooperative methods, where learning occurs through collaboration with parents. Vygotsky (1978) views learning as a social activity in which shared mathematical meanings are constructed collectively. Children often follow in their parents' footsteps, engaging in similar work and utilizing the same mathematical concepts and techniques. Nevertheless, our school pedagogy heavily emphasizes rote learning and diverges from the knowledge generation and distribution methods of the indigenous people (Pradhan, 2017). The research conducted by Acharya (2015) and Pradhan, (2021) revealed that the pedagogy implemented in schools fails to recognize the cultural elements of the students. Despite the prevalence of mathematical activities within cultural contexts, there can be challenges in connecting these informal mathematical experiences to school mathematics. Ethnomathematics seeks to bridge this gap by recognizing and valuing the mathematical knowledge and practices embedded within diverse cultural settings. In same vein, another research participant T2 viewed that

> *The use of students' cultural experience in mathematics teaching is evident, yet integrating it into our classroom instruction remains a challenge. How can a teacher who have responsibility of taking five to six periods in a day can manage their own class from culture friendly pedagogy? How to prepare class with the view of cultural relevant*

pedagogy for certain mathematical content? If a teacher has one or two periods of responsibility, then s/he can think about which cultural metaphor fitted most appropriately.

This narrative reflects a common challenge faced by educators in incorporating students' cultural experiences into mathematics teaching while managing the demands of a busy classroom schedule. Majority of the participants in my research agreed with the view of T1. They recognized that integrating students ethnomathematics into mathematics education enriches mathematical understanding to the students. Mathematical elements are intricately woven into the daily practices and cultural traditions of various indigenous communities, manifesting in ways that are both practical and symbolic. For instance, the Chundara people, known for their expertise in crafting wooden objects, apply mathematical principles in the design and construction processes, as detailed by Pradhan (2017). These principles are not merely theoretical; they are embedded in the precise measurements, geometric patterns, and structural integrity required to create functional and aesthetically pleasing wooden artifacts. Similarly, the Tharu community integrates mathematical concepts into their everyday activities, as explored in the studies by Paudel (2008) and Adhikari (2009). Whether in agricultural practices, weaving, or the construction of traditional dwellings, the Tharu people's daily routines are underpinned by an implicit understanding of mathematics, passed down through generations.

The Chariot construction process, a significant cultural event in Newar indigenous societies, also reveals deep connections to mathematical modeling (Pradhan, Sharma, and Sharma, 2021). This ethnomodeling not only preserves cultural heritage but also serves as a pedagogical tool, illustrating complex mathematical ideas through tangible, real-world applications. Furthermore, Sharma and Orey (2017) examine the cultural artifact of Dhols, highlighting how these drums serve as mathematical resources in the process of glocalization—where global and local practices converge. The crafting and tuning of Dhols involve precise calculations and an understanding of acoustics, which are rooted in the community's cultural knowledge.

Through interactions with my research participants, it became evident that the construction of *Rangauli* patterns incorporates numerous informal mathematical concepts, which serve as effective mediated tools for developing spatial reasoning and conveying abstract mathematical ideas. Connecting with same question, some research participants expressed concerns regarding how teachers can effectively incorporate cultural elements into their lessons given their limited time to manage. Other teacher participants emphasized that while time constraints exist, the real challenge lies in teachers' attitudes and knowledge regarding the use of culture friendly pedagogy in mathematics classroom. Most of them argued that the issue is not time itself, but rather teachers' lack of familiarity with appropriate cultural elements for the teaching of specific content of mathematics. Some teachers feel overwhelmed by the prospect of incorporating culture friendly pedagogy, believing it requires additional time and extra effort beyond regular classroom teaching.

Concluding Remarks

Cultural artefacts, such as the *Rangauli* mandala, hold rich mathematical ideas and cultural significance. By exploring these artefacts, we can enhance students' understanding of mathematical concepts in a meaningful way. The study highlights the importance of incorporating cultural elements into mathematics education, as it provides a familiar context for learning and helps students connect abstract concepts to real-life situations. Employing qualitative research methods, including in-depth interviews and non-participant observation, the study unveiled the intricate connection between cultural practices and mathematical concepts. The *Rangauli* mandala, a cultural tradition deeply rooted in Hindu rituals and beliefs, serves as a testament to the fusion of mathematical sophistication and artistic expression. Through interviews and observations, it became evident that the construction of the mandala involves complex mathematical activities such as spatial reasoning, symmetry, and geometric patterns.

The process of creating a *Rangauli* mandala intertwines mathematical thinking with cultural traditions, highlighting the interconnectedness of mathematics and culture in everyday practices. Ethnomathematics provides a framework for understanding and appreciating the mathematical dimensions of cultural artifacts like *Rangauli*, enriching our understanding of both mathematics and culture. Furthermore, the study highlighted the importance of incorporating cultural artefacts into mathematics education to make learning more meaningful and culturally relevant for students. By tapping into students' familiar environments and everyday interactions with cultural artefacts, educators can provide opportunities for students to engage with mathematical ideas in contexts that resonate with their lived experiences.

However, the study also brought to light the challenges educators face in integrating cultural metaphors into mathematics teaching due to factors such as overloaded curricula and lack of time. Nevertheless, the findings underscored the value of cultural metaphors in enhancing students' conceptual understanding of mathematical concepts and called for a reevaluation of pedagogical approaches to better acknowledge and leverage students' cultural backgrounds in mathematics education. This study contributes to the growing body of literature on ethnomathematics and underscores the potential of cultural artefacts as pedagogical tools for teaching and learning mathematics, paving the way for more culturally responsive mathematics education practices in schools.

References

Acharya, B. R. (2015). *Relevancy of primary level mathematics education in Nepal: A cultural perspective*. [Unpublished doctoral dissertation]. Tribhuvan University.

Adhikari, I. P. (2009). *Ethnomathematical studies on the heritage of the Tharus*. [Unpublished M. Phil dissertation]. Tribhuvan University, Kathmandu, Nepal.

Bonotto, C. (2007). How to replace word problems with activities of realistic mathematical modelling. In W. Blum, P. L. Galbraith, H. Henn & M. Niss (Eds.), *Modeling and Applications in Mathematics Education: The 14th ICMI Study* (185- 192). Springer.

Creswell, J. W. (2009). *Research design: Qualitative, quantitative and mixed method approaches* (Third Edition). Sage.

D'Ambrosio, U. (1998). Ethnomathematics: The art or technique of explaining and knowing. *ISGEm*.

D'Ambrosio, U. (2006). *Ethnomathematics: Link between traditions and modernity*. UNICAMP.

D'Andrade, R. (1981). The cultural part of cognition. *Cognitive Science*. 5, 179-195.

Denzin, N. K. & Lincoln, Y. S. (2005). Introduction: The discipline and practice of qualitative research. In N. K. Denzin & Y. S. Lincoln (Eds.), *Handbook of Qualitative Research*, (1-32). Sage.

Eglash, R. (2001). Rethinking symmetry in ethnomathematics. *Symmetry: Culture and Science*, 12 (1-2), 159-166.

Gueudet, G., & Trouche, L. (2009). Towards new documentation systems for mathematics teachers? *Educational Studies in Mathematics*, 71(3), 199-218.

Mundy, P. A. & Compton, J. L. (1995). *Indigenous communication and indigenous knowledge: The cultural dimension of development*. Intermediate Technology Publications.

Paudel, K. P. (20008). *Tharu culture: An ethnographic perspective*. [Unpublished Master's thesis]. Kathmandu University.

Pradhan, J. B. (2017). Mathematical ideas in Chundara culture: Unfolding a Nepalese teaching and learning system. In: M. Rosa, L. Shirley, M. E. Gavarrete & W. V. Alangui (Eds.), *Ethnomathematics and its diverse approaches for mathematics education* (125-152). Springer.

Pradhan, J. B. (2021). Cultural artefacts and mathematics: Connecting home and school. In D. Kollosche (Ed.), *Exploring new ways to connect: Proceedings of the Eleventh International Mathematics Education and Society Conference*, 3, 819–828. Tredition. https://doi.org/10.5281/zenodo.5416225

Pradhan, J. B., Sharma, T. N., & Sharma, T. (2021). Ethnomathematics research practices and its pedagogical implications: A Nepalese perspective. *Journal of Mathematics and Culture*, 15(1), 110-126.

Rosa, M., & Orey, D. C. (2010). Ethnomodeling as a pedagogical tool for the ethnomathematics program. *Revista Latinoamericana de Ethnomatheamtica*, 3(2), 14–23.

Sharma, T., & Orey, D. C. (2017). Meaningful mathematics through the use of cultural artifacts. In M. Rosa, L. Shirley, M. E. Gavarrete & W. V. Alangui (Eds.), *Ethnomathematics and its diverse approaches for mathematics education* (153-179). Cham, Switzerland: Springer. https://doi.org/10.1007/978-3-319-59220-6_7

Vygotsky, L.S. (1978). *Mind in society: The development of higher psychological processes*. Harvard University Press.

Zaslavsky, C. (1996). *The multicultural mathematics classroom: Bringing in the world*. Heinemann.