Mathematical Ideas in Cultural Artefacts: A Metaphor for Teaching of School Mathematics

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Abstract- *Mathematics is taken as one of the difficult subject in school education. One of the reasons for taking mathematics as a difficult subjects is due to its abstract nature. The metaphor is a mapping of two conceptual domains: sources and target. The source domain helps student to translate their everyday experiences into an abstract and unfamiliar mathematical content knowledge known as target domain. The main objective of this paper is to explore the mathematical ideas embedded in cultural artefacts and its possibilities in the process of teaching mathematical content. The ethnography methodology was adopted and the procedures included in-depth interviews and observations were made. The mathematical knowledge hidden in their construction of Rangauli mandala and cultural meaning for community members have been analyzed with the written documents, photographs, video graphs produced. The mathematical ideas embedded in the cultural artefacts, arts and pattern design mediated to teaching of mathematical knowledge.*

Index Terms- Cultural Artefacts, Ethnography, Ethnomathematics, Metaphor, School Mathematics.

I INTRODUCTION

Metaphor is a mapping between two conceptual domains which provides a powerful tool to understand one domain of knowledge in terms of another. The conceptual metaphors help to deal with relatively unfamiliar and more abstract domains of experience in a familiar and tangible way. Metaphor simply means the representation of abstract entities through very simple, familiar and meaningful objects. It can be taken as a mapping that the abstract ideas map into concrete, strong and meaningful images that are developed in different social and cultural context for a different purpose. Thus, metaphors help to understand abstract ideas by mapping them into strong, meaningful images that are originally developed in a different context. English (1997) sees metaphors as tools for creating formal concepts out of image schemas, and of restructuring these concepts in complex ways. Lakoff and Nunez (2000) also argue that the conceptual metaphor's "primary function is to allow us to reason about relatively abstract domains using the inferential structure of relatively concrete domains," (p. 42) with structures of image schemas preserved by this mapping. Thus, metaphor can be considered as a mechanism for connecting two types of knowledge of which the new knowledge is comprehended through already existed familiar concepts.

Fyhn (2007) viewed that patterns in snow are examples of metaphors. Fyhn further maintained that "Some Sami mittens have the pattern grouse footprints on their edges. These repeating patterns show a connection between embodied experiences and ornamentation. Ski trails as well as animal footprints perform patterns in the snow, patterns with different symmetry properties" (p. 246). Further, Barton (2005, p. 100) points out that "Rather than thinking of the mathematics which is known world over through formal education, we need to expand our vision to include any form of quantitative, relational or spatial systems". Barton (2005) uses boats as a metaphor for mathematics. He claims that different boats can be used for different purposes, the fishing

boat can go to rocky places where the ferry cannot navigate and the ferry can travel under conditions too hard for the fishing boat. "It is the same world, but it is a different understanding. Neither is the truth" (p. 100).

Lakoff and Nunez (2000) discussed another type of metaphor called extraneous metaphors. According to them "…extraneous metaphor or metaphors that have nothing whatever to do with either the grounding of mathematics or the structure of mathematics itself. Unfortunately, the term metaphor when applied to mathematics has mostly referred to such extraneous metaphors" (p. 53). The staircase is an example of extraneous metaphor of the "step function" because when graphed the step function can look similar to a staircase. The image of staircase has nothing whatever to do with either the inherent content of the grounding of the mathematics, although the visual is a helpful reminder of how this function would look when graphed (Lakoff & Nunez, 2000, Bearden, 2012). Likewise, "Function is a machine" is a metaphor. The source domain of this metaphor is "machine" and the target domain is the mathematical concept of "functions". Extraneous metaphors can be eliminated without any substantive change in the conceptual structure of mathematics, whereas eliminating grounding or linking metaphors would make much of the conceptual content of mathematics disappear.

Cultural artefacts is anything created by the culture of particular group of people which provides information about the culture of its creator and users. Gueudet and Trouche (2009) extend the definition of artefact by introducing the term resources to encompass any artefact with the potential to promote the process of learning. In this vein, Bonotto (2007) viewed that the extensive use of cultural artefacts makes school mathematics more meaningful. There are different types of cultural artefacts which reflects the cultural identity of different groups of peoples. Some of them are dress, houses, stuffs, paintings, design, and patterns and so on. For him, the cultural artefacts, introduced into mathematics classroom are concrete materials, which children typically meet in real life situations. Those concrete materials can be the suitable tools to transfer from one domain to another domain of knowledge. In this paper, I explored mathematical ideas embedded in cultural artefacts of *Rangouli* mandala and its use as an instructional materials that mediated the teaching and learning of school mathematics.

II RESEARCH QUESTIONS

This study was intended to explore the cultural artefacts and its pedagogical implications to assist students in enhancing their understanding of mathematical concepts at basic level of education. Considering these, the following research questions were formulated:

1. What are the ethnomathematics embedded in *Rangoli* design?
2. What mathematical concepts does teacher teach from cultural artefacts in mathematics classroom?

III METHODS AND PROCEDURES

The main objectives of my study were to explore mathematical ideas embedded in the cultural artifacts of *Rangouli* mandala and to analyze its possibilities in the process of teaching school mathematics. To do this, I have chosen to use qualitative research method, as I wanted to make sense of the complex world of the mathematical ideas and knowledge embedded in the out-of-school context of the students. Qualitative research relies primarily on the collection of qualitative data. It is a field of inquiry that crosscuts disciplines and subject matters (Denzin & Lincoln, 2005). In my study, I chose qualitative research design as I want to make sense of the complex world of the cultural artefacts, mathematical knowledge embedded in the *Rangouli* mandala and its implications in teaching of school mathematics. It would not be possible for me to quantify such ideas, perceptions and knowledge in figures and numbers. The mathematical ideas embedded in cultural artefacts and people's feeling, beliefs, perception, attitudes understanding etc. regarding their activities cannot be captured and converted quantitatively.

Ethnography is a qualitative research methodology that seeks to understand human behavior within its own social setting. It is a process which combines the knowledge of participants who belong to certain cultures and the skills of the researcher or the ethnographer (D'Andrade, 1981). Thus the ethnographic research is an amalgam of participant observation and many of the characteristics of nonparticipant observation studies as well in an attempt to acquire as holistic picture as possible of

a particular society, group, institution, setting or situation. To carry out my research objectives, I used in-depth interviews and non-participant observation. I prepared an interview guideline and observation protocol for parents and teachers so that it would be easier for me to generate the data in the fields (Creswell, 2009).

Interviewees were asked some questions and based on their responses another question was asked to get information for the study. Interviewees were allowed to speak freely about their feelings. Because taking notes can interfere with the flow of conversation, a voice recorder was used by the researcher to record all the responses from participants of interview. I carefully recorded all the possible conservations with the help of the video camera and take field notes as much as I could. My data generated from the out-of-school culture reflect how much they are rich in terms of ethnomathematical ideas and knowledge. I collected the data from the multiple sources during the course of my study. I reviewed all of the data gathered from the multiple sources of data (Creswell, 2009) and then organize it into categories or themes that cut across all of the data sources. And then, I converted the conversations and interviews into manuscripts so that I could easily analyze and interpret them.

The main task in the research is to analyze and interpret the data that I collected from the field. After observing the data, I linked with many possible theories to interpret them. I triangulated the data, triangulated the theoretical closures and gave meaning to my findings. In this process, I tried to produce the accurate descriptions of the contents. Interpretation involved attaching meaning and significance to the analysis, explaining descriptive patterns, and looking for relationships and linkages among descriptive dimensions. In my study, the cultural artefacts in the students' community and their ways of understanding the natural phenomena, and their ethnomathematical knowledge were analyzed with the notions of pluralism. In this study the analysis of the research was validated and make more reliable by triangulating the statements among the research participants, their ways of presenting the text in the several times of data collection periods.

IV MATHEMATICAL IDEAS EMBEDDED IN CULTURAL ARTEFACTS

Nepal has rich cultural traditions and peculiar rituals. *Rangauli* is a symbol of good fortune. Rice powder used for *Rangauli* drawings provides nourishments for smaller animals, such as birds and ants. This is a symbolic act of showing the necessity of sharing and maintaining proper relationships with others. It also reinforces the respect for nature and relationship with other human beings and animals. This art form is almost exclusively practice by Hindu women. Rangauli has been constructing as cultural product from generation to generation in a process of craft model approach.

The *Rangauli* mandala is constructed in the occasion of *Dipawali*. The *Rangauli* is drawn by the rice flower including seven different colors and seen on the floors of buildings and in front of worship room (*Puja Kotha*). This drawing requires different geometrical patterns and spatial reasoning. The number of concentric circles, symmetries, vertical and horizontal reflections and rotations etc are found in the *Rangauli* mandala. The different colorings are also associated with this drawing. Regarding the construction of *Rangauli* mandala, I asked to one of my research participant P_1, how to draw a mandala pattern. 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.*

Figure 1. *Rangauli Mandala*

From the interview with P_1, I have come to know that the construction of mandala is a mental construction. Embodied cognition of the creator of the mandala help to perform their task. They have already shaped the image of the mandala in their mind. However, the different geometrical pattern found in their construction is largely hidden from the participants. And the ways

of drawing of such cultural arts and artefacts is craft model approach. The figure 1 was the mandala constructed by P_1 herself in front of main doorways of house. I also asked her that how to draw the eight-pointed star. She had already done this before I meet to her but said that she would work it out. She started with a rough diagram. The process of her drawing was that first, she draw a circle, and then she first divide the circle in four equal parts by drawing two mutually intersecting lines. Further the four parts be divided in to another halves by bisecting the quadrants. She draw a concentric circles with larger radii than previous one. She made isosceles triangle whose vertex at the circumference of the outer circles and the base at the inner circles.

From the observation of rough sketch of the ways to drawing an eight-pointed star, I have come to know that they are practising sophisticated mathematical ideas in the process of constructing mandala. I asked another research participants P_2 about the knowledge they learnt to construct such beautiful artefacts and her mathematical ideas associated with it. She replies:

> *I learnt to make this artefact by observing the ways of drawings of my mother as in the same of how these children observing patiently to my activities here. First I draw a sitting place for goddess Laxmi at the centre as we are going to worship the goddess. Then I drew some larger circle and eight petals of lotus as we believe that she likes to lye over the lotus flower.*

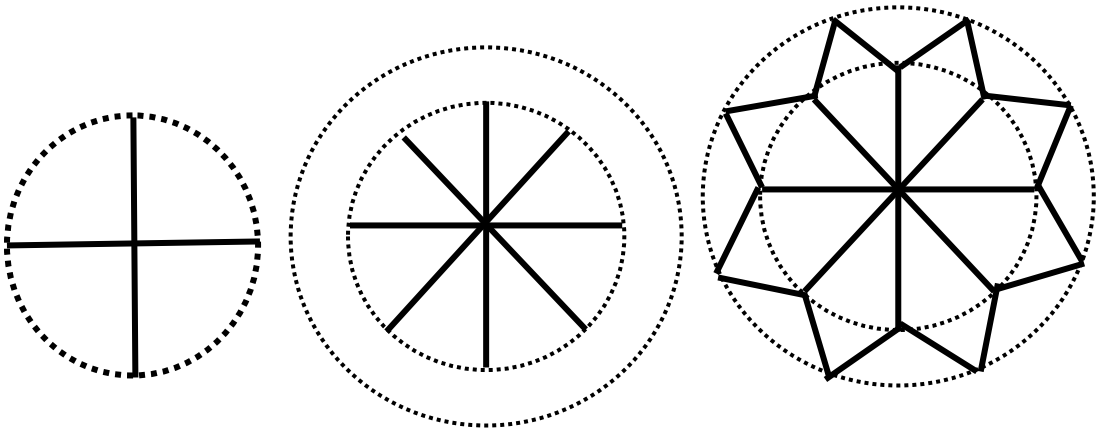

Figure 2. *Process of Construction of Mandala*

The *astamatrika* or eight-pointed star has great significance and has religious meaning in Hindu culture. The *Rangauli* drawing involves complex mathematical activity and strategic understanding of spatial reasoning. It is important to explore the hidden mathematical ideas in the process of constructing such cultural artefacts. For that, I have conducted interviews with some people who are constructing such artefacts as their cultural tradition. On the basis of an interview with some people and observations of ways to construct as their cultural tradition, I have come to know that they possess sophisticated mathematical ideas of concentric circles, coordinate axes, and symmetry in the process of construction of the mandala. The common practice of creating mandala is based on the concept of both bilateral and rotational symmetry. The different colorings are also associated with drawing. The *astamatrika* or eight-pointed star has great significance and has religious meaning in Hindu culture. The creation and perception of the pattern have a logical as well as aesthetic component (Ascher, 1991). The use of mathematics in the arts and design makes the things pretty and aesthetic (Hardy, 1978). Every beautiful thing in the world possesses the mathematical properties, and the images possess the golden ratio. If we observed patiently the objects, many mathematical ideas of ratio and proportion, symmetry, tessellations, reflection are found. However, the designers and workers might not have formal mathematical knowledge.

V POSSIBILITIES OF INCORPORATION IN MATHEMATICS TEACHING

Teaching mathematics becomes more interesting if the contents are related to the students' familiar environments. Students' everyday interaction with the cultural environment provides more opportunities to interact and conceptualise mathematical ideas. The cultural environment activities and artefacts of the students involve a lot of mathematical knowledge and

ideas. The mathematical ideas embedded in the students' cultural environment which is familiar to the students provide a good environment to learn. This environment plays important tool to communicate mathematical ideas.

Mathematical ideas and thinking are embedded in every environmental activity of a group of people. However, the mathematical ideas they possess in order to perform their everyday job remains largely hidden. Mathematical anthropology uses mathematical modeling in historic, ethnographic, and material culture studies to describe material and cognitive patterns of certain group of people (Eglash, 2001). In this vein, Rosa and Orey (2010) viewed that mathematical modeling is a methodological tool that may be used in the ethnomathematical program. Ethnomathematics can reshape our greater cultural identity in a positive way by requiring the inclusion of a greater representation of the true mathematical practices and problems for a students' own community (D' Ambrosio, 1998; Zaslavsky, 1996). The people of the different culture around the world prevalence of symmetry in designing textiles, sand painting, wall painting, pottery, arts, and artefacts.

The mathematical ideas practiced in students' environmental context may be used as a cultural metaphor for the teaching and learning of school mathematics. The informal mathematical ideas and knowledge that practices and uses in the everyday activities are the sources domain for the understanding of abstract mathematical ideas. Thus, the ethnomathematical system of the cultural group can enable a better understanding of school mathematics. Regarding the possibilities of incorporation of cultural artefacts for teaching of school mathematics, one of my research participants T_1 says:

> *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.*

Most of the research participants reported that mathematics originated from the cultural activities of different society, from different racial groups around the world. Different professional group of people are using mathematical concepts and ideas without knowing the meaning of mathematics. My data in the construction of the *Rangauli* mandala claims the embeddedness of hidden mathematical ideas on it. Their implicit mathematics knowledge of the group of people provide an opportunity to their children to learn mathematics in the classroom. Our school pedagogy has given much importance to rote learning and it is not converged with the ways of knowledge generation and distribution of the local people (Pradhan, 2017). Thus, I observed that the pedagogy we adopt in school does not acknowledge out-of-school knowledge of the students. However, the pedagogy used in out-of-school context was the craft model approach, which is common to the knowledge generation and distribution. This involves participatory and cooperative approaches in which they learn with the help of their parents as Vygotsky sees learning as an activity in which shared mathematical meanings are constructed socially. Thus, the mathematical ideas embedded in out-of-school context and the pedagogy they use could be the powerful metaphors for the teaching and learning of school mathematics. Teachers who have children cultural background and funds of knowledge can link in the classroom. In same vein, another research participant T_2 viewed that

> *I never felt that mathematical ideas can be found in the out of school culture. However, mathematics is the cultural product. How can school mathematics be taught to the students' taking help of their home cultural activities becomes problematic task.*

Other research participant T_3 opined that:

> *We teachers do not have time to think about to make mathematics teaching more culture friendly because of the overloaded curricula and over duties in classroom teaching.*

Connecting with same question, other research participants questioned that how teacher can think his lesson more culture friendly if they do not have sufficient time to manage. But, other teacher gives serious limitations of the teachers to make their class more culture friendly. Time is not the problem at all to use cultural metaphors in the teaching and learning of school mathematics. Attitude and knowledge of the teachers about the cultural metaphors for teaching school mathematics is more problematic. But the problem is that the lake of ideas on the selection of cultural metaphors for the teaching of particular content

of school mathematics. The teacher of mathematics need not to think about the cultural metaphors for teaching and learning. They believe that incorporation of culture friendly pedagogy need more time and extra effort to classroom teaching. With regarding to the use of cultural metaphors for the teaching of school mathematics, my research participant T_1 opined that:

> *The use of cultural metaphor in the mathematics teaching is evident. But we are unable to use it in our classroom teaching. 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 metaphor 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.*

Most of my research participants agreed with the view of T_1 They all accept the importance of cultural metaphors for the conceptual understanding of the mathematical concepts. The incorporation of cultural metaphors in the process of teaching and learning of mathematics enhances mathematical understanding to the students. From the interaction of my research participants, it was found that there are a lot of informal mathematical ideas present in the construction of *Rangauli* patterns. Those mathematical ideas are the effective metaphors to develop spatial reasoning and communicate the abstract mathematical ideas. I found that the teachers were using ethnomathematical ideas of a different group of people as a metaphor in the process of teaching and learning of classroom teaching.

VI CONCLUDING REMARKS

There are different cultures and traditions in every society. The significance and rationale behind the cultural arts and artefacts are almost unknown in reference to the mathematical concepts, ideas and knowledge; though the different group of people have been engaged for a long time. The people has implicit mathematical knowledge while performing their everyday job. The way that they construct is usual activities but possesses high mathematical concepts from the eyes of ethnomathematics. Using ethnomathematics as the pedagogical tools in the mathematics classroom help students learn not only mathematical concepts but also cultural elements.

The cultural artefacts regarding mathematical ideas are considered as the cultural metaphors for the teaching and learning abstract concepts of mathematics at the basic level of education. The mathematical ideas practising in students' environmental context may be used as cultural vehicles for the teaching and learning of school mathematics. The informal mathematical ideas and knowledge that practices and uses in the everyday activities are the source domain for the understanding of abstract mathematical ideas. Thus, the ethnomathematical system of the cultural group can enable a better understanding of school mathematics.

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