Chapter 7
Meaningful Mathematics Through the Use of Cultural Artifacts

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Abstract This chapter offers a perspective on how to make mathematics meaningful for students by using a cultural artifact named dhol, which is a musical instrument constructed and played by the members of the Rai cultural group in Nepal. The authors discuss how the use of culturally contextualized mathematics found in these drums may help students to connect school mathematics with their own home cultures by elaborating ethnomodels. The theoretical basis of ethnomathematics and culturally relevant pedagogy could be an appropriate response for education in Nepal. In this context, the authors invite the readers to connect mathematics with their own community and cultural practices in order to make mathematics meaningful for students.

Keywords Cultural artifacts · Culturally relevant pedagogy · Dhols · Ethnomathematics · Rai culture

7.1 Introduction

Traditionally, education in Nepal was not accessible to everyone; it was originally limited to the ruling families. Over time, the wealthy and other people of means have an increasingly better chance for an education. However, the educational condition of the minority groups continues in decline, where many of the children cannot take part in their primary education because they must work and earn money to maintain their family or help out at home.

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However, currently, the Nepali government is committed to the progress, development and growth of education for all. Nepal has introduced school education from preschool education (kindergarten level) to school education (primary and secondary). At the same time, educational opportunities are disseminated unfairly according to gender and geographical location. Nepal has three different regions (Himalaya, Mountain and Tarai). Each region has its own way of seeing the world, religion, and celebrating life, and distinct ways of living.

Nepal is a country rich in sociocultural aspects, but there are still several educational issues and challenges to overcome, such as: (a) low literacy rate, (b) quality of education standard lower than expected, (c) the state of sociocultural and educational infrastructures have not been substantially developed, (d) relevancy of education since the human resource produced by the existing education system could neither find proper place in the employment market nor is able to generate self-employment, (e) literacy rate of women, marginalized and oppressed group, people with disability, and geographically disadvantaged is not satisfactory, and (f) adequate educational opportunities are not available to children, women, marginalized and oppressed group, people with disability, and geographically disadvantaged people (Nepal 2007).

According to the previous assertions, in relation to school education, the major problem relates to both access and equity, which makes learning experiences very different from region to region in Nepal. However, although access to primary education has increased considerably, increasing this access and improving equity in education still remain a formidable challenge (Mathema 2007, p. 47). For example, there are many reasons for the unsatisfactory access and equity at school level. For example, while primary school is free, parents have to pay many direct and indirect costs for their children’s education.

Among other barriers that exclude children from educational opportunities in Nepal is their distance from school, the negative attitude of teachers toward poor children’s ability to succeed, and language, and cultural factors. In the context of Nepal, there over 123 languages with Nepali as the most widely spoken. Over 44.6% of Nepalis have Nepali as their mother tongue. Learners who do not speak, or have Nepali as a second language, have many difficulties in schools (Mathema 2007; Civil 1995, 1998). As well, participation in school education is unequal across social, cultural, gender, regional, linguistic, and income groups (Mathema 2007). Educational challenges are still in existence due to geographical, social, and cultural aspects (Nepal 2007).

Despite all these challenges, Nepali education at present is in the process of transformation including recent policies on student assessment. With the development of new teaching and learning theories, new technologies, the teaching and learning process of mathematics in Nepal is transforming from a teacher centered to use of cultural artefacts as a teaching material for mathematics classes, which is related to the innovative pedagogy named *student centered teaching* that helps teachers to create and develop attention of the students and respect for their cultural background and develop understanding of their mathematical knowledge (Luitel 2009).

In this regard, the existing domination of teacher centered teaching methods in school contradicts the essence of student assessment and ultimately, letter grading. The idea of letter grading can only evaluate student performance, if the teaching and learning process is student centered. Addressing the issue of ownership and identity of the students is the key issue for educators in Nepal.

Since it instantly overcomes many boundaries and language barriers, globalization has acquired a new meaning for Nepali educators. The new mathematics activities must respond to new meanings of globalization and will, necessarily, be transdisciplinarian and transcultural. Therefore, we agree that the theoretical basis of ethnomathematics (D'Ambrosio 1985, 2000) could be an appropriate response for education in Nepal.

7.2 Issues of Culture

The students' culture has been identified as one of the factors that influence mathematics learning, particularly in respect to indigenous learners as quoted in defines culture as the body of learned beliefs, traditions, and guides for behavior that are shared among members of any human society (Barrett 1984; Hollins 1996). Similarly, Erickson (1986) states: "Culture, as a social scientific term, refers to learned and shared standards for ways of thinking, feeling, and acting" (p. 117). However, it was Hall (1976) who concisely described the function of culture, thus:

> Culture is man's medium; there is not one aspect of human life that is not touched and altered by culture. This means personality, including how people express themselves (shows of emotion), the way they think, how they move, how problems are solved, how their cities are planned and laid out, how transportation systems function and are organized, as well as how economic and government systems are put together and function (pp. 16–17).

Moreover, Huntington (1993) stated that individuals of different cultural groups have different worldviews that are a product of centuries, which will not disappear rapidly because they are far more fundamental than differences among political ideologies. In addition, culture is expanded to include also the cultures of differing professional groups and age classes (D'Ambrosio 1985) as well as social classes and gender. On the other hand, Bullivant (1993) defined culture as a social group's design for surviving in and adapting to its environment. Despite these definitions of culture, according to Banks and Banks (2002) culture is considered as the ideations, symbols, behaviors, values, knowledge and beliefs that are shared by a community (Civil 1995, 1998).

Looking closely at the above discourse, we agree with Rosa (2010) who states that culture may have a pervading influence on how a group of people live and learn. The culture of local populations, for instance, would influence how students learn and retain what they are taught in schools. It is the culture itself that shapes learning styles in mathematics, determining to a large extent, to what use they put the mathematics knowledge they acquire in schools. Because culture provides the essence of who we are and how we exist in the world, and because it is derived from understandings acquired by people through experience and observation about how to live together as a community, how to interact with the physical environment, and knowledge or beliefs about their relationships or positions within the universe, culture can be a an essential tool in learning mathematics (Hollins 1996; D'Ambrosio 2006). Hence, culture plays a vital role in the development a world-view of teaching mathematics.

Within this context, D'Ambrosio (1985) affirms that culture considerably affect the way in which people understand mathematical ideas, procedures, and practices. Hence, ethnomathematics has demonstrated how mathematics is made of many diverse and distinct cultural traditions because each cultural group has developed unique ways of incorporating mathematical knowledge and has often come to represent given cultural systems, especially in ways that members of cultural groups quantify and use numbers, incorporate geometric forms and relationships, and measure and classify objects.

For example, Rosa (2010) affirmed that if a mathematical problem is not contextualized students may not be able to use their prior knowledge to develop learning activities. This is especially true if this knowledge is based on their histories, experiences, and interactions with the environment where they live. Many educators forget that context plays an important role in the teaching and learning process. Thus, context is the most powerful and influential factor in this case because it focuses on and relates to prior knowledge to the mathematics of the classroom. From this point students find mathematics in their everyday life, they feel mathematics as flexible, and they increase their conceptual understanding in order to solve mathematical problems.

If teachers are aware of the cultural context of their students, they will encourage understanding of mathematical concepts (Sharma and Neupane 2016). As suggested by Shirley (1995), ethnomathematics is a key to finding connections between students everyday lives and school, that is, within mathematics, the members of distinct cultural groups blend two or more mathematical areas to other subject areas such as art, geography, economics, etc., in order to meet their needs as they look at the *culture of the others*; and to the local culture in order to incorporate local mathematics. Therefore, they develop their own mathematical language and symbols to understand phenomena, and to empower themselves.

Hence, Hofstede (1986) argues that culture influences mathematics through its manifestations such as cultural traits, geometric shapes, values, artifacts, and symbols. His premise was that the values preferred by a group of people separate them from other groups and, thus, cultures can be compared with each other using values as a standard. Under this circumstance, local mathematical manifestations focus on the meaning of objects such as cultural artifacts in the lives of the members of different cultures have also applied values to explain how people organize information in their own environment, which are the ideas according to which phenomena, such as mathematical, are organized, constructed, evaluated, and diffused.

For example, cultural artifacts such as musical instruments themselves can be considered as the solid reminders of the commitment of Nepali people to a musical and spiritual life, connections between its cultures, signs of great creativity, and physical emblems of the sounds they create. Music is about expression, communication, release, celebration, worship, ritual and enjoyment, and musical instruments support all of these *cultural traits.*[1]

Therefore, Dunipace (2010) stated that Nepali musical instruments are understood according to the purposes of the members of the cultural groups who use them. Some of these instruments are used in Nepali classical music, for folk music, by the Gandharba and Damai musician castes, for religious or spiritual ceremonies and processions, and some for specific purposes in the life of Nepal's many ethnic groups. Most of the instruments used in Nepal originated in India and to a lesser extent Tibet, but all have developed in uniquely Nepali ways.

7.3 Cultural Artifacts

Cultural artifacts are objects created by the members of cultural groups, which give cultural clues and information about the culture of its creators and users (D'Ambrosio 1993). They have some significance in the daily life of distinct cultural groups because "the language of the shapes, the designs, the myths, and the colors, confirm the community's sense of reality and give it control over its own time and its own space" (Voltz 1982, p. 45). In this regard, these artifacts are made to adorn walls, ceilings, baskets, utensils, clothes, jewelry, and even the human body itself as well as to serve as religious purposes (Onstad et al. 2003).

However, it is important to emphasize here that the essence of cultures is not only the development and use of their cultural artifacts, tools, or other tangible cultural elements, but the distinct ways that their members develop in order to interpret, use, and perceive their main characteristics of their own culture (Banks and Banks 2002). Cultural artifacts such as language, myths, and literature influence the representational system of diverse civilizations may be used in different cultures in distinct ways as well as for different purposes.

Hence, members of distinct cultural groups develop models that represent systems taken from their own reality in order to help them to understand and comprehend the world by using small units of information named *ethnomodels*, which link cultural heritage with the development of their mathematical ideas, procedures, and practices. According to D'Ambrosio (2016), humanity:

[1]Cultural traits are related to the appreciation of features developed by the members of a specific culture such as religion, language, government, customs and traditions, social organization, and arts as well as the establishment of relations between the members of that group. In this context, it is important that educators, investigators, and researchers understand the cultural roots of other cultures in order to value the ideas, procedures, and mathematical practices used by students from distinct cultural contexts (Rosa and Orey 2016).

> (…) develops the perception of past, present and future, and their linkage, and the explanations of facts and phenomena encountered in their natural and imaginary environment. These are incorporated to the memory, individual and collective, and organized as arts and techniques, which evolve as representations of the real (models), as elaborations about these representations which result in organised systems of explanations of the origins and the creation of myths and mysteries (mentifacts). Some of the representations materialize as objects, concrete representations and sophisticated instruments (artifacts) (p. 41).

Through the elaborations of models, humanity try to explain phenomena that occur in their daily lives. These explanations are organized as arts, techniques, theories, as strategies to understand and deal with daily facts and events. These strategies, have been historically organized, in different groups, in different spatial and temporal contexts, which are the support of cultures as systems of knowledge frequently represented by the elaborations of models (D'Ambrosio 2016). In general, a model is a representation of an idea, a concept, an object, or a phenomenon (Gilbert et al. 2000).

Therefore, ethnomodels is defined as cultural artifacts that are the pedagogical tools used to facilitate the understanding and comprehension of systems taken from reality of the members of distinct cultural groups (Rosa and Orey 2009). In this regard, according to Rosa and Orey (2013a, b), ethnomodels are considered as external representations of local phenomena that are precise and consistent with the scientific and mathematical knowledge socially constructed and shared by members of specific cultural groups. The main objective for the elaboration of ethnomodels is to *translate* the mathematical ideas, concepts, and practices developed by the members of distinct cultural groups into school mathematics.

This approach helps the organization of pedagogical actions that occur in classrooms by using local aspects of mathematical thinking through the development of cultural artifacts as well as "provides an important opportunity for educators to link current events and the importance of these artifacts in the context of ethnomathematics, history, and culture" (Rosa and Orey 2008, p. 33). Consequently, D'Ambrosio (2008) states that representations given by these elements enable the expansion of students' reality by incorporating the artifacts regarding mathematical simulations and models.

7.4 Connecting Cultural Artifacts with Mathematics

Early knowledge acquired by youngsters is inter-twined with the cultural milieu and environment in which the children are born and grow up. Hence, by the time children get to school, they already have a considerable amount of experience and prior knowledge ingrained in them through their home and peer group interactions. If the school culture reinforces the students' home cultures, by respecting prior knowledge and learning experiences, then learning is facilitated for these students; if not, learning is drastically inhibited.

The situation described here holds true, to a greater or lesser degree, for all students, but is more cogent for local students, most of who live in different regions of Nepal. For example, important objectives of Nepali education is to “develop positive attitudes towards the norms and values of democracy and diverse culture of the nation” and to “familiarize with the national history, culture, geography, economics, ethnic and cultural diversity and environment for nation’s development by promoting national unity, cordiality and peace” (Nepal 2007, p. 42).

When students attend schools and encounter abstract and academic subjects such as mathematics, they find themselves disadvantaged because the mathematics curriculum currently in use in most schools is alien to them and so are the teaching and learning styles adopted in classrooms. Shirley (1995) addressed this issue by stating that the problem for many teachers is that most of the mathematical content in our academic curriculum has been derived from the developments in European mathematics and many educators have difficulty finding examples that do not seem to be Eurocentric.

Since our schools have increasingly heterogeneous populations from many different cultures around the world, an apparently Western-based (without connection to Nepali culture) curriculum can be counterproductive to our interest in recruiting members of underrepresented groups into mathematics. In accordance to Sharma (2012), if our children learn to see mathematics only from a foreign perspective, they may believe that our culture is less powerful and might not work with mathematics or, even worse, that they cannot work with the mathematics that they see in schools, as it is for *others*.

If children come from a South Asian cultural heritage, this belief may be dangerously extended to “I cannot work with mathematics”. Thus, a culturally relevant pedagogy can go a long way towards rectifying errors that currently exist, and making mathematics attractive to all students, especially students from the under-represented indigenous groups. This kind of pedagogy was developed out of concern for serious academic achievement gaps experienced by low-income students, students of color, and students from culturally diverse environments (Gay 2000).

Culturally relevant pedagogy uses cultural knowledge, prior experiences, frames of reference, and unique learning styles of ethnically diverse students to make learning more relevant and effective with the objective to strengthen their connectedness with schools and as a consequence reduce behavior problems and enhance learning (Klotz 1994). In this regard, educators can benefit from being culturally relevant by contextualizing instruction and schooling practices while maintaining academic rigor and helping students to achieve their academic potential (Ladson-Billings 1995). The use of a culturally relevant approach to teaching has resulted in success in some recent cases (Rosa and Orey 2015a).

The most important assertion in the previous paragraph is to remind us that it is necessary to discourage teaching mathematics to students from indigenous cultures through instructional methods that emphasize the abstract, as opposed to the concrete, the imaginary rather than the real (Davison 1992) because the “abstract, decontextualized teaching of mathematics has affected many American Indian students' school success" (Davison 1992, p. 243). In order to redress this situation, it is important to recommend that:

> Wherever possible, mathematics concepts should be presented in a culturally relevant manner, using situations that the students find interesting and familiar. Above all, the presentation of mathematical ideas needs to be consistent with how students learn. The use of tactile or visual approaches assists students to form meaningful images (Davison 1992, p. 243).

For instance, Simard (1994) reported the impressive outcome of an integrative, culture-based approach employed at a Winnipeg high school in Canada, the children of the Earth High School, an example of an urban school that teaches the standard curriculum from a cultural perspective. The school has been very successful in graduating students from the grade 12 program into post-secondary institutions. The use of community people and their wide array of talents helped them put back meaning into education. Several researchers and pioneers in this field (Cajete 1994; D'Ambrosio 1980; Davison 1992) have advocated the use of holistic and multisensory approaches to mathematics and science teaching.

For indigenous students in particular, teaching mathematics through the use of methods and instructional designs that glorify the familiar explain-example-exercise pattern of expository teaching (Matang 2001) has led to high dropout rates from mathematics and associated science courses. For such students, *rules without reasons* frequently used in mathematics teaching as exemplified by *change side, change sign* (Backhouse et al. 1992) has often led to confusion, not comprehension.

7.5 Mathematical Practices with Culturally Relevant Pedagogy

Nepal is a tiny country made up of numerous multicultural and multiethnic communities that also contribute to a large diversity in the quality and understanding of the teaching and learning process. Because children learn better in their own contexts, the diversity of religions, cultural practices, geographies, castes, ethnicities, languages, and histories contribute to the learning process. It has a national curriculum framework, which demands specific skills, behaviors and knowledge for all children.

Thus, a *National Curriculum Framework for School Education in Nepal* (Nepal 2007) was developed to play the role of the core document of Nepali school education. In accordance to this document:

> It is expected that it will provide a long term vision of school education. It has presented the policy and guidelines on contemporary curricular and other important aspects, issues and challenges, vision of school level education, basic principles of curriculum development, objectives and structure of school education, student assessment and evaluation policy, and open education (Nepal 2007, p. iv).

Even though Nepal has a national curriculum framework, a single and unique standardized teaching process has not been able to address the context of distinct cultural groups nor to reach expected learning achievements for all learners. One of the reasons for this problem is that, often, the "teaching in all levels is examination oriented" (Naidoo 2004, p. 55).

At the same time, Nepali children have their own ways of learning. Moreover, living in extremely diverse contexts such as Nepal is highly dependent on cultural practices. In order to address this issue, in relation to the teaching methods, the national curriculum framework of Nepal states that the process of teaching and learning should be:

> (…) practical and effective in order to transform the learning achievements set by the curriculum. Schools and classroom environment as well as the activities conducted in classes are considered as the key elements for the successful implementation of the present day formal school curriculum. The relation between school and community, teacher development and management, education materials, and the evaluation system bring about great effect on instructional approach. Similarly, instructional approaches are considerably significant from the angle of teaching and learning because a teacher has to play the role of a communicator, colearner, facilitator, motivator and an agent to make learners inquisitive in learning (Nepal 2007, p. 21).

This assertion may suggest that culturally relevant pedagogy play an important role in the teaching and learning of mathematics because it can help teachers to make mathematics learning contextual and create activities where students can easily relate to their own culture and everyday life. A culturally relevant pedagogy approach provides ways for students to maintain their cultural identity while succeeding academically. It is designed to fit school culture with students' culture to help them understand themselves and their peers, develop and structure social interactions, and conceptualize mathematical knowledge (Ogbu and Simons 1998).

Therefore, ethnomathematics encourages the use of and study of cultural aspects of mathematics. It presents mathematical concepts of the school curriculum in a way in which concepts are related to the students' cultural backgrounds, thereby enhancing their abilities to make meaningful connections and deepening their understanding of mathematics (D'Ambrosio 1985). In accordance to this context, Rosa (2010) argues that there is a need to examine the embeddedness of mathematics in its cultural context by drawing from a large body of literature that takes on the students' cultural roots of knowledge production in the context of the mathematics curriculum.

The application of ethnomathematical approaches and culturally relevant pedagogy into the mathematics curriculum are intended to make school mathematics more relevant and meaningful to students and to promote the overall quality of their education. In order for teachers to implement a sense of cultural connection, they need knowledge of and respect for the various traditions and languages in their communities (Rosa and Orey 2011). Consequently, schools need to be "encouraged to conduct practical classes by developing appropriate teaching materials and made them capable in the development and management of teaching materials by using local means and resources" (Nepal 2007, p. 56).

In this regard, our research asks, “How can we make mathematics teaching and learning processes more relevant with our cultural practices, realities, and our children’s prior knowledge as well as we share a number of questions related to school mathematics in Nepal, which include:

1. How we might assist students to become multidimensional thinkers, rather than linear thinkers;
2. How can we empower and encourage students to seek mathematics in their everyday life;
3. How cultural practices makes mathematics meaningful; and
4. If empowerment can happen, how does it make school mathematics meaningful to children?

In order to find the answers to these questions, we agree with Irvine and Armento (2001) that a culturally relevant pedagogy allows teachers to provide and use meaningful learning materials; create environments, which include cultures, customs, and traditions that are different from their own; and include lessons that assist students in making meaningful connections between their lives and school-related experiences. In this direction, Rosa (2010) states that in a culturally relevant mathematics pedagogy, teachers construct bridges between the home culture and school learning of the students, where it promotes the background, experience and knowledge of learners.

In this case, local cultural artifacts provide a natural means for students to access the framework for their own conceptual understanding of mathematics. Thus, it is important to emphasize that “Human development is a cultural process. As a biological species, humans are defined in terms of our cultural participation” (Rogoff 2003, p. 3). Therefore, culture is one of the most important resources for teaching and learning of mathematics (Rosa and Orey 2011).

This context allows us to state that teaching through cultural aspects increases student conceptual understanding. In this regard, Ladson-Billings (1995) describes culturally relevant pedagogy as a pedagogical approach that empowers students intellectually, socially, emotionally, and politically by using cultural referents to impart knowledge, skills and attitudes. If a form of culturally relevant pedagogy is used in the classrooms, it can help to develop a student’s whole personality (intellectual, social, emotional, and political).

In relation to the pedagogical work developed in schools, the “views of pedagogy within the literature on ethnomathematics are compatible with work on culturally relevant pedagogy” (Hart 2003, p. 42), which examines the cultural congruence between students’ communities and schools. However, in order to implement the main ideas of cultural congruence in schools, Zeichner (1996) emphasizes that teachers must have knowledge of and respect for the various cultural traditions and languages of students in the mathematics classrooms.

Thus, Rosa (2010) recommends that teachers also need to develop general sociocultural knowledge about their students’ development as well as the ways that socioeconomic circumstances, language, and culture shape their mathematical performance. Finally, teachers should develop a clear sense of their own ethnic, social, and cultural identities in order to understand and appreciate those of their students.

7.5.1 Comments on Ethnomathematics and Culturally Relevant Pedagogy

In the context of this study, culturally relevant pedagogy focuses on the role of mathematics in the sociocultural context of the students, which involves ideas and concepts associated with ethnomathematical principles related to geometric concepts. According to Rosa (2010), this process of teaching mathematics through cultural relevance and ethnomathematical perspective by using cultural project-based learners help students to know more about their own reality, culture, and society by providing them with mathematics content and approaches that enabled them to master academic mathematics.

Thus, when practical or culturally-based problems are examined in proper sociocultural contexts, students realize that mathematical practices developed by the members of different cultural groups reflect themes that are profoundly linked to their daily lives (Rosa and Orey 2015a). It becomes connected to objects and places they literally walk by everyday. Thus, students may be successful in mathematics when their understanding of it "is linked to meaningful cultural referents, and when the instruction assumes that all students are capable of mastering the subject matter" (Ladson-Billings 1995, p. 141). Consequently,

> Students investigate conceptions, traditions, and mathematical practices developed by members of distinct cultural groups in order to incorporate them into the mathematics curriculum. Teachers learn to engage students in critical analysis of the dominant culture as well as the analysis of their own culture (Rosa and Orey 2015a, p. 902).

This approach aims to draw from the students' cultural experiences in using them as vehicles to make mathematics learning meaningful as well as to provide students with the insights of mathematical knowledge as embedded in their sociocultural environments (Rosa and Orey 2013a, b). This is one important element of the use of ethnomathematics and its connection with cultural relevant pedagogy for mathematics teaching and learning process since it most certainly includes indigenous populations, but also cultures of labor and artisan groups, communities in urban environments and in the periphery, farm communities, and all types of professional groups. According to D'Ambrosio (2016), all these groups have specific strategies of a mathematical nature, that is, they have developed their own strategies for observing, comparing, classifying, ordering, measuring, quantifying, and inferring.

7.6 Dhols as Cultural Artifacts in Nepal

Dhols are double sided drums, which are traditional musical instruments in Nepal, mostly, in communities in the Himalayan belt. People from diverse communities in Nepal also construct the dhols as they need for the festivals or other functions such as artistic events. These musical instruments can be easily found in stores in Nepal. Figure 7.1 shows one of the Nepali dhols.

The dhols play an important role in the Nepali culture because it has emerged as a musical instrument in which the members of distinct cultural groups use them as a symbol of their ethnic identity. Culturally, the dhol is very important to these members because they use it for their celebrations and other events.

Many different and diverse occasions are associated with these musical instruments that are played across the Indian subcontinent, which includes festivals, jatras, religious ceremonies, folk dramas and other circumstances of celebration such as weddings or children birth. It is also widely used on diverse events ranging from wrestling bouts to folk dances as well festive occasions. Different Nepali musical instruments such as dhols are used for diverse purposes. For example, the dhols are mostly used for marriage and other social ceremonies (Basu and Siddiqui 2011).

These musical instruments are made in diverse varieties and materials, which give them colour and rhythm to any music they are associated with during the performance of its players (Barthakar 2003). In accordance to Schreffler (2010), throughout history, diferent rhythms were played on the Nepali dhols. However, with the decline or disappearance of some cultural practices, recent generations of dhol players have become unfamiliar with many of these rhythms.

There are considerable variations in techniques to play the dhols, which are usually played with free hands or by using two wooden sticks and various combinations of both. The most well-known style is the *bhangra* that uses sticks on both sides of the dhols. There is also variation as to whether the low pitched side should be played on the left side or on the right side. However, throughout most of South Asia, it is more common to play the lower pitched side with the left hand (Courtney 2016).

Fig. 7.1 Dhol drum. *Source* Personal file

For example, people from the Newar community use two different sticks to beat the dhol, one for each head of the drum, but the members of the Rai cultural group only use one side for beating. In fact, for them, it does not matter which side, left our right, they beat the dhol to produce the sound. It is importante to state here that sound is not produced because of the size of the drums, rather, it is the quality of the wood and the leather that influence the sound produced by the dhols.

Nepali people who construct these drums, generally, use leather that come from the ox[2] and the wood they call *utis* (alder), but currently they are using wood from the *Siris* and other locally available trees. Mostly, they are able to get these materials from the mountain area of Nepal. They may also purchase them from the local suppliers.

Historically, Schreffler (2002) argues that the dhols are drums that date back to the 15th century. It was probably introduced to the Indian subcontinent via the Persian drum type dohol (duhul) (Thakur 1996; Nabha 1998). Evidence of this fact is found in the *Ain-i-Akbari*, which is the *Constitution of Akbar*, a 16th-century, detailed document recording the administration of Akbar's empire, written by his vizier, Abu'l-Fazl ibn Mubarak (Majumdar 2007) who describes the use of dohol in the orchestra of the Mughal emperor Akbar (Schreffler 2002).

However, the Indo-Aryan word dhol only appears in print around 1800 in the *Treatise of Sangitasara* (Tarlekar 1972). However, Schreffler (2002) states that images of dhol players appear to be present in the bas relief carvings on Indian temple walls from the earliest times. It is possible that both the instrument as well as the name have some deep Indo-European connection.

Musical instruments in Nepal have a very strong relationship with Nepali religion, culture, and society. The musical traditions of Nepal are as diverse as the various ethnic groups of the country. In the course of the past 2000 years, the musical culture in the Himalayas has absorbed mostly Indian influences in shaping a unique musical tradition (Shankar 2011).

In the Nepali society, special groups play musical instruments in specific events such as the Bratabandha, which is a *Vedic Brahmanic* ritual, and welcoming ceremonies and in any other festivals in order to perform their rituals and traditions (Shankar 2011). Hence, musical instruments as cultural artifacts are very important in Nepali culture and society, mainly, for the members of the Rai cultural group.

Mostly, the Rai people live in the Eastern mountain region of Nepal. They are one of the most ancient indigenous ethnolinguistic groups, with their own unique cultural practices. They possess a rich and unique cultural heritage and are known for the construction of the dhol musical instrument*s*, which is one of the cultural artifacts that represent the Rai community.

[2]Since more than 80% Nepali people are Hindu by religion and they do not eat cow and ox, it is getting difficult to provide these kinds of leather. Currently, they are using buffalo leather that has less quality than the ox leather. However, people from the Rai community can eat ox and this kind of leather is provided to them.

Fig. 7.2 Dhol players playing the instrument. Retrieved from: https://en.wikipedia.org/wiki/File:Sakela_dhol.JPG. Accessed on December 29th, 2016

In the Rai community dhols are played in their festivals such as the *Sakela Sili*, which is one of a few rituals in Nepal that are performed collectively, and that is found among all the Kirati people. It gives a noble sense of feelings such as awareness of we, togetherness, motivations and mystical harmony with a deified nature. The main characteristic of this festival is the *Sakela* dance performed by large group of Rai people (Schlemmer 2004).

The beating of the *Dhol* and jhayamta (drums and cymbals) accompanies the rhythms and the styles guided by the *Silimangpa* and the *Silimangma* that remind them of their devotion towards their *God* and *Goodness*, ancestors, home, village, and the *Mother Nature*. The small size of the dhols they play reflects their tendency to dance and run around with the drum during performances. They use the *Dhole* in *Chandi Sili* on the important full days of *Ubhauli* and *Udhauli* (Rai 2012). Figure 7.2 shows dhol players beating the instrument.

Even though the Rai people perform different ways of dancing, Rai (2012) argues that the dance moreover symbolizes the folkloric practice with the aim of requesting agricultural prosperity from the ancestors. It also helps to preserve traditional musical instruments such as different types of cymbals, drums and different types of Sili, which have been practiced throughout history.

7.7 Mathematical and Geometric Manifestations in the *Dhol Drums*

If we connect cultural artifacts such as musical instruments (dhols) in the classroom teaching process, children may be able to enjoy learning and also come to explore their own mathematical and geometric concepts as well as its application in their day-to-day life. For example, the results of diverse studies have revealed sophisticated mathematical ideas, procedures, and practices developed by the members of distinct cultural groups, which include geometric principles in craft work, architectural concepts, and practices in the activities and cultural artifacts of many local cultures (Eglash 1999; Orey 2000; Rosa and Orey 2009).

These mathematical ideas, procedures, and practices are related to numeric relations found in measuring, calculation, games, geometry, divination, navigation, astronomy, modeling, and a wide variety of other mathematical procedures and cultural artifacts (Eglash et al. 2006). For example, the Rai people developed their own concepts about counting numbers and unique ways of calculations that they use in their real life contexts such as the measurement used in the construction of the *dhol* drums.

Here, the authors have taken advantage of this cultural artifact to explore the dhols and their relation to mathematics and geometry. Therefore, it is necessary to state that in "relation to the pedagogical work in schools, mathematical curricular activities must be relevant to the students' cultural backgrounds" (Rosa and Orey 2015a, p. 900).

7.7.1 Making the Dhols

Typically, Nepali dhols have diferent names in relation to the distinct cultural groups that use them. In general, the size of the drums depends on the leather and wood accessed from local sources in the process to making these musical instruments. Lengths and sizes of the heads of these drums vary from region to region, which may be the reason that there are no common standards to make these drums (Barthakar 2003).

Informants from dhol-makers cultural group in the Rai community in Nepal describe the practices they acquired from their ancestors to construct the dhols. For example, in an interview, a representative from the Folk Music and Instrument Museum of Nepal informed the researchers that they have a special *myth* related to the construction of these drums.

In this story, a shaman sent a tika to find a tree in a forest to make a dhol. According to this tradition, before starting the process of making the dhol, the drum makers pray at home with a shaman. As part of this custom, they are blessed by the shaman with a *tika.*[3] On the next day, they go in search for the tika in the forest. It is believed that when they see a tika on a tree they have found the right tree that provides the best wood for them to construct the musical instrument they want to make. Again, they pray to and bless the tree before cutting it down to make the drums.

[3]Tika is a small spot of bright orange colored rice that people place on their forehead for blessings.

Similarly, they have a special myth or story related to the quality of the leather. People of that community say that only an instrument with a special process can work for blessing or fulfillment of their desire. In this regard, different instruments may have special reasons, and special blessings and power associated with them.

The museum informant stated that, currently, it is very difficult to determine the correct process of making dhols or any such musical instruments, but they also believe that dhols are special musical instruments that help them to develop their spiritual and religious traditions. For this reason, they are not able to conform that they are using the same measures or standard sizes that their ancestors used to make these instruments.

According to the informant, the skills required for the proper construction of these musical instruments are highly refined and it is the main differentiating factor in their quality. Therefore, in relation to the quantifiable aspects of the drums, these makers do not apply standardized mathematical procedures and techniques to make them, yet they have developed from generation to generation a sense of measurement as they estimate the amount of strings, wood, and leather they need to make the dhols. In this context, D'Ambrosio (2006) affirms that mathematical ideas, procedures, and practices are developed in different cultures in accordance to common problems that are encountered within a cultural context.

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In order to make a dhol, wood is found that allows for a hollow to be carved inside of a wooden cylinder that will be shaped for the body of the drum. More often than not, a solid piece of wood is used that can be carved from a single block or a tree trunk. The drums they construct have, in general, a average length of about 22 in. and a diameter of 18 or 19 in. for the two drum heads. In general, both ends of the drum will have the same size or measure. The outer part of the body of the instrument measures about 0.75 in. of thickness. Thus, the total diameter of the dhols decreases by 0.75 in. +0.75 in. or about 1.5 inches.

The members of this cultural group do not have a scientific reason or formula that is equal to what we use in academic mathematics (circumference or diameter) to fix the measurement of the dhol, but they are used to working with from a sense of estimation which produces a quality sound. Earlier, people from the *Rai* community did not use current measurement units, rather they estimate when constructing the dhol. People from the dhol user community told the researchers that, dhol makers used their fingers for estimation. For example, the distance from an elbow to nail of middle finger measures about 1.5 ft. Likewise half of a hand from elbow to middle finger's nail measures a tighter or maximized length of palm.

In the traditional village areas we still find dhol makers who use the process of estimation rather than standard units. Other communities in Nepal, have slightly different kinds of practices and measurement scales. In future work with the Center for Activity Based Instruction (ABI) we make use of these differences and the diversity of measurement. A deeper discussion about this issue will have to wait for future research since it is part of future ABI curriculum project work. According to Kandel (2007) most communities use about 1.5 times diameter for length of a classic or traditional dhol. This shows that there are different perceptions and practices of dhol making. However, in the present context, many dhol makers we worked with use standard units for measurement like inches or centimeters.

It is important to emphasize here that, for musical purposes, the volume of the drum is irrelevant for Rai people, yet it is important to name different dhols such as dhaa, dhime, madhime, and tainai because they are constructed in diverse sizes, which implies that they have distinct volumes. However, it is possible to determine the volume of a dhol by using an etic approach. For example, if the drum has a given length, the volume of the dhol can be determined by developing the process: from 18”–1.5” (0.75” + 0.75”) = 16.5 in. diameter and length 22 inches.

For academic purposes, it is possible to find it by using the formula volume cylinder, which is: $V = \pi r^2 h$. This etic ethnomodel can be used as mathematics classes teaching material. If a dhol has a diameter of 18 in., then they use 0.75 in. thickness for drum’s wood for round. For the smaller ones, they only use 0.5 in.. Figure 7.3 show an etic representation of the outer and inner measurement of the dhol.

Etic constructs are considered accounts, descriptions, and analyses of mathematical ideas, concepts, procedures, and practices expressed in terms of the conceptual schemes and categories that are regarded as meaningful and appropriate by the community of scientific observers, researchers, and investigators (Rosa and Orey 2013a, b).

Similarly, the determination of the lateral area of the dhol does not make sense to the drum makers, but they know that if drums have bigger sizes, then they have bigger areas, yet they have to estimate the amount of leather to cover the dhol and

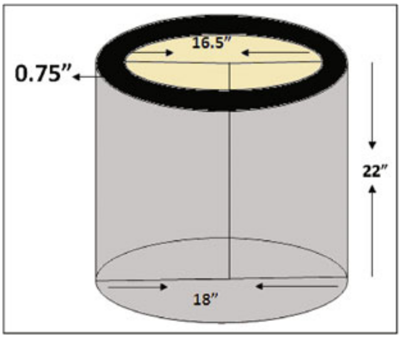

Fig. 7.3 An etic representation of the outer and inner measurement of the dhol. *Source* Personal file

its two heads. For this, they do not have standard skills and myth for estimating of leather to cover the dhol and its two heads they just see the hole of two heads and estimate it in square form.

Their process is still very traditional; they just put wood on leather then they cut it form bigger sized leather. Thus, they just estimate the total coverage area and the two heads and, and then, cut the amount of leather they need. There is no standard size for the amount of leather they use to make the dhol, but generally they cut it from bigger pieces of leather. In this context, according to their tradition a wooden frame is covered with an animal skin. Thus, they need to estimate the amount of leather they need to make the dhols. Similarly, the two open ends (heads) of the dhol are covered with goatskin, with the latter being tightened with the strings that stretch along the body of the instrument (Basu and Siddiqui 2011).

There is a variety of tightening arrangements for the dhol. There are rawhide lacings, rope, and, screw turnbuckle systems. Sometimes they are laced with rope, or rawhide, in which case, a series of metal rings are often used to pull and tighten the instrument. Sometimes metal turnbuckles are also employed (Courtney 2016). They can be retained and tightened in a direct manner by means of continuous loops of single twisted cord passing through both heads at several points on their circumferences. The cord passes through the head and around a wooden collar which is wrapped in the skin. Every two strands of the cord pass through a movable brass ring, which serves to regulate the tension of the heads (Dupree 1973).

The skins can be stretched or loosened with a tightening mechanism made up of either interwoven ropes, or nuts and bolts. Tightening or loosening the skins subtly alters the pitch of the drum sound. The stretched skin on one of the ends is thicker and produces a deep, low frequency (higher bass) sound and the other thinner one produces a higher frequency sound (Dupree 1973). However, dhols with synthetic, or plastic, treble skins are also very common.

Usually, the thickness of the skin is from 1/8–1/10th of an inch. The skins are laced together with one piece of cotton rope threaded through the edges of both skins. This is the more authentic way of setting up the skin in the drum. The skin on both the heads is stretched round leather hoops fastened to the skin and kept taut by means of interlaced leather thongs or thick rope. A leather band passed round the skin and over the braces serves to tighten the 2 heads to the pitch (Barthakar 2003; Dupree 1973). They use same leather but still cannot say its thickness because they also do not have exact measures of thickness. It depends on leather they find in the community.

In relation to the material for making the dhols, their focus is on the use of leather and wood. For example, for better sound they dry and wet the leather 4 (four) or 5 (five) times during the completion of the process of sound fixing. They use cold water to wet and heat the leather to make it flexible. After the regular process of making it tight and flexible they get the sound they have expected. After getting expected sound they stop the process for dry and wet. For fixing its sound dhol makers or user do experiment on dry and wet process.

Dhol user said that, differences in flexibility and tightness of the leather produces different types of sound. When leather becomes tight (cold), it gives bad sound then they dry its surface for few minutes to set their used sound. Moreover, in order to produce rough sound and piercing sound they use string to tight leather they use on both heads of the dhol. In the percussion instruments, the vibrating:

> (…) element is usually a wooden, sometimes shaped in thickness to tune its second mode to a harmonic of the fundamental. Apart from necessary mechanical hardness and durability, the main acoustic features desired are high density, so that considerably vibrational energy can be stored, and low internal losses, so that the sound rings for a relatively time. Percussion instruments made with wooden material have a mellow tone and shorter ring time because of the greater internal losses of wood, particularly at high frequencies (Fletcher 1999, p. 8).

The membranes of drums are "traditionally made from animal skins, for want of any alternative, and these suffered from uneven thickness, only modest strength, and sensivity to both temperature and humidity. The damping of a drumhead is almost enrirely caused by viscous losses to the air and by sound radiation, so that, the requirements on the membrane are almost purely mechanical" (Fletcher 1999, p. 8).

On the other hand, even spaced holes are cut around the circumference of the heads of the drum. A rope is them passed through the holes of the two skins, bracing them together, which fixes both heads with lather. In order to fix the lather on both heads, dhol makers use spaces holes on both sides of heads. For that they have common practices to make holes on the circumference of the heads to use string to tight them. If a drum has a diameter of 18 in., then there are 36 holes for the strings they use on the lateral surface area. To find the length of the strings they use a common formula to determine it.

For example, in this emic ethnomodel, a drum with 18 in. of diameter has 36 holes on the circumference of each head, then, there are $36 \times 2 = 72$ holes on both heads. They estimate for 36 holes on circumference. Interestingly, they know the relationship between measurement of circumference and diameter. They estimate circumference by multiplying diameter by 3 times. After getting estimation measurement of circumference, they divide it by 36 and get the space gap between holes in the circumference. So, they need 72 ft of string for one drum, which is also made with ox leather. Thus, they tight strings are tightening in order to produce better sound

In this context, emic approaches are concerned with differences that make mathematical practices unique from the *insider's* view point. Emic ethnomodels are grounded in what matters in the mathematical ideas, procedures, and practices that matter to the insiders' views of the world being modeled (Rosa and Orey 2013a, b). They represent how people who live in such worlds think these systems work in their own reality. Therefore, emic constructs are the accounts, descriptions, and analyses expressed in terms of the conceptual schemes and categories that are regarded as meaningful and appropriate by the members of the cultural group under study. This means that an emic construct is in accordance with the perceptions and understandings deemed appropriate by the insider's culture (Rosa and Orey 2013a, b).

Fig. 7.4 Geometrical patterns of the dhol. *Source* Personal file

Since, the surface of the dhols is decorated with engraved or painted patterns (Barthakar 2003). Since Rai children play the dhol in numerous festivals, the elaboration of ethnomodels may help them to understand mathematical and geometric concepts in classrooms while connecting school mathematics with their own home cultures. Figure 7.4 shows the geometric patterns of the dhols.

Thus, Rosa and Orey (2015b) argue that by using ethnomodels, students try to understand the world by means of explanations that are organized as procedures, techniques, methods, and theories, as it aims to explain and deal with daily facts and phenomena. These strategies are historically organized in every culture as knowledge systems. The elaboration of ethnomodels of cultural artifacts tends to privilege the organization and presentation of mathematical ideas, notions, and procedures developed by the members of distinct cultural groups by the elaboration of local ethnomodels. Therefore, the:

> (…) elaboration of models that represent these systems are representations that help the members of these groups to understand and comprehend the world by using small units of information, named *ethnomodels*, which link their cultural heritage with the development of the mathematical practice. This approach helps the organization of the pedagogical action that occurs in classrooms through the use of the local aspects of these mathematical practices (Rosa and Orey 2015b, p. 140).

The *etic*[4] ethnomodel below attempts to investigate and understand phenomena and their structural interrelationships through the eyes of the members of the Rai community as well as by considering aspects of mathematical procedures practiced in the mathematics school curriculum. In this context, the "etic ethnomodels represent how the modeler thinks the world works through systems taken from reality" (Rosa and Orey 2013a, b, p. 70). Hence, students can relate school mathematics with home mathematics.

[4]The etic approach corresponds to an outsider's interpretation of the mathematical ideas, procedures, and practices developed by the member of distinct cultural groups (Rosa and Orey 2013b).

In general, dhols have a cylindrical form and its sides are in circular shape. There are different line patterns and angles on these drums. They can be used as cultural artifacts for teaching geometric concepts such as cylinder, circle, lines, and angles as well as mathematical concepts such as measurements. In the mathematics classrooms, it is possible to show that a dhol resembles a cylinder and as such we are able to derive the formula to determine its total area and volume.

(a) Determining the Total Area of a Cylinder

Area of circular face = πr^2
Area of circular face = πr^2
Areas of curved surface = $2\pi rh$
Total area of a cylinder = Area of circular face + Area of circular face + Areas of curved surface
Total area of a cylinder = $2\pi rh + \pi r^2 + \pi r^2$
Total area of a cylinder = $2\pi rh + 2\pi r^2$
Total area of a cylinder = $2\pi r\,(r + h)$
Figure 7.5 shows the etic ethnomodel of the total area of the cylinder that represents the dhol.

(b) Determining the volume of a Cylinder

V = Base area times height
$V = \pi r^2 h$
Figure 7.6 shows the etic ethnomodel of the volume of the cylinder that represents the dhol.

However, it is necessary to point out that this method presents an approximated calculation for the area and the volume of the dhol as employed by the students. In this context, Rosa and Orey (2013a, b) states that ethnomodels are etic in the sense that they are built on an outsider's view about the mathematical world being modeled.

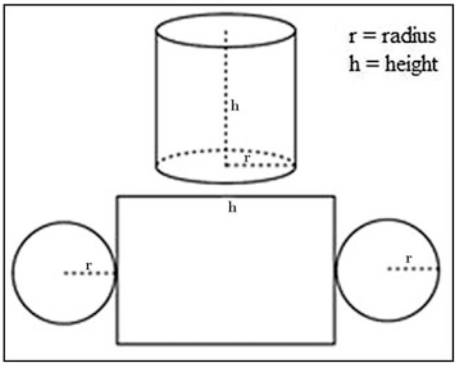

Fig. 7.5 The etic ethnomodel of the total area of the dhol. *Source* Personal file

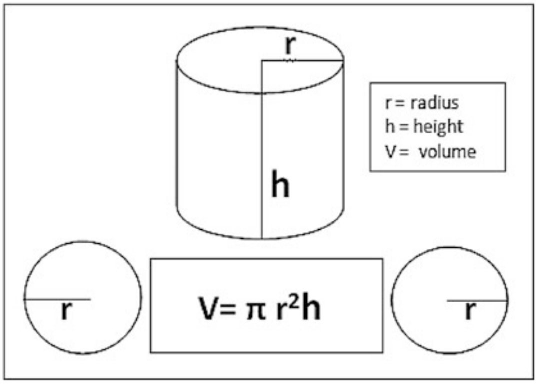

Fig. 7.6 Ethnomodel for the volume of the dhol. *Source* Personal file

7.7.2 Some Considerations About the Ethnomodel of the Dhols

The primary goal of this ethnomodel is to develop a descriptive idiographic orientation that describes the effort to understand the meaning of contingent, unique, and often-subjective mathematical phenomena since it emphases the uniqueness of mathematical practices developed by the members of distinct cultural groups (Rosa and Orey 2016).

Consequently, Rosa and Orey (2007) stated that this approach to the mathematics curriculum helps students to develop their cultural intelligence as it relates to the discovery of a hidden mathematical knowledge applied in this cultural artifact, which motivates them to rediscover their own cultural background. With this activity, students are able to incorporate abstract geometric concepts implicit in the dhol in order to help them to explain, understand, and comprehend organizational principles of their own culture.

It is important to state here that this "pedagogical approach is achieved through dialogue when community members, teachers, and students discuss mathematical themes that help them to reflect about problems that are directly relevant to their community" (Rosa and Orey 2015a, p. 902). During the development of the dhol activity, Rai students may be able to relate their everyday life with formal school mathematics as they begin to seek mathematics in their real world situation. It is important to emphasize that, this "perspective matches teaching styles to the culture and home backgrounds of their students, which is one of the most important principles of culturally relevant pedagogy" (Rosa and Orey 2015a, p. 908).

It seems to us that the cultural component in the mathematics curriculum is critical because it helps to emphasize the "unity of culture, viewing culture as a coherent whole, a bundle of [mathematical] practices and values" (Pollak and Watkins 1993 p. 490) that often appears incompatible with the rationality and the elaboration of traditional mathematical activities in schools. Thus, ethnomathematics attempts "to establish a relationship between the local conceptual framework (emic) and the mathematics embedded in relation to local designs" (Rosa and Orey 2013a, b, p. 66). This pedagogical work examines the "cultural congruencies between the community and school. This means that cultural congruence indicates the teachers' respect for social, cultural, and linguistic backgrounds of their students (Rosa and Orey 2015a, p. 899).

However, Orey and Rosa (2014) argue that in the context of mathematical forms of knowledge, what is meant by the *cultural component* varies widely and ranges from viewing mathematical practices as learned and transmitted to and from members of diverse groups to mathematical practices viewed as abstract symbolic systems with a deep internal history and logic that provides a symbolic system to its mathematical structure.

This context allowed the authors to describe this mathematical practice (emic) by using the members of the Rai cultural group own mathematical knowledge (etic) in a dialogical way between these two approaches. This means that they strive to compare, interpret, and explain the type of mathematical knowledge they observe and that the members of this particular cultural group are experiencing.

The results of the study conducted by Orey and Rosa (2014) shows that the dialogical observation of this mathematical practice tries to understand it from the perspective of the internal dynamics of the member of the Rai community (emic) while providing cross-cultural comparisons in order to comprehend it from the point of view of individuals from different cultural backgrounds (etic).

Thus, this approach is necessary to understand and explain this particular mathematical practice as a whole from a dialogical point of view, which is the dynamic of the encounters between two different cultures. In this regard, D'Ambrosio (2000) states that ethnomathematical practices can be considered as corpora of knowledge that derives from quantitative and qualitative practices, such as counting, weighing, measuring, sorting, inferring, classifying, and modeling.

7.8 Final Considerations

These are just a few of the many mathematical activities that have been developed in Nepal, which are helping to promote our own diverse cultures and respect for our diversity. Adding meaningful contexts for local activities makes for easy and sensible connections with classroom mathematics and has been shown to bring a change in the attitudes of our teachers and students in the teaching and learning of mathematics (Kathmandu University 2008). The core idea of the work presented here was to assist mathematics teachers in making it easier to help their student come to understand content in a way that they can connect to.

We are developing a series of activities as part of an ethnomathematics lab for teaching and learning with different kinds of artifacts. As the collection grows, we are engaging teachers in various regions of the country to begin to develop their own artifact-centered ethnomathematics. There are many more benefits from which student, school and communities can work together to form and use of cultural artifacts for meaningful learning. For example: an ABI school can create a ethnomathematics lab activities by using cultural artifacts found in the student's community and which directly match standardized curricular objectives.

It is important to understand that the use of the student's own unique social and cultural contexts increases possibilities that enable them to play a vital role in constructing their mathematical knowledge process. This is increasingly more important for us during this complex and difficult transition to democracy, after two tremendously disastrous earthquakes. The above presented artifacts are just a few of the examples we are developing by Rai community teachers. There is no doubt that our work is linking school mathematics to diverse cultural practices. We are learning to do mathematical modeling in ever-sophisticated levels; both our teachers and students are learning to solve algorithmic problems with the help of modeling and connecting the real life context to that of particular cultural concepts. Moreover, unique and diverse cultural practices can come to play a vital role for understanding a phenomenon.

When we teach mathematics without linking context; it ultimately does not help to create and develop a meaningful uses of mathematical ideas; and it may devalue the cultural context of our diverse communities (Rosa and Orey 2011). We have found that this work also helps to reduce mathematical anxiety because when children start seeing classroom mathematics outside of in their own cultural practices they start enjoying and teaching becomes meaningful. In schools with little financial resources, culturally relevant pedagogies are inexpensive yet powerful resources.

In the context of classroom culture, mathematics and culture are not separate issues. This is especially true in highly diverse contexts such as found in Nepal, because every student comes to the classroom with their own cultural roots and prior knowledge in relation to particular phenomena. ABI seeks to connect this with curricular objectives and trains teachers to help students to be successful by teaching mathematics that can be meaningful with cultural artifacts.

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