Ethnomathematics + Modeling: An Ethnomathematical Approach

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Abstract: The application of ethnomathematical techniques and tools of modeling allow us to examine systems taken from reality and give us insight into forms of mathematics done in a holistic way. The pedagogical approach that connects a diversity of cultural forms of mathematics is best represented through ethnomodeling, which is a process of translation and elaboration of problems and the questions taken from academic systems. Seen in this context, we would like to broaden the discussion of possibilities for the inclusion of ethnomathematics and associated ethnomodeling perspectives that respect the social diversity of distinct cultural groups with guarantees for the development of understanding different ways of doing mathematics through dialogue and respect.

Key words: Ethnomathematics, Ethnomodeling, Mathematical Modeling.

Introduction

Culture and society considerably affect the way individuals understand mathematical concepts. Thus, it is possible to use and apply significant amounts of knowledge in diverse cultural forms in order to enable the expansion of and familiarity with the diversity of the scientific and mathematical knowledge developed and acquired by members of distinct cultural groups. Ethnomathematics has demonstrated how mathematics is made of many diverse and distinct cultural traditions, not just those emerging from the Mediterranean.

In this regard, 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. This means that the process of teaching and learning mathematics should include and place equal importance upon the knowledge originating from indigenous and non-Western contexts.

For all these reasons, each cultural group has developed unique and distinct ways to *mathematize* their own realities. In this context, mathematization is a process in which individuals from different cultural groups come up with different mathematical tools that can help them to organize, analyze, comprehend, understand, model, and solve problems located in the context of real-life situations. These tools allow them to identify and describe specific mathematical ideas, concepts, procedures, and practices in a general context by schematizing, formulating, and visualizing a problem in different ways, discovering relations and regularities, and transferring a real world problem to a mathematical idea through mathematization.

Inclusion of a diversity of ideas brought by students from other cultural groups can give confidence and dignity to these students, while allowing them to see a variety of perspectives and provide them a base in which they are able to learn academic-Western mathematics (Bassanezi, 2002). Equally important is the search for alternative methodological approaches.

As Western mathematical practices are accepted worldwide, it is paramount to record historical forms of mathematical ideas that occur in different cultural contexts before many of these ancient or local practices are lost to time. One alternative methodological approach is *ethnomodeling*, which may be considered the practical application of ethnomathematics, which adds the cultural perspective to modeling concepts.

When justifying the need for a culturally bound view on mathematical modeling, our sources are rooted on the theory of ethnomathematics and modeling (D'Ambrosio, 1990; Rosa & Orey, 2003). We also argue that recognizing cultural differences in mathematics would reveal new perspectives on the scientific questioning methods. Research of culturally bound modeling ideas addresses the problem of mathematics education in non-Western cultures by bringing the cultural background of students into the mathematics curriculum in order to connect the local-cultural aspects of the school community into the teaching and learning of mathematics (Rosa & Orey, 2010a). On the other hand, the same local views may be used also in global collaborations, possibly widening other views of mathematics.

Ethnomathematics

Ethnomathematics as a research paradigm is much wider than traditional concepts of mathematics and ethnicity and any current sense of multiculturalism. D'Ambrosio (1990) affirmed that *ethno* is related to distinct groups identified by cultural traditions, codes, symbols, myths, and specific ways of reasoning and inferring. In so doing, ethnomathematics may be considered as the way that various cultural groups mathematize their own reality because it examines how both mathematical ideas and mathematical practices are processed and used in daily activities. It can be also described as the arts and techniques developed by students from diverse cultural and linguistic backgrounds to explain, to understand, and to cope with their own social, cultural, environmental, political, an economic environments (D'Ambrosio, 1992).

In accordance to Barton (1996), ethnomathematics embraces the mathematical ideas, thoughts and practices as developed by all cultures. From his perspective, a body of anthropological research has come to focus on both the intuitive mathematical thinking and the cognitive process that are largely developed in locals and minority cultural groups. Ethnomathematics may also be considered as a program that seeks to study how students have come to understand, comprehend, articulate, process, and ultimately use mathematical ideas, concepts, and practices that may solve problems related to their daily activities.

Seen in this context, the focus of ethnomathematics consists essentially of a critical analysis of the generation and production of the mathematical knowledge and intellectual processes, the social mechanisms in the institutionalization of knowledge; and the diffusion of this knowledge (Rosa & Orey, 2006). In this much more holistic context of mathematics that uses an anthropological perspective to include diverse perspectives, patterns of thought, and histories, the study of the systems taken from reality help students to come to reflect, understand, and comprehend extant relations among all of the components of the system. Rosa (2000) defined ethnomathematics as the intersection of cultural anthropology, mathematics, and mathematical modeling, which is used to help students to translate diverse mathematical ideas and practices found in their communities.

The unique cultural background of each student represents a set of values and the unique way of seeing the world as it is transmitted from one generation to another. Detailed studies of mathematical ideas and practices of distinct cultural groups most certainly allow us to further our understanding of the internal logic and beliefs of diverse group of students.

Ethnomathematics and Ethnomodeling

Ethnomodeling is a process of elaboration of the problems and questions that grow from real situations that form an image or sense of an idealized version of the *mathema*. The focus of this perspective essentially forms a critical analysis of the generation and production of knowledge (creativity), and forms an intellectual process for its production, the social mechanisms of institutionalization of knowledge (academics), and its transmission (education).

According to D'Ambrosio (2000), "this process is modeling" (p. 142). In this perspective, by analyzing reality as a whole, this holistic context allows those engaged in the modeling process to study systems of reality in which there is an equal effort made by them to create an understanding of all components of the system as well as the interrelationships among them (D'Ambrosio, 1993; Bassanezi, 2002).

The use of modeling as pedagogical action for an ethnomathematics program values previous knowledge and traditions by developing student capacity to assess and translate the process by elaborating a mathematical model in its different applications and contexts. By having started with the social context, reality and interests of the students and not by enforcing a set of external values and curriculum without context or meaning for the learners.

Bassanezi (2002) characterizes this process as "ethno-modeling" (p. 208), and defines ethnomathematics as "the mathematics practiced and elaborated by different cultural groups, and involves the mathematical practices that are present in diverse situations in the daily lives of members of these diverse groups" (p. 208).

In considering ethnomodeling as tool to uncover and study ethnomathematics, teaching is much more than the transference of knowledge because teaching becomes an activity that introduces the creation of knowledge (Freire, 1998). This approach in mathematics education is the antithesis of turning students into containers to be filled with information (Freire, 1970).

In our opinion, it is necessary for school curriculum, to translate the interpretations and contributions of ethnomathematical knowledge into systemized mathematics because students will be able to analyze the connection between both traditional and non-traditional learning settings.

Examples of Ethnomodeling

According to Bassanezzi (2002), mathematical modeling uses mathematics as a language for understanding, simplification and resolution of real world problems and activities. Data gleaned from these studies are used to make forecasts and modifications pertaining to the objects initially studied. In this regard, one of the traditional definitions of a mathematical model is a body of symbols and mathematical relationships that represent the studied object, which is composed by a system of equations or inequalities, algebraic expressions, differentials, and integrals that are obtained through the establishment of a relationship between considered essential variables of analyzed phenomena (Bassanezzi, 2002).

It is the systematic study of algorithmic processes, theory, analysis, design, efficiency, implementation, and application, which describes and transforms information. This definition of the Western mathematical modeling includes all data structures, which is a part of both *theory* and *design*; algorithms that deals with analysis and efficiency; mechanical and linguistic realizations, which deals with implementation; and applications that naturally applies the mathematical ideas and concepts to solve problems.

Thus, Western mathematical activities can be regarded as modeling by this definition and due to its cultural roots in the non-Western society it can be defined as ethnomodeling in the non-Western settings. For example, the importance of a non-traditional view on mathematics is emphasized with the emergence of the new types of problems related to artificial intelligence.

A characteristic of these new problems is that they cannot be solved using syllogistic, that is, classical Aristotelian logic, but need multivalued logic, often called *fuzzy logic*, which is the logic that underlies inexact or approximate reasoning (Zadef, 1984). According to Ascher and Ascher (1986), multivalued logic is used in attempts to formalize human-like processes that are culturally bound.

In this perspective, Zadef (1984) affirmed that the Hindu, Chinese and Japanese cultures have contributed to the development of fuzzy logic more than Western science because, in these cultures, there is a greater acceptance of a truth-value that is neither perfect truth nor perfect falsehood.

D'Ambrosio (2002) commented about an ethnomathematical example that naturally comes across as having a mathematical modeling methodology. In the 1989-1990 school year, a group of Brazilian teachers studied the cultivation of vines that were brought to Southern Brazil by Italian immigrants in the early twentieth century. This was investigated because the cultivation of wines is linked with the culture of the members of the cultural group in that region in Brazil. Both Bassanezi (2002) and D'Ambrosio (2002) believed that this wine case study is an excellent example of the connection between ethnomathematics and mathematical modeling through ethnomodeling (Rosa & Orey, 2007a).

Ethnomodels

In general, a model is a representation of an idea, a concept, an object, or a phenomenon (Gilbert, Boulter & Elmer, 2000). We define ethnomodels as cultural models that are pedagogical tools used to facilitate the understanding and comprehension of systems that are taken from reality of cultural groups. In this regard, ethnomodels can be considered as external representations that are precise and consistent with the scientific and mathematical knowledge that is socially constructed and shared by members of specific cultural groups.

From this perspective, the primary objective for the elaboration of ethnomodels is to *translate* the mathematical ideas, concepts, and practices developed by the members of distinct and diverse cultural groups.

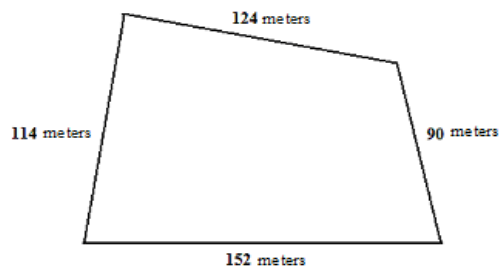
Measuring Land

Knijnik (1996) proposed activities about the demarcation of land from research work with the participants of the Landless Peoples' Movement (Movimento dos Sem Terra - MST) in Southern Brazil. The demarcation of land activity was about the method of *cubação* of the land, which is a traditional mathematical practice applied by the participants of this movement. Flemming, Flemming Luz and Collaço de Mello (2005) defined the term *cubação* of the land as the solution of "problems of the measurement of land using diverse shapes" (p. 41).

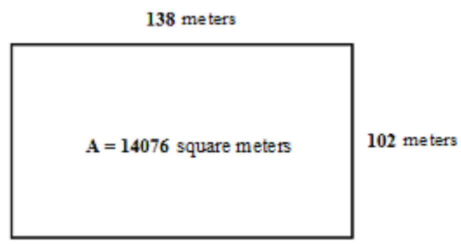
Thus, the use of the practice of *cubação* of the land as a pedagogical proposal to elaborate activities for the teaching and learning of mathematics shows the importance of the contextualization of problems in the learning environment of ethnomodeling through the elaboration of ethnomodels.

An Ethnomodel to Calculate the Area of the Land

Flemming, Flemming Luz e Collaço de Mello (2005) presented the following problem to calculate the area of figures with quadrilateral shapes: *Calculate the a area de land with a quadrilateral shape that measures 114 meters x 152 meters x 90 meters x 124 meters" (p. 42).*



Thus, the mathematical knowledge of the Landless People can be represented by a model that transforms "the shape of the given land in a [rectangle] of 138 meters x 102 meter with an area of 14076 square meters.



The model of this mathematical practice can be explained by the following ethnomodel:

Transform the shape of the irregular quadrilateral in a rectangle whose area can be easily determined through the application of the formula $A = b \bullet h$.

Determine the dimensions of the rectangle by calculating the mean of the two opposite sides of the irregular quadrilateral.

$$Base = \frac{152 + 124}{2} = 138 meters$$

$$Height = \frac{114 + 90}{2} = 102 meters$$

In order to determine the area of this irregular quadrilateral, it is necessary to determine the area of the rectangle.

$$A = b \bullet h$$
$$A = 138 \bullet 102$$
$$A = 14076 m^2$$

Regarding to this problem, there is another ethnomodel proceeding from the mathematical knowledge of the Landless People that can be explained through another ethnomodel. According to Flemming, Flemming Luz and Collaço de Mello (2005), the irregular shaped quadrilateral parcel presented in this example can also be transformed in to "a square with sides of 120 meters, therefore with an area of 14400 square meters (p. 42). It is possible to observe that the value of 120 was calculated by adding the dimensions of the quadrilateral and then dividing it by four, which is the number of sides of the irregular quadrilateral.

In this context, Bassanezi (2002) stated that a model is efficient when we realize that we are only working with approximations of reality. Thus, Flemming, Flemming Luz and Collaço de Mello (2005) affirmed that from the view point of mathematics, both methods present an approximated calculation of the area the irregular quadrilateral that fully satisfy the necessities and the life history of the participants of this specific cultural group.

Modeling the Tipi

Spatial geometry is inherent by the shape of the tipi and it was used to remind, indeed symbolize the universe in which the Plains Peoples lived. The word tipi from the Sioux language refers to a conical skin tent or dwelling common among the prairie peoples.

According to Orey (2000), the majority of Sioux tribes use the tripod foundation or three-pole foundation because it is stronger and offers a more firm foundation than a quadripodal or four-pole tip foundation.

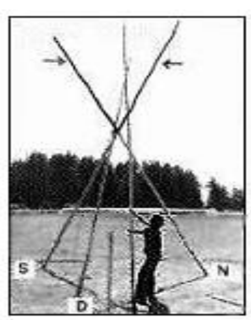
Tripodal versus Quadripodal Foundations of the Tipi

An ethnomodel explains why a tripod is more flexible than a quadripodal or four-legged structure. In this regard, imagine three points, A, B, and C that are not collinear. There are an infinite number of planes that pass through points A & B that contain the straight line AB. Only one of these planes also passes through point C therefore we can say that three points are not collinear if they determine one plane.

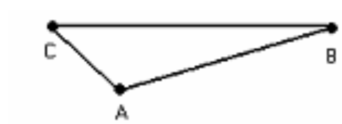
This means that these non-collinear points exist on one plane and that three collinear points do not determine the only plane. Hence, given any three non-collinear points, there is only one plane to which exist these same three points. This can be explained using the postulate for the determination of a plane. In other words, given any three non collinear points, there is only one plane to which exists these same three points.

For example, in the 4-legged table, it has the possibility of the extremity of one of the legs that do not belong to the same plane. A table that has 3 legs, therefore, is always balanced. Similar to a three-legged table, the structure of the tipi appears to be perfectly adapted for the harsh environment in which it was used. It had the advantage of providing a stabile structure, was lightweight and portable.

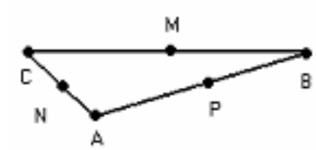
At the same time it withstood the prevailing winds and extremely variable weather of this region. Let us look at this information mathematically.



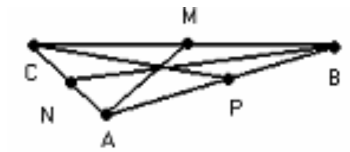
The base formed by the tripod is ΔABC.



The midpoints of each of the sides of ΔABC are points M, N, and P.



It is possible to match each vertex of ΔABC to the midpoint of each opposite sides that gives us the straight lines AM, BN, and CP.



These straight lines form three medians, which are the straight lines connecting the midpoint of each opposite side of the triangle and its vertex. The medians intersect at only one point called centroid. Archimedes demonstrated that medians of a triangle meet at its balance point or center of gravity, which is the centroid of the triangle. Native Americans place their fire and altar at this point in the tipi. Cartographers call this point the geographic center (Orey, 2000). The tipi cover is folded in half and the poles are laid together before tying them to form the tri or quadripodal frame, which forms the foundational base for the structure.

Final Considerations

Any study of ethnomathematics and mathematical modeling represents a powerful means for validating a student’s real life experience, and gives them the tools to become critical participants in society. Educators should be empowered to analyze the role of what Borba (1990) refers to as a student’s ethnoknowledge in the mathematics classroom.

In this regard, ethnoknowledge is acquired by students in the pedagogical action process of learning mathematics in a culturally relevant educational system. In this process, the discussion between teachers and students about the efficiency and relevance of mathematics in different contexts should permeate instructional activities. The ethnoknowledge that students develop must be compared to their academic mathematical knowledge. In this process, the role of teachers is to help students to develop a critical view of the world by using mathematics.

There exists a need to create a new role to mathematics instruction that empowers students to understand power and oppression more critically by considering the effect of culture on mathematical knowledge by working with their students to uncover the distorted and hidden history of mathematical knowledge. This perspective forms the basis for significant contributions of a Freirean-based ethnomathematical perspective in re-conceiving the discipline of mathematics and in a pedagogical practice.

The use of Freire’s (1970) dialogical methodology is seen as essential in developing the curricular praxis of ethnomodeling by investigating the ethnomathematics of a culture in constructing a curriculum with people from other cultures to create curricula that enable the enrichment for all people’s knowledge of mathematics.

Ethnomodeling seems to be important especially in new fields of research such as artificial intelligence and fuzzy logic. Current research does not give ethnomodeling of non-Western cultures much chance to introduce new views into old themes. Our opinion is that different cultures can contribute to the development of mathematical concepts and ideas and enrich them in the field of Mathematics Education.

In addition to the development of mathematical modeling and education, ethnomodeling holds another equally important objective. As D'Ambrosio (1997) recognizes that ethnomathematics has the common goal of equity and dignity. In this regard, the study of ethnomodeling may encourage the ethics of respect, solidarity, and co-operation across cultures.

Seen in this context, we would like to broaden the discussion of possibilities for the inclusion of ethnomathematics and mathematical modeling perspectives that respect the social and cultural diversity of all people with guarantees for the development of understanding our differences through dialogue and respect. This is how ethnomodeling can empower students against all kinds of domination and oppression.

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