

Ethnomodeling: The Pedagogical Action of Ethnomathematics as a Program¹

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Abstract²

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 real world contexts. Seen in this way, 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, pedagogical action, mathematics.

Resumen

La aplicación de técnicas y herramientas de etnomatemática en modelos permite examinar los sistemas tomados de la realidad y da una idea de formas de las matemáticas realizadas de manera holística. El enfoque pedagógico que conecta la diversidad de formas culturales de la matemática está mejor representado por la etnomodelación, que es un proceso de traducción y elaboración de los problemas y cuestiones extraídas de contextos del mundo real. Visto de esta manera, nos gustaría ampliar la discusión de posibilidades para incluir la Etnomatemática y las correspondientes perspectivas de etnomodelación, que respetan la diversidad social de los distintos grupos culturales, con garantías para el desarrollo de la comprensión de las diferentes maneras de hacer matemáticas a través del diálogo y el respeto.

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Palabras clave

Etnomatemáticas, etnomodelación, modelación matemática, acción pedagógica, matemáticas

1. Introduction

Throughout history, people have explored other cultures and shared knowledge often hidden behind ideas, traditions, practices, and customs. This cultural dynamism has enriched these cultures, including Western culture. The literature, problem solving methods, procedures, and teaching materials on mathematics are based on the scientific and mathematical concepts rooted on this dominant Western tradition that many of us are accustomed to thinking of when we *do* mathematics. Most of the examples used in teaching academic mathematics derive themselves from problems and contexts from a Western cultural paradigm. These procedures and methods mainly rely on the traditional Western-European view of science and mathematics.

If it can be shown that culture and society considerably affect the way individuals understand mathematical concepts, then it is possible to use and apply significant amounts of knowledge in diverse cultural forms, and enables the expansion of and familiarity with the diversity of the scientific and mathematical knowledge developed and acquired by members of distinct cultural groups. In this regard, ethnomathematics has demonstrated how mathematics is composed and that it is made of many diverse and distinct cultural traditions, not just those emerging from the Mediterranean, but that the teaching-learning of mathematics should include and place equal importance upon those originating from indigenous and non-Western contexts. Each cultural group has developed often 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 all these reasons, each cultural group has developed unique and often distinct ways to *mathematize* their own realities. In this regard, 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, and solve specific problems located in the context of their real-life situation. These tools allow them to identify and describe a specific mathematical idea or practice in a general context by schematizing, formulating, and visualizing a problem in different ways, discovering relations, discovering regularities, and transferring a real world problem to a mathematical idea through mathematization.

Western-academic scientific arrogance often presents an overt disrespect of and an outright refusal to acknowledge a cultural identity (D'Ambrosio, 1990 & Zaslavsky, 1996). These *cultural particularities* should not be ignored nor should they be disrespected when individuals attend school. Inclusion of a diversity of ideas brought by non-traditional students or those from other cultures and countries 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 ap-

proaches. As Western mathematical practices are accepted worldwide, it is necessary to record historical forms of mathematical ideas that occur in different cultural contexts before many of these ancient or traditional practices are lost to time.

One alternative methodological approach is *ethnomodeling*, which may be considered the practical application of ethnomathematics and 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 (D'Ambrosio, 1990). 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 and connects 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.

This pedagogical approach is needed in mathematics education because it is a major factor in broadening the modeling process as well as an ethnically fairer view that can help to bridge the mathematical achievement gap of the students. This alternative approach helps in promoting intellectually innovative ideas in the area of modeling by deepening and widening the Western understanding of mathematics. We refer to this pedagogical approach as ethnomodeling.

2. Ethnomathematics and Mathematics Education

Ethnomathematics as a research paradigm is much wider than traditional concepts of mathematics and ethnicity or any current sense of multiculturalism. D'Ambrosio (1990) referred to *ethno* as that related to distinct cultural 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 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 or techniques developed by diverse students to explain, to understand, and to cope with their own environment (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 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 activity.

In this context, Barton (1996) stated that ethnomathematics is not only the study of mathematical ideas because it is also the study of anthropology and history. The study of the history of mathematics assists in identifying the cultural and mathematical

contributions of different cultures across the world. Seen in this context, the focus of ethnomathematics essentially consists of a serious and 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[2] context of mathematics that uses an anthropological perspective to include diverse perspectives, patterns of thought, and histories, the study of the systems[3] 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.

All individuals and students as well possess and develop both anthropological and mathematical concepts. These concepts are rooted in the universal human endowments of curiosity, ability, transcendence, life, and death. They all characterize our essential humanness. An awareness and appreciation of cultural diversity that can be seen in clothing, methods of discourse, religious views, morals, and our own unique worldviews allows us to understand each aspect of the daily life of humans (Rosa & Orey, 2006).

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. Principals of anthropology that are relevant to the work of ethnomathematics include the essential elements of culture such as language, economy, politics, religion, art, and the daily mathematical practices of diverse groups of students. Since, cultural anthropology gives us tools that increase our understanding of the internal logic of a given society; detailed anthropological studies of the mathematics of distinct cultural groups most certainly allows us to further our understanding of the internal logic and beliefs of diverse group of students.

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4. 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 their role in 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 learner. 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.

5. Examples of Ethnomodeling

According to Bassanezi (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 (Bassanezi, 2002). In other words, 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 multi-valued logic, often called *fuzzy logic*, which is the logic that underlies inexact or approximate reasoning (Zadef, 1984). According to Ascher and Ascher (1986), multi-valued 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).

Definition of 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

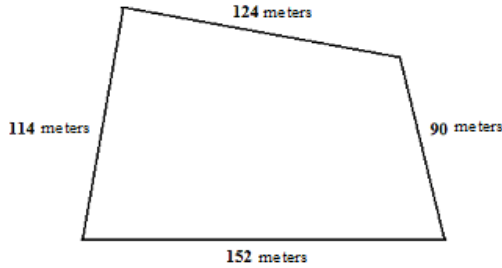
Knijnik (1996) proposed activities about the demarcation of land from research work with the participants of the Landless Peoples' Movement (Movimento dos Sem Terra - MST) in Southern Brazil. The demarcation of land activity was about the method of *cubação* of the land, which is a traditional mathematical 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.

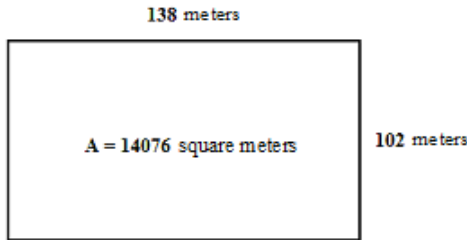
An Ethnomodel to Calculate the Area of the Land

Flemming, Flemming Luz e Collaço de Mello (2005) presented the following problem to calculate the area of figures with quadrilateral shapes:

Calculate the area of 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 $A = b \cdot h$.
- Determine the dimensions of the rectangle by calculating the mean of the two opposite sides of the irregular quadrilateral.

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

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

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

$$A = b \cdot h$$

$$A = 138 \cdot 102$$

$$A = 14076 \text{ m}^2$$

Regarding to this problem, there is another ethnomodel proceeding from the mathematical knowledge of the Landless People that can be explained through another

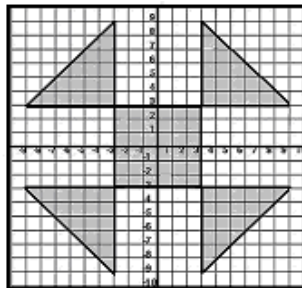
ethnomodel. According to Flemming, Flemming Luz and Collaço de Mello (2005), the irregular shaped quadrilateral parcel presented in this example can also be transformed in to “a square with sides of 120 meters, therefore with an area of 14400 square meters (p. 42). In this regard, it is possible to observe 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.

The Symmetrical Freedom Quilts

Rosa an Orey (2009) affirmed that a quilt theme is a great way to begin one’s work by integrating mathematics, art, history, and reading in an interdisciplinary approach. As a result of this, the authors proposed lesson plans that combined an ethnomathematical-historical perspective that elaborates a history project related to the *Underground Railroad*, which allows teachers to develop classroom activities and projects that help students to better understand history and geometry, especially concepts of symmetry and transformations through ethnomodeling. In this context, *Symmetrical Freedom Quilts* may be considered as links between mathematics, history, ethnomathematics, and the very tactile art of quilting. A quilt theme is a great way to integrate mathematics, art, and history in an interdisciplinary approach. One of the objectives of this project is to stimulate student’s creativity and interest, because quilts may be considered as cultural and mathematical expressions of student’s daily life.

Making quilt blocks are an excellent way to explore concepts of symmetry. As quilts are made from square blocks, usually 9, 16, or 25 pieces to a block, with each smaller piece usually consisting of fabric triangles, the craft lends itself readily to the application of symmetry. The Freedom Shoo Fly quilt shows how its blocks are symmetrical.



Modeling the Shoo Fly Symmetrical Quilt Block

Shoo Fly is one the simplest traditional Symmetrical Freedom Quilts. Although *Shoo Fly* is a basic pattern, its versatility provides quilters with some wonderful opportunities

for creative use of colors, fabrics and stitching. *Shoo Fly* may be adapted to a variety of sizes. Blocks often measure 9 x 9, but variations such as 10 x 10 and 12 x 12 may also be used.

An Ethnomodel about Rotation

A rotation turns the figure through an angle about a fixed point called center. The center of rotation is assumed to be the origin of the $x - y$ coordinate system. A positive angle of rotation turns the figure counterclockwise, and a negative angle of rotation turns the figure in a clockwise direction.

Rotation is a transformation that is present in the *Shoo Fly* quilt block because it moves every point 90° counterclockwise around the origin of the $x - y$ coordinate system. The mapping of this rotation is $R_{90^\circ}(x, y) = (-y, x)$. In so doing, the coordinates of point A in its rotation around the $x - y$ coordinate system are:

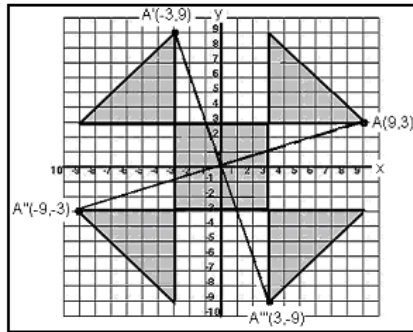
$$R_{90^\circ}A(9, 3) = A'(-3, 9)$$

$$R_{90^\circ}A'(-3, 9) = A''(-9, -3)$$

$$R_{90^\circ}A''(-9, -3) = A'''(3, -9)$$

$$R_{90^\circ}A'''(3, -9) = (9, 3)$$

The figure below shows the rotation of point A around the $x - y$ coordinate system.



The other mappings for rotation are:

- Rotation of 180° , that is, $R_{180^\circ}(x, y) = (-x, -y)$. This is the same as the reflection in the origin of the $x - y$ coordinate system.
- Rotation of 270° , that is, $R_{270^\circ}(x, y) = (y, -x)$.

A rotation creates a figure that is congruent to the original figure and preserves distance (isometry) and orientation (direct isometry).

Modeling the Tipi

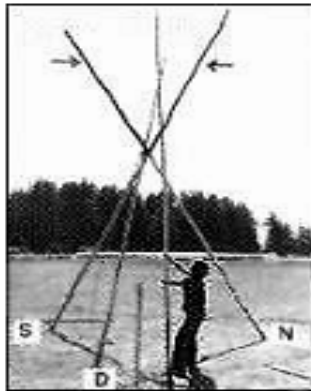
Spatial geometry is inherent by the shape of the tipi and it was used to remind, indeed symbolize the universe in which the Plains Peoples lived. The word *tipi* from the Sioux language refers to a conical skin tent or dwelling common among the prairie peoples.

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.

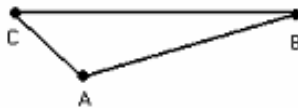
Tripodal versus Quadripodal Foundations of the Tipi

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. This means that 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.

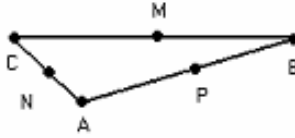
At the same time it withstood the prevailing winds and extremely variable weather of this region. Let us look at this information mathematically.



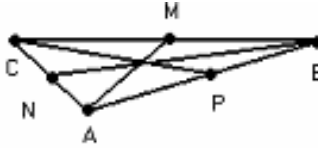
The base formed by the tripod is $\triangle ABC$.



The midpoints of each of the sides of $\triangle ABC$ are points M, N, and P.



It is possible to match each vertex of $\triangle ABC$ to the midpoint of each opposite side 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.

Some Considerations about Ethnomodeling

Ethnomodeling seems to be important especially in new fields of research such as artificial intelligence and fuzzy logic. However, ethnomodeling has been given a chance only in the new research or it has lead to new fields of research. Current normal science 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.

6. 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. In so doing, 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.

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 in this century against all kinds of domination and oppression.

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