Journal of Humanistic Mathematics

Volume 6 | Issue 2 July 2016

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Recommended Citation

Milton Rosa & Daniel C. Orey, "Humanizing Mathematics through Ethnomodelling," *Journal of Humanistic Mathematics*, Volume 6 Issue 2 (July 2016), pages 3-22. DOI: 10.5642/jhummath.201602.03. Available at: https://scholarship.claremont.edu/jhm/vol6/iss2/3

JHM is an open access bi-annual journal sponsored by the Claremont Center for the Mathematical Sciences and published by the Claremont Colleges Library | ISSN 2159-8118 | http://scholarship.claremont.edu/jhm/

Humanizing Mathematics through Ethnomodelling

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Abstract

Ethnomathematical techniques and modelling tools allow us to examine systems taken from the real world and offer us insight into forms of mathematics performed in holistic contexts [3]. A pedagogical approach that connects a diversity of cultural forms of mathematics can be implemented by the use of *ethnomodelling*, a process of translation and elaboration of problems and questions taken from non-academic systems. Here, we offer examples of studies conducted in Brazil and in the United States that explore this pedagogical approach. Our goal is to broaden the discussion of possibilities for ethnomathematics and associated ethnomodelling perspectives that respect the social diversity of distinct cultural group members with guarantees for the development of understanding of the different ways of doing mathematics through dialogue and respect.

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1. Introduction

Over the years, there has been an increased interest in how people incorporate new ideas and technologies in novel and creative ways and how these interactions are increasingly affecting all of our thinking and learning processes. In this regard, we need to make a special effort to open our eyes to the other histories and technological sophistications of indigenous non-western cultures.

It is necessary to emphasize how one's own culture and society considerably affect the way in which individuals understand mathematical ideas, procedures, and practices. The core of ethnomathematics research demonstrates how mathematics is made of many historically rich, diverse and distinct traditions. Every cultural group has developed unique and distinct ways of including mathematical knowledge that often comes to be incorporated into the cultural systems as diverse people interact, immigrate and create new contexts. This is most obvious in ways that diverse groups order, quantify and use numbers, incorporate geometric forms and relationships, and measure and classify objects [3].

Thus, mathematical thinking is influenced by a diversity of human environments and their elements, which include language, religion, mores, economics, social, and political activities. Along with language, it seems that all human beings have come to develop logical processes related to quantification, measurement, and modelling in order to understand and explain their socio-cultural-historical contexts [16]. These processes allow each cultural group to develop their own way to *mathematize*[3] reality. These tools allow for the identification and integration of specific mathematical ideas, notions, procedures, and practices by schematizing, formulating, and visualizing a problem in different ways, discovering the relations, patterns, and regularities, and transferring a real world-situation into mathematical ideas through mathematization.

Inclusion of a diversity of ideas brought by people from distinct cultural contexts can give confidence and dignity to students, while allowing them

[3]Mathematization is a process in which members of a distinct cultural group develop specific mathematical tools that can help them to organize, analyze, comprehend, understand, and solve concrete problems located in the context of their real-life situations.

to perceive a variety of perspectives in order to provide a base in which they are able to learn academic mathematics [20]. Equally important is the search for alternative methodological approaches needed to reach this goal. In this regard, as traditional Western science-based mathematical practices are accepted worldwide, it is even more vital that we record historical, diverse, and alternate forms of mathematical ideas, notions, and procedures before many of these local practices are lost to us. One methodological tool for developing this approach is *ethnomodelling* [16], one of many practical applications of ethnomathematics that add the cultural perspective to the modelling process.[4]

According to this context, it is necessary to offer a brief discussion of *ethnomathematics* and *ethnomodelling* in order to assist the readers in contextualizing aspects of mathematical creativity, which may be described as a multifaceted construct involving both "divergent and convergent thinking, problem finding and problem solving, self-expression, intrinsic motivation, a questioning attitude, and self-confidence" [21, page *ix*]. In this way, students need to see how mathematics is developed and came to realize how individuals help the overall evolution of mathematical knowledge.

2. Ethnomathematics

Ethnomathematics is the application of mathematical skills, ideas, procedures, and practices applied in the past by members of a specific cultural group in distinct contexts, which are often used currently in present day contexts [5]. Much of what we call *modern mathematics* came about as diverse European-based groups sought to resolve unique problems related to commerce, art, religion, exploration, colonization and communications, the construction of railroads, census data, space travel, and other problem-solving techniques that arose from particular communities. Given that communities quite disjoint from one another have often faced similar problems, mathe-

[4]Ethnomodelling is a relatively recent research field. Since change and reform are actually a part of the nature of the scientific paradigm, ethnomodelling is not yet strictly defined as of yet, and offers important new perspectives for problem solving. The purpose of this paper is to provide a discussion of ethnomodelling, a discussion that aims to show through a series of examples how mathematics can be understood and used as a way of translating of mathematical practices originating in diverse cultural contexts.

matical methods and constructss have often been introduced independently of one another in different geographies and historical periods. For example, the Mayans invented the number zero and the positional value around the 9^{th} century [14]. These concepts were transmitted to the European communities via the Arabs who learned of them from the Hindus by means of exchanges and commercial activities.

One of the most important concepts of ethnomathematics is the association of the mathematics found in diverse cultural contexts. In this context, ethnomathematics as a research paradigm is much wider than traditional concepts of mathematics and ethnicity or any current sense of multiculturalism. The prefix *ethno-* relates to the members of distinct groups identified by their cultural traditions, codes, symbols, myths, and specific ways of reasoning and inferring.

Ethnomathematics is the way by which 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 people that help to explain, understand, and cope in their own environment [3]. While making use of modern mathematics and science, ethnomathematics also embraces the mathematical ideas, thoughts and practices as developed by all cultures across time and space. From this perspective, a body of anthropological research has come to focus on both intuitive mathematical thinking and the cognitive processes largely developed in minority[5] cultural groups [1]. It is also a program, which seeks to study how diverse groups of people understand, comprehend, articulate, process, and use mathematical ideas, procedures, and practices in order to solve problems related to their daily lives.

[5] One of the main characteristics people of minority groups have in common is that they often face discrimination, marginalization, and exclusion from society. International human rights laws, which focus on the principle of equality, guarantee the right to education for all people. However, people of many minority groups are likely to be denied this right. In this context, the majority of children who are members of non-traditional, marginalized or out-of-school populations are also deprived of access to formal education that is relevant and responsive to their specific context and needs [26]. For example, globally speaking, there are some educational institutions in which a particular ethnic, racial or cultural group is a majority, thus, the experiences of students of a minority group such as Indigenous, English Language Learners, or Special Education are not reflected in the mainstream cultural and educational materials of the broader national sense.

In this regard, the focus of ethnomathematics consists essentially of a critical analysis of the generation (creativity) and production of mathematical knowledge and its intellectual processes, as well as the institutionalization and diffusion of this knowledge [16]. This *holistic* context includes diverse perspectives, patterns of thought, and histories, the study of the *systems*[6] taken from reality in order to help students to reflect, understand, and comprehend extant relations among all of the components of the system.

In this regard, cultural variables have strongly influenced how students came to understand their world and interpret both their own and others people's experiences [4]. In attempting to create and integrate mathematical materials related to different cultures and that draw on students' own experiences in an instructional mathematics curriculum, it is possible to apply ethnomathematical strategies in teaching and learning mathematics. These strategies include, but are not limited to the historical development of mathematics in different cultures that "use mathematics (e.g. an African-American biologist, an Asian-American athlete). Mathematical applications can be made in cultural contexts (e.g. using fractions in food recipes from different cultures). Social issues can be addressed via mathematics applications (e.g. use statistics to analyze demographic data)" [22, pages 3-4].

Similarly, it is important to show that ethnomathematics describes ideas and procedures that are implicit in the mathematical practices developed locally by members of distinct cultural groups. For example, a study conducted in the South of Brazil investigated the specificity of mathematical ideas, procedures, and practices produced by adolescent and adult construction workers who were also students in an evening adult educational course. The results of this study demonstrated that mathematical knowledge produced, developed, and transmitted in construction sites had curricular implications that were inferred from this kind of knowledge production. It also showed the connections of the local knowledge with academic knowledge legitimized by the school in order to determine mathematical curricular modifications [27].

The challenge that many communities face today is in determining how to shape a new open, modern, international culture, which integrates and respects new and alternative ideas, and where diverse ideas coexist in balance

[6] Systems are sets composed of elements taken from reality. The analyses of the interrelationship among these elements seeks to develop reflection, understanding, and comprehension of phenomenon that are part of reality [3].

with those of western science. This also includes an increased cultural, ethnic, and racial diversity. Indeed the most creative, dynamic, and productive societies do this well [7].

The inclusion of moral consequences into mathematical-scientific thinking, ideas, procedures, and experiences as we explore the mathematics found in different cultural contexts is vital. The acknowledgment of contributions that individuals from diverse cultural groups make to mathematical understanding, the recognition and identification of diverse mathematical practices in varied contexts, and the link between academic mathematics and student experiences should all become central ingredients to a complete study of mathematics. This is one of the most important objectives of an ethnomathematics perspective in mathematics curriculum development.

Within this context, according to the etymology, the prefix *ethno-* is today accepted as a very broad term that refers to the sociocultural context and, therefore, includes language, jargon, and codes of behavior, myths, and symbols. The derivation of *mathema-* is difficult, but tends to mean "to explain, to know, to understand, and to do activities such as ciphering, measuring, classifying, ordering, inferring, and modelling". The suffix *-tics* is derived from *techné* and has the same root as "art" and "technique". In this case, *ethno-* refers to groups that are identified by cultural traditions, codes, symbols, myths and specific ways used to reason and to infer [3].

Ethnomathematics forms the intersection of cultural anthropology and institutional mathematics and uses mathematical modelling to solve real-world problems in order to translate them into academic mathematical language systems. This perspective is crucial in giving minority students a sense of cultural ownership of mathematics, rather than a mere gesture toward inclusiveness [6].

An essential aspect of the program includes an ongoing critical analysis of the generation and production of mathematical knowledge as well as the intellectual processes of this production [16], and seeks to explain, understand, and comprehend mathematical procedures, techniques and abilities through a deeper investigation and critical analyses of students' own customs and cultures.

For example, in Brazil, the use of *Bakairi* body painting in Bakairi schools facilitates the comprehension of spatial relations such as form, texture, and symmetry, which are excellent for the construction and the systematization of

geometrical knowledge by allowing students to experience academic mathematical language through cultural lenses [13]. Thus, the use of artifacts from cultural groups in educational settings raises students' self-confidence, enhances and stimulates creativity, creates a sense of connection, and promotes cultural dignity [5]. The application of ethnomathematics as pedagogical action restores a sense of enjoyment or engagement and can enhance creativity in doing of mathematics.

3. Ethnomodelling

Studies have shown us that sophisticated mathematical ideas and practices that include, for example, geometric principles, appear in craftwork, architectural concepts, activities and artifacts of many indigenous, local, and vernacular cultures [12, 24]. Mathematical concepts related to a variety of mathematical procedures and cultural artifacts form part of the numeric relations found in universal actions of measuring, calculation, games, divination, navigation, astronomy, and modelling [6].

We use the term *translation* to describe the process of modelling local cultural systems, which may have Western academic mathematical representations [16]. Indigenous designs may be analysed simply as forms and the applications of symmetrical classifications from crystallography to indigenous textile patterns [6]. On the other hand, many researchers in ethnomathematics use modelling to establish the relations found between local conceptual frameworks and mathematical ideas embedded in numerous designs. We define this act as *ethnomodelling*; the very act of translation that forms an essential part of the mathematical modelling process [16]

In some cases, translation into Western-academic mathematics is direct and simple, such as that found in counting systems and calendars [6]. However this is not always the case. For example, the mathematical knowledge that lace makers in the northeast of Brazil use to make geometric lace patterns (see Figure 1) involves mathematical concepts that are not associated with traditional geometrical principles; these may be modeled through the techniques of ethnomodelling.

Ethnomodelling takes into consideration diverse processes that help in the construction and development of scientific and mathematical knowledge that includes collectivity, and the overall sense of and value for creative and new inventions and ideas. The processes and production of scientific and

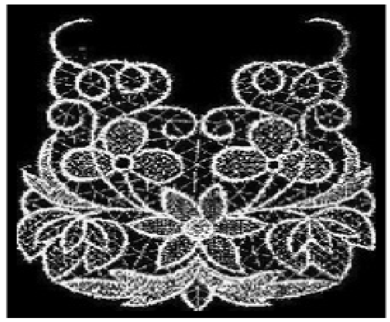

Figure 1: Geometric lace patterns.

mathematical ideas, procedures, and practices operate as a register of the interpretative singularities that regard possibilities for symbolic constructions of the knowledge in different cultural groups. In this context, ethnomodelling may be considered as the intersection of three research fields: cultural anthropology, ethnomathematics, and mathematical modelling (see Figure 2).

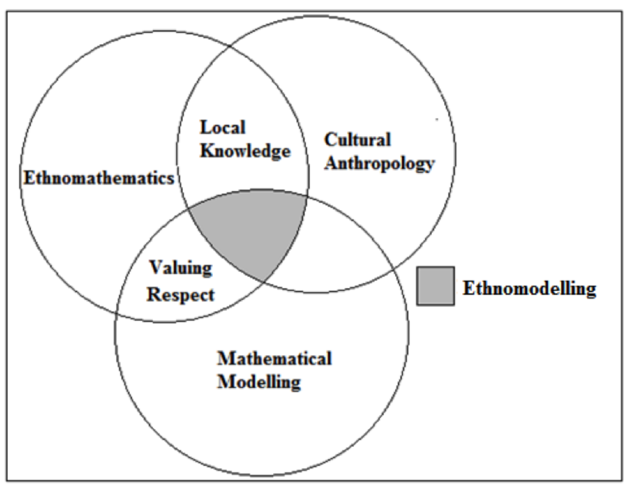

Figure 2: Ethnomodelling as the intersection of three knowledge fields.

In the ethnomodelling process, the intersection between mathematical modelling and ethnomathematics relates to the respect and the valorization of the previous knowledge and traditions developed by students, which enables them to assess and translate problem-situations by elaborating mathematical models in different contexts [15].

Thus, it is necessary to start by using sociocultural contexts, realities, and the many interests and needs of students and not mere enforcement of a rigid set of external values or often-decontextualized curricular activities. This approach facilitates the development of dialogue between mathematical modelling and cultural anthropology in order to reach a critical transitivity, which is a horizontal rather than a vertical or hierarchical relationship [8].

Local knowledge becomes the intersection between ethnomathematics and cultural anthropology when members of distinct cultural groups use it to solve problems faced in their own contexts. It also becomes a body of knowledge often built up by these members over time and across generations of living in close contact with their own historical, social, cultural, and natural environment [3].

This context allows for the development of a definition of ethnomodelling as the translation of mathematical ideas, notions, procedures, and practices related to the specific mathematical knowledge possessed by the members of distinct cultural groups. Thus ethnomathematics adds cultural perspectives to the modelling process through ethnomodelling. In this regard, by using ethnomodelling as a tool towards pedagogical action of an ethnomathematics program, students learn how to find and work with authentic situations and real-life problems [16].

4. General Assertion

Ethnomathematics is a contemporary pedagogical trend in education. For better or for worse, the world economy is globalized, yet traditional academic mathematics curricula neglect, indeed often reject, the truly diverse contributions made by members of colonized and non-dominant cultures. An ethnomathematical perspective offers more inclusive, new and greatly expanded definitions of a given group's particular mathematical-scientific contributions. Pedagogically, ethnomathematics allows school mathematics to be seen as the "process of inducting young people into mathematical aspects of their culture" ([9], page 4). An ethnomathematics perspective can reshape cultural identity in a positive way by requiring the inclusion of a greater representation of practices and problems of a student's own community [3].

Ethnomathematics helps both educators and students alike to understand mathematics in the context of ideas, procedures, and practices used in day-to-day life. It further encourages an understanding of professional practitioners,

workers, and academic or school mathematics. Such depth is accomplished by taking into account historical evolution and the recognition of natural, social and cultural factors that shape human development [5].

5. Some Practical Ideas and Examples

So, how to go about doing this? How does this relate to humanistic mathematics? There is an interesting pedagogical tool named a *Math Trail* that is used to show how to connect our thinking to the mathematics found in the cultural context of a neighborhood school [23]. Activities with the trail demonstrate ways to get students working with each other in order to have them become active learners and to increase respect for their own community [23]. Together with mathematical modelling, we have used this perspective in diverse countries such as Nepal, the United States, and Brazil. Below we have shared examples that may help to engender creativity in groups of learners.

5.1. An Exploration of Addresses in Ouro Preto, Brazil

In 2005, Orey was invited to participate as a visiting professor with the mathematics education group at the Universidade Federal de Ouro Preto (UFOP). During that time, he began working with a group of elementary school children in one of the municipal schools in Ouro Preto. That pilot study became the basis for the Ouro Preto Math Trail. Orey visited the school and worked with the students over a period of eight months.

Figure 3: Students doing research in front of the school in Ouro Preto in 2005 (photo by Orey).

When a group of nine year old students were asked why the first house number on Rua Alvarenga began with a number 7 (see Figure 4), automatically, the responses were "it is 7 meters from the bridge." However, upon exploration and discussion, we found that it was not 7 meters from the bridge.

Figure 4: Number 7 on Rua Alvarenga (photo by Orey).

After some research, we found that measurements in the historic center of Ouro Preto were once based on the old imperial units, such as *barras*.[7] We took the distance from the end of the bridge to the door divided it by seven and found it closely resembled the *barra unit* and then together we realized that all the address were showing distances along our streets. For example, Rosa's apartment building was at 130 Rua Alvarenga (130 barras from the beginning of the street).

These students from a rural village (Coelhos), after visiting the Ouro Preto Math Trail, studied their own street and presented a plan to the mayor's office. The result was that the houses in the village were renumbered by including the International System of Units, but keeping its original

[7]The older standard linear measure that originated from measurements of area and volume was conceived in Egypt around 3000 BC. This measure was once called a cubit or bar, based on the length of the arm to the tip of the middle finger. Colonial Brazil, in the time of the Portuguese-Brazilian Empire, used a system that was often confusing and diverse in its measures because length was often measured in *barras* (bars), and this pattern could vary from person to person, and region to region in Brazil. This procedure did not allow for a high precision in its measurements.

numbering system. This approach allowed students the opportunity to learn and use mathematics in order to make a transformation and a contribution to the community [19]. The idea of learning mathematics and giving back to one's community at the same time is motivating, because it gives all of us reason for hope and a feeling of belonging and connection.

5.2. Transportation, Modelling, and Distance Learning

In June of 2013, millions of Brazilians went to the streets to protest corruption. The movement was spurred on by tremendous amounts of money spent on stadiums for the FIFA World Cup in 2014 while social services, health care, and education suffered. The straw that broke the camel's back, so to speak, was brought on by a sudden rise in transportation costs (mostly bus fares) across the country [11].

During this same time, Orey was teaching his online course entitled *Seminar in Mathematical Modelling* with 110 students enrolled across two states in ten very diverse educational centers named *polos*, which are centers equipped with computer labs and other educational resources. Normally, a good portion of the course is devoted to forming groups and having the students find their own themes. However, this semester everyone was encouraged to select *transportation* (see Figure 5) as a theme.

Figure 5: Bus transportation in Ouro Preto (photos by Orey).

Groups of students all in their own *polos* produced models regarding to the proposed theme. Both students and the professor used this opportunity and were not afraid of using aspects of day-to-day events found in their daily lives in order to teach, learn, and communicate mathematical findings. Because this seminar is a long-distance offering, each group recorded a ten-minute video, placed it on YouTube, and shared the link on the class forum. A PowerPoint and a short paper used in the presentation describing their findings and were shared with the class, the professor, and course tutors.

Each presentation shared a brief introduction on the development of the submitted work; information the students gained through interviews with citizens and public transport users in their respective cities; questions related to the situations presented in the interviews; mathematical models built upon the data researched; possible solutions to the problems outlined, and conclusions and reflections.

This ethnomodelling approach has helped hundreds of students gain tools and experiences that enable them to make useful, data-based arguments for what can often be emotional topics. They learned how to create data, and thoughtfully engage in debate and dialogue in their own communities in order to solve some of the transportation issues they observed while conducting their research. This allowed them to take an active role in the process of the transformation of their community.

5.3. A Brief Interlude

We chose here to describe the examples in Sections 5.1-5.2 to show how mathematical modelling can be used as a teaching methodology that focuses on the development of a critical and reflexive effectiveness, a methodology that engages students in a contextualized teaching and learning process that allows them to get involved in the construction of solutions of social significance [15].

This critical dimension of mathematical modelling is based on the comprehension and understanding of reality, in that students learn to reflect, analyze and take action on their reality. When we explore and engage them in mathematizing examples and problems taken from their own reality, students begin to study the symbolic, systematic, analytical, and critically contexts to their work.

In our distance-education context, the students do all of the above while using technological tools provided in a *virtual learning environment* (VLE). Long distance education contributes and can assist students to overcome difficulties regarding the adoption of critical and reflexive mathematical modelling courses because the technological tools offered, such as *Moodle*[8], are

[8]Moodle (Modular Object-Oriented Dynamic Learning Environment) is a free open-source learning management system (LMS) or e-Learning platform that serves educators

inexpensive, simple, and functional [20]. By using discussion forums and videoconferences, professors and tutors can critically analyze interactions enabled by these tools. In our courses these tools significantly contributed to the reflexive development of the elaboration of mathematical models in the VLE.

5.4. The Symmetrical Freedom Quilts

Quilt themes are a great way to begin the work of integrating mathematics, art, history, and reading in an interdisciplinary approach. Because of this, we 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 ethnomodelling [17].

Despite the controversy around the question of whether the quilts were ever really used in the suggested manner [10, 18], Symmetrical Freedom Quilts, or just quilting in general, may offer tangible links between mathematics, history, ethnomathematics, and the very tactile art of quilting. One of the objectives of this project is to stimulate student creativity and interest, because quilts may be considered as cultural and mathematical expressions of individual students' daily lives.

Making quilt blocks is 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 (see Figure 6).

Shoo Fly is one the simplest and very common symmetrical quilt design. 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 9×9, but variations such as 10×10 and 12×12 may also be used.

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and learners across the globe. In 2002, Moodle was developed by an Australian educator and computer scientist Martin Dougiamas (1969) to help educators create online courses with a focus on interaction and collaborative construction of content.

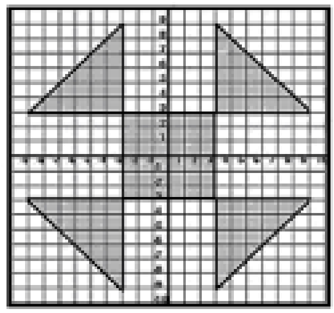

Figure 6: Shoo Fly Symmetrical Quilt Block.

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 xy-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 xy-coordinate system (see Figure 7).

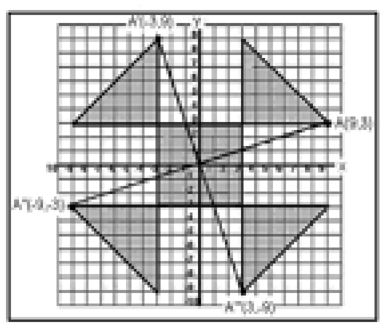

Figure 7: Rotation of point A around the xy-coordinate system.

The mapping of this rotation is $R_{90^\circ}(x, y) = (-y, x)$. The coordinates of point A in its rotation around the xy-coordinate system are:

$$\begin{aligned} R_{90^\circ}(A) &= R_{90^\circ}(9,3) = (-3,9) = A' \\ R_{90^\circ}(A') &= R_{90^\circ}(-3,9) = (-9,-3) = A'' \\ R_{90^\circ}(A'') &= R_{90^\circ}(-9,-3) = (3,-9) = A''' \\ R_{90^\circ}(A''') &= R_{90^\circ}(3,-9) = (9,3). \end{aligned}$$

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

Final Considerations

If one borrows something from someone, then one is more than interested, indeed invested in truly incorporating it, and then sharing it back. Borrowing suggests that one wants to borrow it to do something to the object, as in cooking, or collecting something *exotic* to place in a museum shelf. The act of borrowing is only important for a particular moment and does not serve for the present when diverse elements collide, live, and create new foods, music, science and of course mathematics as is happening in numerous locations in the Americas.

When we *borrow*, we are often acquiring objects or ideas with insufficient thought or a sense of mindfulness about where they come from or how they came to be. Borrowing is often not too interested in knowing the culture of the other.

If culture A meets culture B, then three things may happen:

a) Culture A eliminates culture B.
b) Culture A is absorbed by culture B.
c) Culture A assimilates culture B and produces culture C.

In this context, cultural dynamism is a dynamic sequence of social interactions and exchange between members of cultures A and B who modify and transform their own actions. These interactions form the basis for cultural structure and therefore provide a key object for basic cultural inquiry and analysis.

This perspective emphasizes that it is necessary to confront the limits of uniformity. Who equates *borrowing* with *sameness*? Instead of finding models that encourage diversity, many of our social and educational institutions have grown to force *sameness*, often as an outgrowth of the trend towards globalization, which has in turn promoted the phenomenon of sameness, or what can be labeled *cultural borrowing*. Questions naturally arise in relation to the relevance, applicability, validity, and appropriateness of theories, perspectives, and policies, which are transferred to, or borrowed, or adopted by education systems whose cultures and situational conditions are quite dissimilar from those in which they were conceived [25].

In this context, one of the goals of any educational system should be fostering creative students. Creativity is a dynamic property of the human mind that can be enhanced and should be valued. Therefore, it is important to study creativity and determine its characteristics. Studying the nature of mathematics through an ethnomathematics lens provides a suitable platform for developing creativity through *cultural integration*. It seems to us that *cultural borrowing*, a process of sameness and by which the *good* and the *accepted* have already been defined from the outside, cannot fit within the aforementioned dynamics.

The integration of ethnomathematics and mathematical modelling offers a powerful means for validating a student's real life experience, and gives them tools to become critical participants in their community. Educators should be empowered to analyze the role of students' *ethnoknowledge* in the mathematics classroom [2].[9] 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 and enable them to be successful in developing their academic mathematical knowledge. Here, the role of teachers will be to help students develop a critical view of the world by using mathematics.

In closing, we share a number of questions that we look forward to further exploring:

1. What happens when *non-represented* or *non-majority* cultures begin this process of *borrowing*? What does this borrowing infer, especially when technology gives them access to new mathematical ideas and vice versa? Is there a *sharing* between both parties or just a *taking* of one by the other?
2. Can a reverse sense of *cultural borrowing* also happen? Especially in places with great cultural diversity such as Nepal, Brazil, or California? Or is any instance of such a phenomenon necessarily a case of *power dynamics*?
3. Using ethnomodelling, more traditional ideas can be studied, categorized, and incorporated. How might this be reflected in and create new forms of mathematics?

[9] In this regard, ethnoknowledge is acquired by students in the process of pedagogical action in the learning of mathematics in a culturally relevant educational system.

4. How does technology influence borrowing? Does it accelerate the process, especially in rich environments such as long distance education, mobile learning, smart phones, and internet? Can it be mindfully used to develop true *cultural integration*?
5. How might we use new technologies to create a dialogue by which all mathematical ideas contribute to the good of all humanity?

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