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Naresh, Nirmala

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The role of a critical ethnomathematics curriculum in transforming and empowering learners

El papel de un plan de estudios etnomatemático crítico en la transformación y el empoderamiento de los estudiantes

Nirmala Naresh [1]

Abstract

When thinking about mathematics, seldom does one think about culture, context, history, or diversity. Many teachers believe that there is no place for such constructs in their mathematics classrooms. As an ethnomathematician, my primary goal is to find meaningful ways to bring components of ethnomathematics into the mainstream mathematics curriculum and classrooms. In this paper, I describe key aspects of a mathematics curriculum that was designed to promote meaningful connections between ethnomathematics theory and practice and highlight how this curriculum might help address the key tenets of a critical ethnomathematics curriculum.

Key words: Ethnomathematics; Teacher education; Critical ethnomathematics curriculum; culturally responsive mathematics education.

Resumen

Cuando se piensa en las matemáticas, rara vez se piensa en la cultura, el contexto, la historia, o la diversidad. Muchos profesores creen que no hay lugar para este tipo de construcciones en sus clases de matemáticas. Como etnomatemática, mi objetivo principal es encontrar maneras significativas para traer componentes de etnomatemáticas en el currículo general de matemáticas y en las aulas. En este artículo, describo aspectos claves de un plan de estudios de matemáticas que fueron diseñados para promover conexiones significativas entre la teoría y la práctica Etnomatemática y destacar cómo este plan de estudios podría tratar los componentes claves de un currículo crítico etnomatemático.

Palabras clave: Etnomatemática; la formación del profesorado; currículo etnomatemático crítico; educación matemática con sensibilidad cultural.

[1] Associate Professor, Department of Mathematics. Miami University, United States. Email: nareshn2@miamioh.edu

INTRODUCTION

A strand of ethnomathematics that is of special interest to mathematics educators concerns the interconnections between ethnomathematics theory and practice. Specifically, this strand addresses questions that relate to classroom teaching such as: *What are the implications of ethnomathematics for the practice of the mathematics education? How can we add to and use ethnomathematics to advocate the ideals of culturally relevant mathematics education? If and how can we use ethnomathematics to make mathematics meaningful and appealing to all students in a classroom setting?* In this paper, I draw on my practical and professional experiences and present a narrative that addresses some of these questions. I situate this narrative in a teaching project aimed to promote connections between ethnomathematics theory and its practice as it applies to a mathematics teacher education context.

AN OVERVIEW OF MY PERSONAL, PROFESSIONAL EXPERIENCES

My Background

An educator's pedagogical decisions and actions are greatly informed and influenced by his/her personal, practical, and professional experiences. In light of this, it is necessary to situate this paper in the broader context of my personal and professional background. I was born and raised in Chennai, a metropolitan city in Tamilnadu, a state in South India. My undergraduate and graduate learning experiences were rooted in an imported curriculum that is devoid of any connections to the immediate context and culture, and the broader society. My mathematical learning experiences led me to believe that mathematics is a powerful tool that can "help people move along the dominant path of progress"; I saw firsthand how many educational institutions used mathematics as a "subtle weapon" to "monopoliz[e] what constitutes knowledge" (Fasheh, 2012, p.94). As a result I held a narrow perception of mathematics that limited my ability to perceive and present mathematics as a human activity. I was oblivious to the mathematical ideas inherent in the mathematical logs maintained on the walls of my grandmother's ancestral home, the kolam designs and rangoli patterns on the thresholds of the homes in my neighbourhood, the mental mathematics embodied in the activities of just plain folks in my community, and the contributions of my forerunners to the historical evolution of mathematical ideas.

My perceptions and beliefs about mathematics and its pedagogy continued to prevail until I took a course on ethnomathematics as part of my doctoral program in mathematics education. This course provided both an immersive and a transformative learning experience during which I became an ardent enthusiast of ethnomathematics and its theoretical and practical implications. Embracing an ethnomathematics perspective has opened my eyes to a world of mathematics that exist and flourish outside the rigid boundaries of the academia. Beyond that it has enabled me to develop a renewed perception of mathematics and its pedagogy, its status in the society, and the role that it can play in the advancement of mankind. I have come to realize that mathematics is a human endeavor and developed a "respect for the "other" and the intellectual achievements of all" (Mukhopadhyay, Powell, & Frankenstein, 2009, p.4). This perspective has deeply impacted both my teaching and research and has pushed me to re-envision the ways in which I enact these practices.

Ethnomathematics: Research influences

My dissertation research serves as a key piece of evidence of the impact of ethnomathematics on my research activities – here I present a brief synopsis of this ethnomathematical investigation. I grew up in Chennai, where public transportation is very important in the everyday lives of millions of its citizens. The major form of transport for people in Chennai is the public transportation system of buses provided by the Metropolitan Transport Corporation (MTC). Every bus has a driver and a conductor. The driver is responsible for operating the bus and the conductor is in charge of issuing tickets to the commuters who travel in his/her bus. As I grew up, I travelled in these buses every day to commute to school, college, and work. Back then, I was not aware of the significance of bus conductors' work-related activities, and the potential for research arising out of their everyday activities. It was only after my entry into the doctoral program in mathematics education and my exposure to research on ethnomathematics that I decided to look at their practices with renewed interest. In my doctoral research report, I have used ethnographic case studies to document the workplace mathematical activities of this group of professionals (Naresh, 2008). This report offered glimpses into bus conductors' mental mathematical activities as they strived to fulfil the economic goals of their employers while at the same time succeeded in serving their customers. Amid tough working conditions, conductors used context and related parameters to acquire, adapt, and use efficient mental strategies to complete in situ computational tasks and contributed to a repertoire of knowledge that I term "conductors' mathematics". As a result of this research engagement, I have discerned much broader understandings of workplace mathematics and have since extended my field of inquiry to network with peers who share a similar passion for this genre of research (Naresh & Chahine, 2013).

Ethnomathematics: Practical Implications

As a mathematics educator in an institution of higher education, one of my key responsibilities involves educating prospective and inservice teachers. As an ethnomathematician, my primary goal is to find meaningful ways to bring components of ethnomathematics into the mainstream mathematics curriculum and classrooms. The problem is that usually in the school setting, mathematical knowledge is presented as a "prized body of knowledge"(Millroy, 1992, p.50), stripped of its rich cultural and historical connotations, and far removed from the "lives and ways of living of the social majorities in the world" (Fasheh, 2000, p.5). When thinking about mathematics, seldom does one think about culture, context, history, or diversity. Many educators believe that there is no place for such constructs in their future mathematics classrooms. Prominent mathematics educators, in particular ethnomathematicians (e.g., Civil, 2002, D'Ambrosio, 1985, Mukhopadhyay et al., 2009) oppose this view and argue for countering the narrow vision of mathematics that confines it to the school walls. Although a teacher educator and a researcher might hold such perceptions about the teaching and learning of mathematics, it is necessary to begin such processes at the teacher education level "as it is necessary to [change] teacher attitudes as well (Presmeg, 1998, p.325). The constructs of ethnomathematics lends itself well to this cause. Many teacher education programs have begun to address some of these questions by designing and redesigning their existing programs to focus on issues related to cultural diversity (e.g., Orey & Rosa, 2006). Prospective teachers (PSTs) enrolled in such programs not only experience learning mathematics content and pedagogy through a cultural and historical lens (Civil, 2002) but also gain a greater "respect for world cultures within the study of mathematics" (Zaslavsky, 2002, p.66). In this paper, I present one such initiative.

THEORETICAL UNDERPINNINGS

The research field of ethnomathematics contributes to the broader theoretical base. Definitions of the term ethnomathematics range from very specific, such as: "the mathematics which is practiced among identifiable cultural groups such as national, tribal societies, labour groups, children of certain age brackets, and professional classes" (D'Ambrosio, 1985, p. 45) to very broad: "The arts or techniques developed by different cultures to explain, to understand to cope with their environment" (D'Ambrosio, 1992, p. 1184). Ethnomathematical studies could be broadly categorized into the following strands: a) Those that challenge the traditionally told euro-centric history of mathematics (e.g., Joseph, 1987), b) Ethnomathematics of the people belonging to indigenous, little known cultures of the world (e.g., Ascher, 1991, Gerdes, 1997), c) Ethnomathematics of social groups in everyday settings (e.g., Lave, 1988, Millroy, 1992; Naresh, 2008), d) ethnomathematics and its connections to mainstream academic mathematics (e.g., Greer, 1996) and e) socio-cultural-political influences on the development and evolution of ethnomathematics (e.g., Powell & Frankenstein, 1997). Mukhopadhyay et al., expand the scope of ethnomathematics to include the mainstream academic mathematics and school mathematics. From this perspective "ethnomathematics is not proposed, as is often believed, as an alternative to either academic mathematics or school mathematics" but could co-exist and thrive within the realms of academia (p. 70) and this approach inspired the ideas discussed in this paper.

Ethnomathematics rejects the dominant Eurocentric approach to the history of mathematics and challenges the elitist state bestowed solely on the academic mathematics which oppresses other forms of mathematics (e.g., non-western mathematics, ethnic mathematics, everyday mathematics, workplace mathematics). Thus, as expected, it faces opposition from some patrons of the mainstream academic mathematics. However, it also faces challenges from unusual quarters - certain leaders of historically oppressed groups and educational activists from some developing nations. Such individuals strongly believe and fear that an overemphasis on ethnomathematics and its pedagogy will impede their communities' educational, intellectual and technological progress (Mukhopadhyay et al., 2009). The ethnomathematics community has an ethical responsibility to address and counter such widely-held dogmas and present plausible approaches to alleviate the concerns.

An ethnomathematics curriculum with a critical perspective will help us attend to these concerns and thereby generate a meaningful dialogue centred on a culturally responsive mathematics education. A culturally responsive pedagogy (Gay, 2000) is aimed to empower and transform learners. The key tenets include: helping students connect the academic mathematics to other forms of mathematics, connecting school mathematics to the socio-cultural-ethnical aspects of their home culture, enabling teachers to practice equitable pedagogical practices that cater to all learners, and allowing both students and teachers to acknowledge and celebrate their own and each other's cultural background (Gay). In order to accomplish these goals, it is necessary to embrace a curriculum that will offer the maximum scope to empower all learners by broadening their perspective of mathematics and its pedagogy. A traditional mathematics curriculum seldom offers learners or teachers an opportunity to accomplish this goal. On the other hand, a critical ethnomathematics curriculum (CEC) draws on the principles of a culturally responsive pedagogy and addresses the challenges that it poses to a traditional mathematics curriculum. a) it challenges the "Eurocentric narrative" to quell the dominant belief that the academic mathematics that is currently known and taught in schools was solely created by European mathematicians, b) confronts "what counts as knowledge in school mathematics" to establish and celebrate the connections between mathematical content, context, and culture of both familiar cultures and non- familiar cultures, and c) attends to the disconnect between "mathematics education and social and political change" (Mukhopadhyay et al., 2009, p. 72).

RESEARCH GOALS: A FOCUS ON PRACTICE

I have initiated a larger research project that aims to promote connections between ethnomathematics research and practice as it applies to the mathematics teacher education context. The key goals of the research project are (a) to develop and implement a mathematics content course using the principles of a CEC and (b) to investigate whether and how participation in this course positively impacted participants'' (both students' and the instructor's) perceptions of mathematics and its pedagogy. In this paper, I focus on the first research goal. The purpose of this paper is to present an archetype of a CEC and describe key aspects of a mathematics curriculum that was designed to promote meaningful connections between ethnomathematics research and practice and highlight how this curriculum might help address the key tenets of a critical ethnomathematics curriculum.

The term 'mathematics curricula' is used in a broad sense to denote a set of ideas that students are taught and expected to learn. In particular, it could also refer to a variety of instructional materials including course content, concepts, and activities (Shirley & Kyeleve, 2005). For the purposes of this paper, I will use the term in reference to a prospective teacher education course that was developed to address the research goals. In order to attain the goals of a culturally responsive teaching, it is necessary to develop and use curricular materials that "emphasize both the mathematical and sociocultural aspects of topics" (Croom, 1997, p. 4). To this end, I consulted multiple sources such as the national and state standards, textbooks, video resources, and content from online and print media to adapt and develop curricular materials for classroom use. Methods and results of research are evident in the descriptions of the curriculum that was developed for the prospective teacher education course titled "Patterns and Structures through Inquiry".

THE ENACTED CURRICULUM

Empirical Setting

The geographical setting for the study is a large mid-western university in the United States. The contextual setting is a mathematics content course Patterns and Structures through Inquiry (PSI) for prospective teachers. This is a three credit-hour (38 contact hours) course, which a prospective teacher completes near the end of the program of study. It emphasizes sharing of ideas, synthesis, and critical, informed reflections as significant precursors to action. Prospective teachers pursuing licensure to teach middle school mathematics typically enrolled in this program culmination (capstone) course in their fourth year at the university. Pre-requisites for this course include successful completion of at least nine hours of mathematics education courses that address topics such as numbers and operations, algebra, geometry, technology, and the history of mathematics.

PSI Course goals

This course is designed to foster critical thinking, solving complex problems, engaging with other learners, and communicating mathematical ideas. In particular, the course provides prospective teachers (PSTs) an opportunity to explore advanced mathematical ideas in depth and explain these concepts with clarity and precision. Specific course goals are as follows: a) engage in a deeper analysis of problems and concepts to gain new mathematical insights and understandings, b) examine from a social, cultural and historical standpoint the evolution of mathematical theory and school mathematics, c) unravel, understand, and appreciate the connections between culture, context, and mathematics content and d) explore connections among various mathematical concepts and become more proficient in communicating mathematical ideas.

PSI Course Structure

The course was designed in line with the principles highlighted in Presmeg's (1998) ethnomathematics course "mathematics of cultural practices". In addition, I drew inspiration from Rosa & Orey's (2011) visions for a culturally relevant curriculum to design the course content, structure, and presentation. Course content was delivered using practical and research components. As part of the practical component, each week, PSTs participated in at least one mathematical task set in a social/cultural/historical/political context. The research component required participants to identify and investigate a personally meaningful practice that emphasizes that mathematics is a human activity.

In this course, as members of a community of learners, PSTs were required to participate enthusiastically in class activities, listen to and learn from their colleagues, and respect the opinions of other participants. During problem-solving activities, they worked in small groups and shared their work with peers through formal and informal presentation sessions. Participants were asked to think critically by exploring problem solving activities set in real-life scenarios. In particular, they were encouraged to think about “why a solution works” in addition to learning about “how to find a solution” to a mathematical problem. To establish specific connections to ethnomathematics, participants were asked to think deeper about the types of tasks and activities that are usually presented in a traditional mathematics curriculum; compare and contrast such tasks with those that were presented in the PSI course. Specifically, they were asked to attend to and explore the connections between a given mathematical task and the local and global contexts that framed the tasks. Furthermore, PSTs were asked to describe and reflect on their perceptions of mathematics and articulate their beliefs on what constitutes a mathematical activity. Assessments in the form of homework assignments, reflection assignments, course projects, and exams were assigned to gain insights into PSTs’ mathematical understandings. They attended one-to-one meeting sessions with the instructor to discuss their homework assignments, plans for the formal presentations, and their visions for their course projects.

PSI Course Content

This course is a study of the structure of mathematical systems, developed through student-centred inquiry, pattern recognition, hypothesis formation and testing, and proof. The mathematical topics that are investigated include logic, algebra, fractions, probability, geometry, and statistics. Course activities can be broadly classified into the following categories: a) Content Explorations (emphasis: Local/global contexts and cultures), b) Leading a class discussion (emphasis: History of Mathematics), c) Course readings that promote reflection and action (emphasis: Ethnomathematics & Everyday mathematics) and d) Course Project (emphasis: connections between Everyday mathematics and Academic mathematics).

Content Explorations

Each week PSTs participated in at least one mathematical task set in a social/cultural/historical/political context. During the task analysis sessions, participants (re) examined mathematical topics (while accessible to school students and teachers) that typically lies outside the focus of the traditional school mathematics curriculum. The tasks were chosen to enable PSTs to make mathematical connections to the social, cultural, and historical contexts. In particular, participants investigated the mathematical elements inherent in the activity and explored its potential for developing a robust mathematical understanding. Some examples of mathematical lessons that were developed and implemented for this course are listed here (Figure 1). The themes in parenthesis denote the mathematical strand that was addressed within the activity.

- Cultural dimensions
    - Indian and Chinese cultures: The game of Chess (Problem solving, Algebra, Geometry)
    - African culture: Fractals, Sona Patterns (Discrete mathematics)
    - Egyptian and Native American cultures (Problem Solving, Indirect measurement)
    - Indian culture: Number tricks, Kolam patterns (Number systems, Algebra, Geometry, Discrete mathematics)
    - Indigenous cultures: Warlpiri kin relationships (Group theory)
    - Cultural games from around the world (Probability)
- Social and Political dimensions
    - Data sets from the world bank, UNICEF, WHO, and the United States Census Bureau (Data analysis)
    - Population Connections (Data representation and interpretation)
    - *Gapminder* explorations (Interactive data analysis)
    - *Plinko* Investigations (Probability)
    - Misuse of Statistics (Social statistics)
- Historical dimensions
    - Creating timelines (e.g., Geometry, Probability)
    - Problems from the Rhind Papyrus and Babylonian clay tablets (Problem Solving)
    - Chinese Magic Squares (Patterns, Algebra)
    - Egyptian, Babylonian, Chinese, and Indian perspectives (Pythagorean Theorem)
    - Japanese Origami (Spatial visualization)
    - The tower of Brahma (Sequences and Series)
    - Chinese Tangrams Explorations (Geometry, Algebra)

Figure 1. Content Exploration activities.

Leading a class discussion (LCD)

For this activity, participants worked in small groups - each group chose an ancient civilization, learned about the mathematical activities unique to that civilization, and facilitated a class discussion session. For example, a group that chose to investigate the mathematical contributions of Babylonian civilization learned about the *sexa-gesimal* system that is unique to that civilization and taught this number system to their peers.

Course readings and reflection

Throughout the course, participants read and reflected on course readings that focused on ethnomathematics, everyday mathematics, and workplace mathematics. Three reflection assignments were assigned as a measure and evidence of what students learned as a result of participating in content explorations. For each reflection assignment, participants focused on a specific content area (e.g., geometry) and read articles and book chapters (e.g., Women, art, and geometry in Southern Africa (Gerdes, 1998), Computation, Complexity and Coding in Native American Knowledge Systems (Eglash, 2002), An ethnographic study of the mathematical ideas of a group of carpenters (Millroy, 1992), that described ethnomathematical investigations related to that content area.

PSTs were asked to reflect on their content exploration and LCD sessions and establish connections to the course readings. Specifically, they were asked to describe ways in which this exposure a) contributed to a greater understanding of mathematical content, b) challenged some myths (e.g., such tasks do not pose cognitive challenges, cannot be aligned with standards benchmarks) about the use of mathematical tasks set in distinct social, cultural and historical contexts, and c) impacted their stance on the teaching of mathematical ideas using an ethnomathematical perspective.

Course Project

For this project PSTs were required to identify and investigate a personally meaningful practice that highlights the fact that mathematics is a human activity. Each participant developed a mathematical activity and engaged in both content and pedagogical explorations. Content explorations enabled participants to explore in depth the mathematical content inherent in the activity and through pedagogical explorations they drew upon their mathematical understandings to design and facilitate a mathematics lesson for a group of eighth grade students. Some examples of student projects are presented here

(Figure 2). The themes in parenthesis denote the mathematical strand that was addressed within the activity.

- Dr. Math: Pharmacy and nursing (Measurement - Unit conversions)
- Shipping logistics (Data interpretation, Algebra)
- My mother, a lunch lady and her mathematics (Data analysis, Measurement)
- The mathematics of seamstresses and tailors (Geometry, Number sense)
- Dave, the fabricator (Geometry, problem-solving)
- Coffee place mathematics (Number sense, Problem solving, measurement)
- My dad, a construction worker and his ethnomathematics (Pythagorean theorem)
- My parents' mathematics: Walking in their shoes (Everyday Mathematics)
- Mesothelioma and mathematics (Social Statistics)
- Speaking mathematics using the sign language (Transformational geometry)

Figure 2. Course project examples.

THE PSI COURSE AND THE TENETS OF A CRITICAL ETHNOMATHEMATICS CURRICULUM

Challenging the "Eurocentric narrative"

In the PSI course, it was a key priority to help students better understand the evolution of mathematical ideas from a non-Eurocentric standpoint. To this end, I chose and presented mathematical activities that were useful in offering a counter narrative to the dominant Eurocentric narrative. Here is an example. As part of content explorations on geometry, the following activities were planned and offered: a) Creating a timeline for the evolution of geometry (Lumpkin, 1997), b) Tracing the origins of Pythagorean Theorem: The case of Plimpton 322 (Robson, 2002), c) investigating the geometry of Sonas and Kolams (Gerdes, 2006; Siromoney, 1978), and d) exploring geometry and technology through cultural artefacts (Eglash, 2002). To create a timeline, each student group chose a different region (e.g., hallway, classroom walls, the black board), debated on the choice of scales and units that will be appropriate for the chosen region and explored ways to depict that information on that region. An investigation of the Plimpton 322, introduced them to the *sexa-gesimal* number system. As PSTs grappled with the base-60 numbers and their operations, they developed a greater respect for the Babylonians who adeptly solved numerous problems that emerged out of their everyday practical needs. Course readings specific to Plimpton

322 (e.g., Robson, 2002) enabled them to better understand the origins of Pythagorean Theorem and the Pythagorean triples. The use of reciprocal pairs and the method of completion of squares provided a novel, yet an intriguing approach to these concepts that are seldom part of a traditional mathematics curriculum. Student engagement in this geometry-focused strand initiated a discussion on the following questions: What is geometric thinking? Who gets to decide and define what geometric thinking is? What sparked the need to formalize geometry? This purposeful discussion also prompted a much broader discussion centred on the evolution of mathematical ideas and the historical interpretations of the evolutions of mathematics. Discussion questions that were posed by both the instructor and the learners include: What mathematical ideas are exemplified in historical artefacts unique to the ancient civilizations? Who discovered these ideas? What is the role and purpose of mathematics in those societies? From a dominant Eurocentric view, who is credited with these ideas? Why might this be the case? What can we do about this?
Such discussions led PSTs to better understand that the interaction between different cultures of the world has contributed to the growth of mathematics. Furthermore, as advocated by the tenets of a culturally responsive teaching, these sessions enabled PSTs to "understand why the record [dominant perspective] is wrong, and [realize] how that wrong record is culturally disrespectful" (Mukhopadhyay et al., 2009, p. 74). Many PSTs began to acknowledge that much of the so-called Western mathematics "originated in the ad hoc practices and solutions to problems developed by small groups in particular societies" (Katz, 2003, p. 557) and that traditionally told histories of mathematics have neglected the contributions to mathematics from the non-European cultures and have presented a Eurocentric view of mathematics (Joseph, 2000). As educators, we have a moral responsibility to tell the story of mathematics from multiple standpoints, which can certainly include European mathematics. However, if it is the only view that is presented and propagated, then we not only rob many individuals, groups, societies, and civilizations and of their significant contributions to the evolutions of mathematics but also deny our students an immersion in mathematical experiences informed by cultural and historical perspectives. A history-based mathematical approach also presented significant cognitive challenges as PSTs attempted to (re) discover mathematics the way in which our ancestors

did and this process helped dispel a widespread belief that culturally relevant mathematics and meaningful mathematics cannot or do not co-exist in a school curriculum.

What counts as knowledge in school mathematics?

Research on ethnomathematics has revealed the diversity of mathematical systems and practices in different cultures around the world. This line of research describes in detail the mathematical practices of people belonging to "small-scale cultures" – such as finger counting techniques in Roman times, an investigation of number words used by Lincolnshire shepherds, board games from Ghana and Nigeria, probability activities from Brazil, and geometry in Islamic art (Ascher, 2002, p. 2). This strand of ethnomathematics also describes the mathematics used by people in everyday settings. The research field of everyday cognition (Nunes, 1992) presents the mathematical thinking and practices of participants in situations where they developed mathematical knowledge in a social context (e.g., Carraher, Carraher, & Schliemann, 1987; Saxe, 1991). In the PSI course, participants were introduced to the social constructions of mathematics through course readings that highlighted the contributions of people who were not necessarily from the mainstream academia. To encourage participants to look for personal connections to mathematics in their culture, I first presented a mathematical activity that had deep connections to my personal and social culture. Here, I provide a brief description of this activity.

Kolam Patterns

In South India, the women of the household draw interesting and intricate Kolam designs in the threshold of their homes (Figure 3). Kolams are created using rice flour and decorated with flowers; they are considered auspicious signs and used to welcome guests; they are also believed to avert misfortunes. The ritual of Kolam drawing can be viewed as a socio-cultural activity with applications in the fields of mathematics (Ascher, 2002), computer science (Siromoney, 1978), education (Chenulu, 2007), and cultural anthropology (Laine, 2009).

Figure 3. Kolam pattern in front of my home.

As part of the socio-cultural mathematical investigations, I introduced PSTs to some of the Kolams that I created, encouraged them to engage in this social activity, and uncover the potential it held for teaching and learning mathematics. Some of the student-identified teaching ideas include the following: a) Geometry– Polygons & Transformations (e.g., Identify and name polygons in a given Kolam, Identify the symmetries and transformation in a given Kolam) b) Algebra – patterns & sequences (e.g., Determine the patterns & sequences in a series of Kolams, c) Combinatorics (e.g., Decorate Kolams using a set of colors subject to specific constraints), and d) Discrete Mathematics (Investigating graphs, paths, circuits in a given Kolam).

Prospective teachers enjoyed learning about (and doing) the mathematics inherent in the socio-cultural activities of a group that they barely knew – the women of South India. For too long, our students are presented with only European, so called refined version of mathematics, only taught to regurgitate whatever processed form we have limited academic mathematics to. In light of their exposure to the mathematical activities of just plain folks, PSTs were willing to look for and acknowledge other forms of mathematics that exist outside the realms of the academia. Evidence to this fact is exemplified in their course project creations – I provide a brief overview of two such projects (Figure 4).

Dave, the stair fabricator. The fabrication of stairs is one example of how to integrate ethnomathematics into a middle school classroom. This project focuses on a professional fabricator, Dave, who builds stairs for many buildings including the County Mall and the Local Community College. We have developed a task that will enable you to better understand how Dave uses the Pythagorean Theorem in his line of work.
My mother, the lunch lady. Using statistical analysis and measurement, we find that the lunchroom is full of hidden mathematical concepts that offer food for thought. Through this presentation and corresponding activity, students will gain the knowledge required to collect and interpret data, and make decisions based on available data as well as predetermine nutritional requirements. This activity, aligned with the Common Core mathematics standards, will allow students to understand how my mother, a lunch lady used mathematics to inform her work place activities.

Figure 4. Everyday Mathematics and Academic Mathematics: Course project exemplar.

Mathematics education for social and political change

Disciplines such as social sciences and humanities serve as natural places for teachers to discuss the implications of these disciplines for the betterment of the society. However, this is seldom the case with mathematics and statistics. Many teachers do believe that as our society continues to become more diverse in race, culture, ethnicity, class, and sexual orientation the current educational systems must also revise their purpose and their context. However, teachers of mathematics may not necessarily believe that there is room for such constructs in their classrooms. Or they may not sufficiently understand how to integrate such topics into their existing mathematics curricula and revise their pedagogical methods to teach this content. As teacher educators, it is our responsibility to equip teachers with the empathy, consideration, and the skills necessary to realize that mathematics could be used a vehicle to promote social change.

In the PSI course, I drew upon the domains of mathematics and social justice to design a teaching module on statistics primarily intended to enable PSTs to use a critical mathematics perspective to investigate social issues so that the inequities become apparent and ideas for change may be discussed. Course readings from Rethinking Mathematics (Gutstein & Peterson, 2013) and subsequent reflections enabled PSTs to negotiate broader meanings for mathematics and statistics and their role in today’s society. We used world population data to delve deeper into statistical problem solving. Use of such data sets helped us to attend to and understand our personally-held beliefs about issues facing our community. The *Gapminder* free online data visualization software (www.gapminder.org) was used to investigate and interpret data compiled from various international sources (e.g., UNICEF, WHO). In particular, we focused on understanding the dynamics of the graphs and the available options for choosing scales (linear or logarithmic), indicators (e.g., life expectancy, infant mortality) and categorizations (e.g., income, religion) to generate graphical displays. As PSTs became familiar with new resources on teaching mathematics using a social and cultural lens, they too were inspired to develop activities that are relevant and most meaningful in their immediate context. I present a course project activity as an exemplar (Figure 5).

Statistics for Social Justice Project. The project is designed to focus on key aspects of a model of equity pedagogy – self, society, students, and schools (Darling-Hammond & Bransford, 2007). The mathematical activity designed by prospective teachers (selves) enables learners (selves & their students) explore the distribution of government (societal) funds to the local "school" district. By analyzing school funding data allocated to teachers, administrators, transportation, extra-curricular activities, and building maintenance, learners will better understand how the school district operates and begin to view themselves as part of a much larger "society" beyond the classroom. Data analyses using marginal and conditional probability distributions and subsequent interpretation of findings will help identify effective ways to distribute funds. Learners will engage in mock debates during which they will be assigned specific roles (e.g., parents, taxpayer, teacher, students) and encouraged to seek additional funding and campaign for their causes. Such discussions are intended to help learners gain insights into others' viewpoints and view the society from multiple standpoints.

Figure 5. Mathematics for Social change: Course project exemplar.

By creating and participating in this project and other such mathematical activities, PSTs were able to "experience the power of mathematics and their own agency through the use of modeling tools to critique and act upon their own educational circumstances" (Mukhopadhyay et al., 2009, p. 78).

THE JOURNEY CONTINUES

The foundation of ethnomathematics rests in its "openness to acknowledging as mathematical knowledge and mathematical practices elements of people's lives outside the academy" (Mukhopadhyay et al., 2009, p. 75). Although there are several contexts in which mathematical ideas develop and are discussed, mathematics education has mostly been associated with the institutional context – The PSI course was designed and taught to challenge this traditional perspective. Although the primary focus of this paper is to describe key aspects of the PSI course, I will present some evidence that serves to highlight the impact of this course on its participants. Participant feedback that was collected in terms of student evaluations and final reflections reveal that this course has positively impacted PSTs' perceptions of mathematics and its pedagogy. It has challenged their perceptions of mathematics, enhanced mathematical understandings, offered a glimpse into cultures, societies, and the mathematical activities that live and thrive in such contexts. One participant's comment offers a succinct summary:

Abstract algebra is where I was first introduced to dihedral groups, yet I was never one hundred percent confident in my complete understanding of the topic. This changed once I participated in the Warlpiri kinship activity; it made concepts meaningful and relatable to a real-world context while at the same time offered a glimpse into a completely different culture. From a multicultural perspective, the activity allows [students] to look into the structure of the Warlpiri Tribe and compare [it] to the social structure of their own background.

Challenges and Opportunities

During the course, many PSTs also identified some key challenges for the implementation of culturally responsive mathematics instruction in their future classrooms. In their own words, they are "the time needed to understand the concepts buried in the activities would conflict with the time needed to practice skills needed for doing well in tests", "unlike traditional mathematics tasks, I didn't always know where the math was going to appear or what exactly I would be using", " it is teachers' understandings of various cultures as opposed to their understanding of the mathematics content that makes multicultural education a possibility and this could be intimidating". Striving to develop and implement a course based on the principles of a culturally responsive mathematics instruction is not an easy task. Often time there is no context, nor content for such a course in a traditional teacher education program or in a conventional school mathematics program. Limited modes for curricular resources, professional development, or models exist to demonstrate that an ethnomathematics curriculum will blend with and enhance other content disciplines.

The PSI course introduced participants to an archetype of a CEC that addressed some of these challenges. During the course, prospective teachers were provided a repertoire of curricular artefacts that they could one day use in their own mathematics classrooms. The course project activities that they developed became a part of this collection. Many of the course activities (e.g., content exploration, leading a class discussion) required participants to make explicit connections between the context-based activities and the mathematics learning standards highlighted in the official (national) curriculum. As a result, many participants realized that such activities, that are part of a culturally-responsive curriculum, called for deeper and richer exploration of content (mathematics) while at the same time catered to the 'the thematic strands' highlighted in the national standards.

Other obstacles that were addressed in this course concerns a widespread belief that students are not mature enough or ready to engage in a discussion centred on sensitive social issues. Another barrier concerns the notion that when using a cultural and historical lens, meaningful mathematics, is absent from the curriculum. In the context of our research and development for this class, we, the collective whole, came together to address some of these challenges – We understood and embraced the concept that if we failed to produce meaningful dialogue (between teachers and learners), or if dialogue is absent, change cannot occur. As a learning community, we have come to realize that it is important to "empower students, through broadening, not narrowing their knowledge of mathematics; through inspiring their participation and creativity in contributing to the development of mathematical knowledge, and, for teachers, through the creation of a culturally responsive teaching (Mukhopadhyay et al., 2009, p. 72).

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