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Teaching Secondary Mathematics and Science Contents embedded in Historical and Cultural Contexts: Challenges and Possibilities

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1. Introduction:

Mathematics and Science are dynamic studies of patterns and relationships (Wheatley & Reynolds, 1999) that evolve as people participate in and contribute to their cultural and historical activities. "It is estimated that about 95% of mathematics known today has been produced since 1900" (Berlinghoff & Gouvea, 2004, p. 53). Because mathematics and science are connected to the culture and history of each individual, many educators are convinced that teaching and learning of these disciplines ought to be relevant and meaningful to learners. Ethno-mathematics as an area of study developed from researchers' (Ascher, 1994; Bishop, 1991; D'ambrosio, 2001; Frankenstein, 1995; Nunez, 1992; Orey & Rosa, 2001) focus on relevance. A straightforward definition of ethno-mathematics is the integration of history and culture with mathematics. According to those authors, there are many ways to understand and have better appreciation of teaching and learning mathematics and science contents if they are presented in relevant contexts. Many pre-service teachers come to understand that they must cross the boundaries of their own familiar cultural and historical contexts in order to meet the needs of diverse students. In this sense, pre-service teachers must move into the unfamiliar territory of teaching differently from the way they were taught. This qualitative and descriptive study examines the evolution of secondary pre-service

teachers' views on teaching and learning mathematics and science in historical and cultural contexts.

The researchers mentioned above have argued that the contributions to mathematics and science of many people around the world have not received sufficient attention, and, in some cases, they have been ignored. For example, groups and individuals from various non-European cultures developed sophisticated systems of mathematics and science. Several of these include Egyptians from North Africa, Chinese from Far East Asia, Indians from Near East Asia, Arabs and Persians from Middle East Asia, Mayas from Guatemala, Aztecs from Mexico, and Incas from Peru. Yet, these contributions are rarely mentioned in textbooks or dictionaries published in North America (Orey & Rosa, 2001). However, some educators believe that the study of ethno-mathematics would benefit all teachers and students because this approach will help them to learn, respect, appreciate, and celebrate contributions of people in all parts of the world. Integrating history and culture into teaching and learning mathematics and science contents helps to generate interest and engagement in learning. Such heightened interest and engagement may increase students' persistence in problem-solving and encourage creativities (Zaslavsky, 1973).

Research shows that brain evolution, cultural interaction, and communication all play a major role in the development of mathematical and scientific knowing and understanding (Lakoff & Nunez, 2000; Lave & Wenger, 1991; Lerman, 2000). Teachers' understanding of what mathematics and science are might have a strong influence on the way they think, reflect, plan, teach, and provide opportunities for their students to learn the subjects. That is, such understanding in pre-service teachers could aid them in moving beyond rote and mechanical processes in order to foster their students' ability to think about problems:

> Recent discourse in mathematics education has coalesced around the importance of focusing on and fostering students' mathematical understanding. This agreement among mathematics educators has led to a commitment to generate new learning goals for students that are less skewed in favor of skill and facts learning and more focused on students thinking. (Simon, 2006, p. 359)

Similarly, publications of The National Council of Teachers of Mathematics (NCTM, 1989, 1991, 2000 2000) state that mathematics and science are something people do; they have broad contents encompassing many fields, and mathematical and scientific power can and must be at the command of all students in a technological society. "Mathematics [and science are] the greatest cultural and intellectual achievements of human kinds, and citizens should develop an appreciation and an understanding of that achievement" (NCTM, 2000, p. 4). Mathematics and science as language emerged out of necessity and curiosity of people across societies, continents, and millennia.

2. Background:

The theoretical and philosophical assumptions of this study are grounded in autopoiesis systems theory (Maturana, 1980, 1981, 1988) and emergent perspective (Cobb, 1994; Cobb & Yackel, 1996). Both of these perspectives are important for

understanding and examining teaching practices, beliefs, and underlying world views implicit in actions, stated beliefs, and classroom dynamics. Maturana defines autopoiesis as a self-producing, self-organizing, and self-sustaining entity. Autopoiesis theory argues that a living system (i.e. learner) must be understood through the process of the system's interaction with its environment. An interactively open system cannot be studied in isolation: It must be studied through the process of "structural coupling" (Maturana, 1988). Structural coupling means the reflexive relationships between the system and its local situation, the cultural/historical condition (Hatch & Gardner, 1993), and other systems, to include individuals and events. The social, cultural, and historical contexts trigger and perturb the transforming processes. "Human behavior, unlike that of physical objects, cannot be understood without reference to meanings and purposes attached by human actors to their activities" (Guba & Lincoln, 1994, p. 106). Underlying perceptions of order are complex interactions that are often not discernible. Organization within complex systems is governed by mutual connections and relationships of systems rather than hierarchies of simple causal connections. These characteristics of open systems are contrary to a closed, mechanistic view of relationships within a system, and directly challenge a more traditional Newtonian approach to causal relations. Classroom dynamics are open system whereby complex interactions and mutual connections prevent attribution of simple causes to classroom events. The open system of a classroom provides opportunities to cross the borders created by closed systems and to expand contexts and opportunities for learning.

Autopoiesis system theory is consistent with emergent perspective (Cobb & Yackel, 1996). According to this perspective, knowing and learning are constantly evolving and are constructed by the individual within the social, cultural, and historical conditions. Emergent theory and practice include several elements beyond the theory and practices of behaviorism. It is not always a simple replacement of traditional "feed in" and "feed out," question-and-answer teaching. Instead, emergent theory and practice attempt to develop knowing and understanding through oral discussions, diagrams/illustrations, concrete materials, science and mathematical models, reading, and writing. Proponents of the Emergent perspective are convinced that learners come to know the contents of mathematics and science better when these contents are embedded in relevant historical and cultural contexts.

This study addresses the following question: How may secondary mathematics and science pre-service teachers transform their perspectives on teaching contents embedded in historical and cultural contexts? Our schools today, more than ever, call for teachers who can build connections and relationships across contents and contexts; teachers who can create an atmosphere of care where discussions are encouraged and a climate where students feel safe and free to express their thoughts and concerns. Establishing a caring community is important for individual growth. It values individual autonomy, curiosity, and sense of wonder (Noddings, 1992).

This study was conducted in a state-supported, urban, university located in Midwestern America. The *Perspectives in Mathematics and Science* course is developed for pre-service mathematics and science interns as they take the course concurrently with their student-teaching requirements during spring semester each year. The three credit-hour course takes place once a week for three hours. There were 28 pre-service teachers (12 with a mathematics background and 16 with a science background), in the classroom during the spring semester, 2015. Eighteen interns were male and 10 were

female from different ethnicities such as African-Americans (4), Spanish-speaking background (3), Asian (2), Eastern European background (5), Middle Eastern (2), and Western European background (12). Their age-range varied from 22 years to 45 years. Almost all of the interns were placed in urban schools for their student-teaching experience.

My (as the instructor of the course and the author of this paper) perspective on this course's development and implementation is influenced by the work of two curriculum theorists, Doll (1993), *A Post-Modern Perspective on Curriculum* and Grundy (1989), *Curriculum: Product or Praxis*. Doll (1993) asserts that "curriculum is a process, not of transmitting what is absolutely known, but of exploring what is unknown; and through exploration students and teacher 'clear the land' together, thereby transforming both the land and themselves" (p. 155). Further, he connects the process with constructivism by saying "A constructive curriculum is one that emerges through the action and interaction of the participants; it is not one set in advance, except in broad and general terms" (p.262). Similarly, Grundy (1989) associates this transformative process with culture: "Curriculum is a cultural construction. It is not an abstract concept which has some existence outside and prior to human experience. Rather, it is a way of organizing a set of human educational practices" (p. 5). From these two compatible perspectives I developed and implemented the course assignments and activities with a qualified hope that my pre-service teachers would find their ways to design and develop their lesson plans and implement them creatively, autonomously, and meaningfully. I trusted that they would make their roads by walking (Horton & Freire, 1990).

The *Perspectives in Mathematics and Science* course has four broad, interlocking goals: 1) provide an overview of the history of mathematics and science; 2) enable future teachers to enact these historical perspectives and contexts throughout their pedagogy; 3) promote intellectual curiosity and sharpen critical thinking skills; and 4) improve verbal and written communication. Throughout the semester interns complete the following required assignments and activities: 1) read, reflect upon, and discuss issues relative to their reading assignments from two required textbooks; 2) participate in and contribute to the classroom activities; 3) choose, prepare, write, and present a project that contains three interconnected pieces—A) a historical development of a mathematics or science topic, B) a biographical sketch of the person(s) connected with topic that they select, and C) a lesson plan and presentation connecting part A and part B to part C; 4) select and communicate with another pair from the classroom and provide pre- and post-critiques of their peers' lesson plan and lesson presentation; and 5) write a final reflective paper relative to their experience throughout the semester.

The two texts include: Berlinghoff and Gouvea (2004), *Math through the Ages: A Gentle History for Teachers and Others,* and Matthews (2014), *Science Teaching*: *The Contribution of History and Philosophy of Science*. The ten reflective reading entries start from week 2 of the semester and end on week 11 of the semester. Each entry has three components, namely summary, analysis, and opinion. The interns turn in a hard copy of their reading reflections at each class meeting and receive comments and feedback from the instructor in the following week. The comments and feedback are constructive and suggestive rather than evaluative. I read interns' entries from the standpoint of understanding and interpreting. If there is any question about readings or clarification needed by interns, I have an individual oral discussion with each intern

before or after the following class meeting. This process is on-going until all reading assignments are completed.

From week two to week 11, each class meeting starts with discussions on readings. It takes roughly an hour. In addition, on week two of the class, interns find their partners, their critical colleagues, and select their historical topics for their project. They start presenting part A of their project from week three through week five, part B of their project from week six through week eight, and part C from week nine through the end of semester. The interns submit a hard copy of their project papers along with their PowerPoint presentation papers to me on the day of presentation and receive feedback on the following week. My on-going conversation with interns about their three parts of project is more focused on consistency between the interns' understanding of the project and my understanding and interpretation of their papers and their presentations.

The pre- and post-critiques of their peers' lesson plan are also more constructive and suggestive than evaluative. In this sense, this portion of course activity promotes development of a caring community of learners in which risk taking, trust and belonging, common interest, and meaning-making are encouraged and celebrated. For example, I play the role of facilitator and coach throughout the semester for development of classroom community.

3. Methodology:

This qualitative and descriptive study is guided by constructivist inquiry (Guba & Lincoln, 1989, 1994; Lincoln & Guba, 1985; McCracken, 1988). In this sense, the study is context specific (i.e., pre-service secondary mathematics and science teachers' views on teaching and learning mathematic and scientific content as embedded in the historical and cultural context of a state-supported, urban, university located in Midwestern America). In this study, the interns' reflections, classroom discussions, and activities such as looking, listening, speaking, reading, intuition, body movement, and feeling, play a vital role for understanding and interpreting the research. These are crucial components of descriptive and interpretive study grounded in constructivist inquiry.

An important aspect of constructivist inquiry is the notion of trustworthiness. Lincoln and Guba (1985, 1994) outlined four criteria of trustworthiness: Credibility, dependability, confirmability, and transferability. Broadly defined, these four criteria refer to certain activities that increase the probability of the findings to be authentic. One such activity is the investment of time. It is imperative that the inquirer spend time for providing adequate feedback to the participants. There is no answer as to how much time is needed for reading, reflecting, and providing feedback to various activities and assignments done by interns. One measure of trustworthiness is acceptance of the findings by the participants. At each stage of the semester, I had interactions with the interns regarding my understanding and interpretations of their stated beliefs and actions. These interactions took place before or after each class meeting. Another measure of trustworthiness is the provision of thick description. In this study, interns' voices and concerns are focal points of the study through thick description.

4. Data Collection and Data Analysis:

Although I have been teaching this course for the past six years, data collection and analysis of this paper are entirely from the spring semester of 2015 with 28 pre-service teacher enrollments (12 with a mathematics background and 16 with a science background). In order to accommodate all students (including students with special needs) and make the assignments and activities meaningful and doable within the time constrains of a semester, I paired interns so that, for each project, two science or two mathematics pre-service teachers would work collaboratively together to fulfill their common goal of a semester long project. In addition, each pair would select another pair in the classroom for pre- and post-critiques of their project. The reciprocal peer critiques provided interns opportunity to reflect, modify, and re-plan their projects and presentations. However, other assignments such as reading reflections and final reflective paper were done individually.

Data sources include university classroom observations, pre-service teachers' verbal and written responses to class discussions, reading assignments, and course activities. However, most data presented in this paper focus on pre-service teachers' written responses to various assignments. I acted as participant-observer, facilitator, and coach in the classroom. In addition, on-going processes of sharing my understating and interpretations of the findings with interns (i.e. triangulation of data processing) played an important role for establishment of a caring community and trustworthiness. Triangulation occurred in two ways. First, I triangulated data via an on-going conversation with interns before and after each class meeting or in the following week after reading their papers. Second, I triangulated data by comparing multiple data sources (i.e. reading reflections, classroom discussions, observations, and one-on-one conversations).

Data collection and data analysis occurred simultaneously throughout a semester-long course that aims to provide an overview of the history of science and mathematics and to enable future teachers to enact these historical perspectives and contexts throughout their pedagogy. These data were compared applying a constant comparative method (Lincoln & Guba, 1985). Based on emergent patterns and themes, several factors were identified as being important considerations in promoting the integration of historical and cultural contexts when planning for and delivering mathematics and science instruction.

5. Findings:

5.1 Search for Meaning:

In order to understand pre-service teachers' prior understanding, knowledge, and experience relative to teaching and learning mathematics and science contents embedded in historical and cultural contexts, in the beginning of each semester I ask three questions: 1) What have you known and experienced regarding teaching/learning mathematics and/or science from cultural and historical perspectives? 2) Is it important to teach/learn mathematics and/or science within cultural and historical contexts? Why or why not? 3) What do you hope to learn in this class? Regarding the first question, most pre-service teachers in this study and in other years indicated little or no

knowledge and experience regarding teaching or learning from these perspectives such as, “I do not have much knowledge and backgrounds but I’d like to learn.” Or, “Never knew anything about my culture. I just knew I came from a bad neighborhood where education was not valued.” Or, “I know very little about the history of math.” Or, “Not a whole lot, just a few famous scientists & mathematicians and where they were from.” Or, “In one of my college classes we talked a little about giving culturally relevant examples in math class but that is about it” (Pre-service Teachers’ Written Responses).
Relative to the second question, almost all of the pre-service teacher participants mentioned that integration of culture and history would make their mathematics or science lessons more meaningful to their students such as, “Yes, it may peak [*sic*] more students’ curiosity.” Or, “Yes, I guess. First, the history is definitely important. Knowing the roots of any subject helps to understand it as a whole. Secondly, culture. I have no opinion.” Or, “Yes, teaching math in a cultural context allows us to connect with multicultural students, those from diverse backgrounds and to educate ‘mainstream culture students’ about other ways of life teaching.” Or, “I don’t know much about it. I’m hoping to learn” (Pre-service Teachers’ Written Responses).

In responding to the third question, most pre-service teachers indicated their desire to learn and understand strategies incorporating history and culture into their lesson plans and instruction, such as “I want to see examples of how to integrate cultural and historical perspectives into my classroom given the limited time and high expectations.” Or, “I’d like to learn why it’s important and how to accomplish teaching math or science from this perspective” (Pre-service Teachers’ Written Responses).

As the semester continued, the participating pre-service teachers’ perspectives evolved as demonstrated by their purposeful reflections on various readings, classroom discussions, and activities. The following sections describe the pre-service teachers’ stated views on the importance of critical reflections on teaching and learning mathematics and science, pre-service teachers’ realizations, and challenges of integrating historical and cultural contexts in mathematics and science contents, discussion, and concluding remarks.

5.2 Importance of Critical Reflections for Teaching and Learning:

Because reflection is an important tool in the repertoire of any good teacher, we cannot underestimate the power and influence of critical reflections on reading assignments and classroom discussions on pre-service teachers’ perspectives. As the pre-service teachers delved into critical reflections and expressed their thoughts and views openly and freely, they became observers of themselves. They made what was previously invisible to them more visible and tangible. One intern shared the following in a written reflection:

> Prior to beginning this course, I had not given much thought to teaching math from a historical or cultural perspective. I had heard about giving culturally relevant examples in math class: for instance, designing word problems to include situations that my students may experience in their day-to-day lives. That was the extent to which math and culture were intertwined in my mind. However, as I progressed in this course, I learned that there is much more to be said about teaching math from a cultural and historical perspective. I learned that teaching

> math from a cultural perspective does not just mean substituting culturally acceptable names into a word problem: it is a much broader and all-encompassing idea, which includes allowing students a window into the development and fluidity of mathematical ideas. My understanding of teaching math from a historical and cultural perspective was shaped throughout my time in this course, in particular by the literature I read throughout the semester. My critical reflections on these readings and the classroom discussions that we had brought me to several realizations about what it means to teach from a historical lens. This course has allowed me to confront my concerns about teaching from cultural and historical perspectives, and has given me some ideas about how my students might benefit from math through such viewpoints. (Pre-service Teacher's Final Written Reflection)

By emancipating themselves from being evaluated by their instructor or by their peers, the pre-service teachers were able to deconstruct their previous views and reconstruct their new ideas. For example, another intern presented his perspective on the value of reflection: "Without the critical reflections, I may have never noticed the issues of my teaching approach and find solutions to problems that I will most likely face in the future. In other words, these reflections have helped me plan ahead for my career and have been invaluable" (Pre-service Teacher's Final Written Reflection). Thinking critically not only on readings and class discussions but also on the lesson plan and presentation was significant.

All participating pre-service teachers agreed that, if the approach was implemented carefully, thoughtfully, and purposefully, high school students would benefit from learning mathematics and science contents from historical and cultural perspectives. One such benefit mentioned by pre-service teachers is students' heightened motivation to learn. Another benefit that interns mentioned is that it gives their students from different cultures a way to identify and celebrate their cultural contributions to the topics. "In my Algebra I class, my kids asked 'who came up with this, anyways?' and I had the chance to tell them a brief history of Algebra, and how it was an Arabic invention. One of my students who happened to be Arabic proudly claimed 'no wonder I'm so good at it'" (Pre-service Teacher's Classroom Presentation). Another pre-service teacher discussed how her mini-lesson on history and culture to students who were struggling with mathematical notations and expressions increased their interest and persistence in problem solving. "By having this kind of information readily available when students show curiosity, I was able to get them engaged fairly quickly, and they surprised themselves by doing math that they thought was way beyond them" (Pre-service Teacher's Classroom Presentation). Pre- service teachers were convinced that teaching mathematics and science contents in contexts would engage and deepen their students' understanding as they begin to perceive mathematics and science as a living, changing body of contributions and ideas. Pre-service teachers stated teaching contents in contexts improved their students' self-efficacy, because students feel that, just as individuals before them struggled with concepts to arrive at mathematical or scientific solutions, they, too, can overcome their struggles.

5.3 Teachers' Realizations:

1. Marginalization. The notion of how marginalized non-western, non-white, and non-male contributions to mathematics and science are in western society emerged several times during the class discussions. During a class discussion, one pre-service teacher commented:

> One realization I made is that young women do need particular attention when teaching math and science. I found that it makes a difference to them if they feel included in the subjects. For example, scientists such as Marie Curie and Rosalind Franklin contributed so much to our current understanding of science, and it is a disservice to young women to ignore contributions of women in a high school science classroom" (Pre-service Teacher's Classroom Discussion).

In addition, another pre-service teacher stated: "The most prominent realization is that mathematics and science did not start from Greece. If we look around carefully for evidence, we find contributions of many people from many cultures" (Pre-service Teacher's Classroom Discussion). The pre-service teachers showed that they had begun to appreciate how much a historical and a cultural context can play a role in scientific understanding.

2. Prior Experience. A second realization that pre-service teachers mentioned during class discussions was that they do not recall learning mathematics or science contents embedded in historical and cultural contexts when they were in middle school or high school. "No one in this class indicate that they learned about these ideas in their middle school or high school, but everyone said that it would have been a useful tool to learn" (Pre-service Teacher's Classroom Discussion). Limited prior experience in teaching and learning mathematics and science combined with limited viable resources (i.e., adequate textbooks) connecting contents and contexts put many participating pre-service teachers in difficult situations while developing and implementing meaningful lesson plans during their student-teaching. "Anybody can put together a lesson plan, but it's the once [*sic*] who takes the time to understand the background behind the lesson that are the most passionate about what they teach" (Pre-service Teacher's Classroom Discussion). Too often, teachers shy away from including history and culture in their teaching mathematics and science because they do not know how. This lack of knowledge and experience implementing history and cultural in mathematics and science classrooms limits learning opportunities for all students. Even when teachers do attempt to provide historical context in their lesson planning and implementation, it is often pseudo- or quasi-history (Matthews, 2014). Unfortunately, this is the extent to which most teachers go when using history and culture for teaching. Classroom discussions yielded many comments regarding the limitations of teachers' knowledge on how to implement history and culture in mathematics and science contents and make them interesting and engaging for the students.

3. Change in Epistemology and Constructivism. Several pre-service teachers discussed changes in epistemology and the notion of constructivism as a way of knowing and understanding mathematics and science. For example. One pre-service teacher stated:

> I believe strongly in a constructivist, problem-based, inquiry approach to teaching science. I find that adding historical and cultural components to my lessons will only serve to strengthen student comprehension and growth, as it brings command, application, and self-efficacy of student-centered learning to new heights. (Pre-service Teacher's Classroom Presentation)

Constructivism asserts that understanding is an activity of the learner. It places the learner at the center of the activity and the teacher as a facilitator of learning. Thus, understanding is built by the learner from his/her experiences as they participate in and contribute to the mathematics or science activities:

> When I first had the idea of teaching mathematics, I was set on teaching the basics, formulas, and everything else that math has to offer. I was very narrow-minded in that regard because that is how I was taught throughout my academic career. But after taking many educational classes, specifically this one, my mind has broadened. (Pre-service Teacher's Classroom Presentation)

From a constructivist perspective many pre-service teachers mentioned obstacles they faced as they tried to integrate the history and culture into their lesson plans and implementations. Overcoming these obstacles certainly required creativity and change in epistemology. In addition, all pre-service teachers mentioned that they need adequate mathematics and science textbooks for teaching the state mandated standards in relevant contexts. They mentioned that they need more authentic teaching models regarding how to integrate history and culture meaningfully in their mathematics and science contents.

5.4 Challenges of Teaching from Cultural and Historical Perspectives:

Typically, teachers plan their lessons by going through prescribed steps such as consulting and citing the state standards, finding suitable activities, handouts, etc. Very few teachers consider the cultural and historical contexts of the contents. As one intern put it:

> I have found through many aspects of this course that I cannot determine how a student will be impacted, or how a student might change as I teach from a cultural and historical perspective. However, I have accepted this, and understand that as a teacher it is not my duty, nor within my power to know how students will react, and interact. With that being said, I can only create a lesson that is conducive to initiate change, growth, and development. (Pre-service Teacher's Final Written Reflection)

1. Notion of Time. The pre-service teachers articulated their concerns, struggles, obstacles, and questions relative to teaching mathematics and science from historical and cultural perspectives, such as the notion of time to prepare and implement lessons from these perspectives:

> I am still struggling with how to incorporate historical and cultural perspectives in a lesson plan, when I do not even have time to present the bare minimum in terms of mandated standards sit before us. I feel as if I am in a constant state of 'catching up' when it comes to teaching a particular lesson. (Classroom Discussions)

Connected to the notion of time is meaningful implementation of a lesson within 50 minutes of instructional time. "My biggest concern and hurdle is how to take a historical or cultural issue and making it relatable or interesting to a group of students living in poor communities" (Classroom Discussions)

2. State Mandated Standards and Standardized Tests. The pre-service teachers repeatedly mentioned throughout the semester the pressure deriving from state mandated standards and standardized tests. **"**When it comes to Common Core Standards, the history of mathematics or science is not a part of those standards and can't take up too much of class time trying to explain" (Classroom Discussions). Another pre-service teacher expressed a similar thought. "As a teacher, my hands are tied by the standards that are mandated by the state, and it is frustrating that the people calling the shots typically have little to no experience in the classroom" (Classroom Discussions).

Teachers and many schools today face a huge dilemma between presenting important mathematics and science that students need to know and preparing students for material specifically for state mandated tests. Because teachers and schools are judged based on their students' performance on those tests, the tests have a great influence on how teachers allocate instructional time. Most teachers are forced to teach to the tests. However, some of the pre-service teachers were convinced that, despite all these limitations, they can and will transform their curriculum planning and instructions by incorporating history and culture into the classroom activities:

> I believe if something is important to me as a teacher, then I will make time to do it. If incorporating history into my lessons and activities is truly important to me, I will find a way to integrate it in a way that support the standards and does not cut into my limited time. I am 100% committed to making significant changes to my math curriculum in order to incorporate historical and cultural perspectives. (Classroom Discussions)

3. Technology. Pre-service teachers also expressed concerns about access and equity regarding the availability of technology such as computers and smartboards in mathematics and science classrooms. Such constraints limit meaningful learning opportunities for all students in this technological society. This limitation has implications regarding social justice. "Technology has changed the way we think and learn, so as educators we must adjust to accommodate for the young minds we are educating. Unfortunately, inner city schools don't have adequate resources to educate youth" (Pre-service Teacher's Final Written Reflection).

4. Science and Religion. Participating teachers discussed the challenge of the conflict between science teaching and religion, particularly on the topic of evolution. Discussions emerged several times in the classroom by the participants relative to using strategies for solving is type of problems in the classroom. Some participating teachers believed that they should take a non-confrontational approach to this sensitive issue.

> I think at this point I will just teach what employers want to be taught at their schools. I realize that certain topics such as evolution, science and religion are still considered 'Taboo'. Therefore, they should be carefully navigated and if possible should be avoided. (Classroom Discussions)

Another participating teacher agreed with this non-confrontational approach by saying:

> In schools, there's a separation of church and state, so do I continue to elaborate when students have questions or do I discard the questions and say that 'this is not a part of your standards, therefore, we must not discuss it?' Till this day, I have not addressed this concern. I avoid touchy subjects because I do not want my students to be uncomfortable or create a cognitive conflict between their own views and what's scientifically proven. (Classroom Discussions)

Yet, some participating teachers challenged the non-confrontational approach by suggesting that, instead of avoiding and/or ignoring this situation, they must face the issue and reconstruct it with their students:

> I have one student in particular who despite understanding the evidence and recognizing its validity, still refuses to accept evolution as a reality. Her rationale is entirely theological. I am uncomfortable with allowing a student to miss out on such an important theory. As such, I was able to differentiate instruction to spend some time working with her so that I could learn her perspective. It is still work in progress. (Classroom Discussions)

Another pre-service teacher, in agreeing with such an approach, mentioned that, when students raise this type of sensitive question, teachers need to be prepared to respond to their questions thoughtfully. "As a teacher I owe it to my students" (Classroom Discussions).

5.5 Discussions of course textbooks:

The two texts served as an opener for reflections and classroom discussions at the beginning of each class. Roughly speaking, we would spend the first hour of each class session for small group interactions and whole class discussions of various issues relative to the reading assignments. All pre-service mathematics and science teachers expressed their enjoyment and appreciation of the mathematics textbook. Throughout the semester they mentioned how practical the text was in their own classroom teaching and that they had gained many insights as to how to incorporate history and culture for teaching mathematics. However, not many mathematics and science pre-service teachers reported having liked the science textbook. Many times during class discussions, pre-service teachers expressed that "the author is biased and very opinionated," or "the book is cut, dry, and boring," or "mostly his perspectives are not applicable and practical in the context of the U.S. public high schools," or "I was disappointed to see that the author mostly focused on the philosophy of science rather than history and culture, so it was not useful for my day-to-day classroom teaching science" (Classroom Discussions). Some Pre-service teachers even mentioned how

frustrated, angry, and offended they were as they read Matthews' perspectives relative to Islam and Muslims. "In his book he presents us [Muslims] like terrorists. He is ignorant of our faith. He even spells Quran incorrectly with capital K" (Classroom Discussions).

In contrast, some pre-service teachers liked the science book. "I like the book not because of the author's perspective but because of our critical reflections and discussions of what Matthews has to offer. For that reason, I think the book was constructive and useful" (Classroom Discussions). Critical reflections and classroom discussions afforded the pre-service teachers the occasions to deconstruct and reconstruct their own meaning. They critiqued the text and analyzed their thoughts. Grundy (1991) explains this transformative process:

> Moving from being uncritical to critical, from being ahistorical to a subject who sees his/her work within an historical framework, requires, not growth, but transformation of consciousness. This is not a process of steady development, but a transformation which might best be called professionalization. This does not imply a spontaneous transformation from constrained to liberated subject. Rather, it is a process of transformation in which knowledge and action are dialectically related through the mediation of critical reflection. (Grundy, 1991, p. 191)

This professional metamorphosis was one of the important realizations presented by the pre-service teachers during the course of the study. One participating teacher's reflection summarizes the process:

> I became aware of the fact that the idea of an effective classroom is not for all students to have the same outcomes, but more so to create an environment that is friendly, welcoming, and full of historical and cultural aspects that celebrates students' diverse backgrounds, and ultimately creates an equitable learning community. (Pre-service Teacher's Final Written Reflection)

Pre-service teachers became more critical of mathematics and science textbooks written from ahistorical perspectives. Their insights became broader, deeper, and more mature as they continued to engage in reflective processes.

6. Conclusions, Implications, and Recommendations:

Primarily, the biggest issue teachers have with integrating historical and cultural constructs into their teaching is the strict expectation of adherence to standards frequently set by district, state, and national education agendas. As a continuing trend in education, many schools persist in emphasizing the importance of high marks on standardized tests, and, with this as the primary focus, schools set their standards and develop curriculum in attempts to maximize test score results. Clearly, integrating cultural and historical aspects of mathematics and science into curriculum that has already been set by schools might not be the most acceptable way to teach students. Administrators may have issues with this approach and in fact might find it to be too time-consuming, with such a wide breadth of materials to "cover." Similarly, incorporating history and culture into a mathematics or science lesson might be very

time-consuming for teachers in two ways--time for researching the topic and planning, and time for instruction and implementation. In addition, lack of adequate textbooks and technology put the teachers in difficult situations for teaching contents in relevant contexts. One participating pre-service teacher summed up the challenges of teaching mathematics and science contents embedded in historical and cultural contexts by saying:

> With all of these issues such as high stakes assessments, pressure from administration, lack of time and resources, varying student achievement I have come to the conclusion, with much ease, that teaching with history and culture in mind to create a strong, student-centered environment is well worth these troubles. (Pre-service Teacher's Final Written Reflection)

Incorporation of historical and cultural context in teaching and learning mathematics and science is important for two reasons. First, the result of promoting reflectivity in pre-service teachers has been under continuous examination for several years and continues to be an essential component of teacher development. Second, cultural contextualization as part of the practice of constructivism is more than a teaching strategy but rather an essential component of praxis (i.e., action and reflection).

Many pre-service teachers have not experienced this approach in their own education and are not likely to implement it unless they are presented with models like the one presented in this research paper in their college courses combined with clinical teaching in public schools. A growing concern in the educational community is that students are losing the ability to create, develop, test, and ultimately think abstractly about mathematics and science contents (Martin, 2006). Incorporating the engaging stories of mathematicians and scientists alike will elicit students' intrinsic curiosity along with a newfound drive to think critically, with new vigor. Furthermore, teaching with history and culture incorporated into the curriculum will challenge students to confront their own internal struggles with differences in the diverse backgrounds of each student in the classroom. Kragh (1992) asserts that this integration is necessary.

> In an educational context, history will necessarily have to be incorporated in a pragmatic, more or less edited way. There is nothing illegitimate in a pragmatic, more or less edited way. There is nothing illegitimate in such pragmatic use of historical data so long as it does not serve ideological purposes or violate knowledge of what actually happened. (p. 360)

In integrating the robust history and culture of mathematics and science, teachers can stimulate a learning environment that celebrates diversity and ultimately promotes positive personal growth and development for all students and teachers. "Historical investigation not only promotes the understanding of that which is now, but also bring new possibilities before us" (Mach, 1996, p. 316). In addition, teaching it from this perspective may forge a strong bond between teacher and students. This caring relationship between teacher and students can be crucial in creating learning processes for success in any avenue of life. The past six years as an instructor of the course have provided me with an enjoyable and inspiring journey. As a teacher educator, I am

hoping to shape the future by educating teachers to develop agency in themselves and in their students. My belief in the importance of teaching and learning mathematics and science contents in relevant historical and cultural contexts has been confirmed by observing my pre-service teachers' passion for using this approach for teaching.

It is interesting to observe that most interns selected their historical topics other than their own sociocultural and socio-historical experience. For example, interns with Middle Eastern backgrounds selected historical topics relative to contributions of African American people. African American interns, Asian interns, interns with East European background, and female interns, all selected topics relevant and connected to other people cultural and social activities. They crossed the boundaries of their own familiar cultural and historical contexts in order to meet the needs of diverse students, and their approach has been a transformative experience for me to observe. The growth of my pre-service teachers in terms of their caring attitudes about their praxis, their students, and the focus on empowering their students marks a professional transformation that has helped them to begin making their road by walking.

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