

PERSPECTIVES ON TEACHING MATHEMATICS AND SCIENCE IN HISTORICAL AND CULTURAL CONTEXTS

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This qualitative and descriptive study examines the evolution of secondary preservice teachers' views on teaching and learning mathematics and science in historical and cultural contexts. Data were collected throughout participants' enrollment in a semester-long course entitled, Perspectives on Science and Mathematics, which is taken in conjunction with student teaching. Data sources included university classroom observations and field notes as well as preservice teachers' verbal and written responses to class discussions, reading assignments, and course activities. Common themes and categories of response were derived from the triangulation of data to include prospective teachers' critical reflections on teaching and learning. The paper ends with a discussion of findings and concluding remarks.

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Introduction

Mathematics and science are dynamic studies of patterns and relationships that evolve as people participate in and contribute to cultural and historical activities (Wheatley & Reynolds, 1999). "It is estimated that 95% of mathematics known today has been produced since 1900" (Berlinghoff & Gouvea, 2004, p. 53). Since mathematics and science are connected to people's culture and history, many educators are convinced that the teaching and learning of these disciplines can be made more relevant and meaningful to learners if embedded in context. As a consequence, increased attention has lately been given the study of ethnomathematics and its role in helping to clarify the nature and development of mathematical knowledge (Ascher, 1994; Bishop, 1991; D'ambrosio, 2001; Frankenstein, 1995; Nunez, 1992; Orey & Rosa, 2001).

Broadly defined, ethnomathematics involves the integrated study of relationships among mathematics, culture, and history. Its classroom application is predicated on the belief that students' understanding and appreciation of mathematics and science will be enhanced when content is presented in relevant contexts. Support for this idea stems from research which indicates 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).

Presumably, teachers' understanding of what comprises mathematics and science may exert a strong influence on the ways in which they think, reflect, plan, teach, and provide opportunities for their students to learn these subjects. The National Council of Teachers of Mathematics (NCTM, 2000, 1991, 1989) holds that mathematics and science are something people do. They have broad contents encompassing many fields that need to be at the command of all students in a technological society. "Mathematics [and science] are the greatest cultural and intellectual achievements of human kind, and citizens should develop an appreciation and understanding of that achievement" (NCTM, 2000, p. 4).

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., preservice secondary mathematics and science teachers' views on teaching and learning mathematical and scientific content as embedded in the historical and cultural context of a state-supported, urban,

university located in Midwestern America). Data sources include university classroom observations and field notes as well as preservice teachers' verbal and written responses to class discussions, reading assignments, and course activities. 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. 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.

All participants in this study were enrolled in a course entitled *Perspectives on Science and Mathematics*. Taken concurrently with student teaching, the design and content of this course has been influenced by work of two curriculum theorists—Doll's (1993) *A Post-Modern Perspective on Curriculum* and Grundy's (1989) *Curriculum: Product or Praxis*. Briefly, 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 continues 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) maintains that

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, course assignments and activities were developed with the qualified hope that preservice teachers would make their own roads by walking them (Horton & Freire, 1990)—autonomously finding creative and meaningful ways to design, develop, and implement lesson plans based on the pedagogical premises of ethnomathematics.

Importance of Critical Reflections for Teaching and Learning

Reflection is an important tool in the repertoire of any good teacher. The power and influence of critically reflecting on reading assignments, classroom discussions, and activities cannot be underestimated. As the preservice teachers who participated in this study delved into critical reflections and expressed their thoughts and views openly and freely, they became more observant of their own practice. They made what were previously obscure connections more visible and tangible. In addition, by emancipating themselves from being evaluated by the instructor or by their peers, they were able to deconstruct their previous views and reconstruct their new ideas. For example, in a final written reflection, one preservice teacher noted,

Without the critical reflections, I may have never noticed the issues of my teaching approach or found 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.

Thinking critically, not only on readings and class discussions, but also on lesson planning and presentations, played a vital role in enhancing teaching performance.

All participating preservice teachers agreed that if implemented carefully, thoughtfully, and purposefully, high school students would benefit from learning mathematics and science content from historical and cultural perspectives. One such benefit mentioned by the preservice teachers was student motivation to learn. Another benefit mentioned by interns was the opportunity such study provides for students to celebrate their respective cultures' contributions to science and mathematics. Take for instance this preservice teacher's comment:

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.

Another preservice teacher had this to say about how a mini-lesson she presented 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.” In short, preservice teachers were convinced that teaching mathematics and science in cultural and/or historic context would engage and deepen their students’ understanding as they begin to perceive mathematics and science as a living, changing body of contributions and ideas. Preservice teachers felt that teaching content in context also led to an enhanced sense of self-efficacy as their students began to believe that they could overcome obstacles in solving problems just as mathematicians and scientists have done in the past.

Teachers’ Realizations

There were three emerging realizations expressed by preservice teachers throughout the semester, particularly during classroom discussions and dialogues. These three realizations were 1) the marginalization of the mathematic and scientific contributions of non-western, non-white, and non-male individuals, 2) the importance of acquiring the knowledge and background needed to teach mathematics and science from cultural and historical perspectives, and 3) the need for an epistemological change in the teaching and learning science and mathematics.

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 class discussions and dialogues. As one preservice teacher commented during a class discussion:

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.

In support of this perspective, still another preservice 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.” In short, as the course progressed, the preservice teachers began to appreciate how much a historical and a cultural context can play in understanding and appreciating scientific advances.

The second realization mentioned by preservice teachers during class discussions was that they personally had no recollection of ever studying mathematics or science from a historical or cultural perspective; albeit, everyone agreed that it would have been useful to do so. Generally speaking, teachers teach the way they were taught. Hence, for lack of exposure and insufficient background knowledge, most shy away from including history and culture in their teaching of mathematics and science. This lack of knowledge limits learning opportunities for all students. Even when teachers do attempt to provide a 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 incorporating history and culture in their teaching. Hence, teachers’ lack of existing knowledge was repeatedly identified as a major impediment to using the history and culture of as a means of engaging students in mathematics and science. On the other hand, as one preservice teacher

observed, “Anybody can put together a lesson plan, but it’s the teachers who take the time to understand the background behind their lessons that are the most passionate about what they teach.”

The third realization mentioned by several preservice teachers was a noted change in their own epistemological beliefs to include constructivism as a way of knowing and understanding mathematics and science. As one preservice teacher noted, “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.” 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 classroom activities in mathematics or science.

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. (Preservice Teachers Classroom Presentation)

From a constructivist perspective, many preservice teachers mentioned obstacles they faced as they tried to integrate history and culture into their lessons. Overcoming these obstacles certainly requires creativity and a change in epistemology. All preservice teachers mentioned that they needed to gain additional knowledge and experience in order to successfully integrate history and culture into their teaching of mathematics and science. They further recognized this as a virtuous goal that they have not fully achieved.

Challenges of Teaching from Cultural and Historical Perspectives

The preservice teachers who participated in this study expressed a variety of concerns, struggles, obstacles, and questions relative to teaching mathematics and science from historical and cultural perspectives. One such issue was the time it takes to prepare and implement lessons from these perspectives. As summarized by one student during a class discussion:

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 set before us. I feel as if I am in a constant state of ‘catching up’ when it comes to teaching a particular lesson.

Still another time-related matter mentioned by preservice teachers throughout the semester was the more formidable required adherence to 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). Similarly, as expressed by another preservice teacher, “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 in many schools today are faced with the daily dilemma in deciding how much attention to devote to important mathematics and science content that students need to know and knowledge and skills required to pass state-mandated tests. Teachers and schools are judged on their students’ performance on those tests. As a result, test content has a great influence on teachers’ instructional time. Most teachers are forced to teach to the tests. However, as evident in the following comment, some of the preservice teachers were convinced that with all these limitations they can and will transform their curriculum planning and instruction by incorporating history and culture into 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 supports 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)

Access and equity in mathematics and science classrooms with respect to the availability of technology such as computers and smartboards for teaching and learning was another dilemma and concern expressed by several preservice teachers. This constraint limits meaningful learning opportunities for all students in this technological society. This limitation has a social justice implication. “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” (Preservice Teacher’s Final Written Reflection). Yet another expressed concern was finding ways to engage urban youth. As expressed by one participant, “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.”

A particular challenge mentioned by preservice biology teachers was the conflict between science teaching and religious beliefs, particularly on the topic of evolution. Dialogues emerged several times in the classroom relative to using strategies for solving this type of problem. Some participants 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 Dialogues)

Another participant 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 Dialogues)

Some participating teachers challenged this non-confrontational approach by suggesting that instead of avoiding and/or ignoring this situation, they must confront 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 Dialogues)

Another preservice teacher agreed with this approach. He mentioned that when students raise sensitive questions, teachers need to be prepared to respond thoughtfully. He said, “As a teacher I owe it to my students” (Classroom Dialogues).

Discussion

Professional transformation was one of the important realizations achieved by the preservice teachers who participated in this study. Other realizations included 1) the marginalization of non-western, non-white, and non-male contributions to science and mathematics; 2) teachers’ lack of necessary knowledge and background experience for teaching mathematics and science from cultural and historical perspectives, and 3) a needed change in epistemology. Summarizing the impact of the

course on professional development, one preservice teacher wrote, “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 celebrate students’ diverse backgrounds, and ultimately creates an equitable learning community.” As the preservice teachers engaged in reflective processes, they became better communicators and demonstrated their growth in critical thinking. In addition, as they prepared lessons and presented them to their peers in the university classroom and shared some of their high school teaching experiences, they showed a great deal of professionalism relative to teaching and learning mathematic and scientific content embedded in historical and cultural contexts.

Primarily, the biggest issue teachers have with ethnomathematic and ethnoscientific teaching is the strict standards that are often set by school districts, states, and nationwide education agendas. As a continuing trend in education, schools continue to urge the importance of high marks on standardized tests, and with this as the primary focus, schools set their standards and develop curriculum to maximize test score results. Clearly, teaching the cultural and historical aspects of mathematics and science along with curriculum that has already been set by schools might be deemed unacceptable or a waste of time by some. Given an increasingly wide breadth of material to “cover,” administrators may have issues with this approach and, in fact, find it to be too time consuming. Similarly, incorporating history and culture into a mathematics or science lesson might prove a daunting task for teachers in both the time needed for researching and planning such lessons as well as the extra time needed for instructional delivery. Despite these obstacles, participants felt the added effort was worthwhile as evidenced in this preservice teacher’s final written reflection:

With all of these issues such as high stakes assessments, pressure from administration, lack of time and resources, and 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.

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 content. By incorporating the incredible stories of mathematicians and scientists alike, teachers will elicit an intrinsic curiosity among students and a newfound drive to think critically. Furthermore, teaching with history and culture incorporated into the curriculum will challenge students to confront their own internal struggles with individuality and diversity. As Kragh (1992) put it:

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 violates knowledge of what actually happened. (p. 360)

In using the robust history and culture of mathematics and science, teachers can create a learning environment that celebrates individual differences and ultimately promotes positive personal growth and development for all students. “Historical investigations not only promote the understanding of that which is now, but also bring new possibilities before us” (Mach, 1996, p. 316). In addition, teaching from this perspective may help establish a stronger bond between teachers and students. This caring relationship is crucial to the learning process.

Closing on a more personal note, I would simply note that while teaching *Perspectives on Science and Mathematics* for the past six years, it has been a transformative experience to observe the growth of my preservice teachers in terms of their attitudes and professed commitment for teaching and learning mathematics and science in historical and cultural contexts. Their professional transformation has, I believe, helped the interns to begin making their own roads by walking.

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