Re-membering Mathematics:
The Effect of Culturally Relevant Lessons in Math History on Students' Attitudes

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Abstract

This study examined the effect of math history lessons (which focused on the accomplishments of Latin American, African, African-American, and Middle Eastern individuals) on the attitudes of fifteen students enrolled in an Algebra 2 class at a predominantly African-American high school. Qualitative data taken during interviews with the participants showed some important subtle changes in the way they viewed their success in math, the usefulness of math, and the role of race in determining mathematical success. The effect of the lessons was analyzed according to three pedagogical theories: situated cognition, role model development, and culturally relevant pedagogy.

Introduction and Review of Literature

Description of the Problem

Students from some oppressed racial backgrounds in modern US classrooms are (on average) experiencing disconnection from their mathematics classes. This phenomenon is evident in the gap in achievement between African-American, Native American, and Latino students with their White counterparts, as well as through other measures of student engagement- such as rates of enrollment in advanced courses, rates of absences from math courses, and student reactions to their classes and teachers (Lloyd, 2001; Peng, Wright, & Hill, 1995; Thomas, 2000). Students from these racial backgrounds tend to perceive math as lacking of relevance to their lives and disconnected from their outside-of-class goals (Presmeg, 1998).

Additionally, students from these cultural backgrounds are less likely than White students to have role models who have succeeded in math or math-related fields. Further evidence for this phenomenon can be seen in the tendency of many students to view mathematics as "a discipline only suited for White students" (Moody, 2004, p. 135).

The National Council of Teachers of Mathematics has recognized these disturbing trends. In the latest version of *Principles and Standards for School Mathematics* (2000), the authors listed equity first among their six guiding principles for school mathematics. Crucial to the equity principle, is a language of "accommodating difference" amongst mathematics learners (p. 13). In this document NCTM has sought to redefine the equitable mathematics classroom as one in which "reasonable and appropriate accommodations" are made to support the development of all students' mathematical capabilities, instead of one which forces students to adapt to prescribed learning styles in order to achieve success in math (p. 12). The NCTM (2000) document challenges educators to find new and innovative ways to reach underserved students in their classrooms (Trafton, Reys, & Wasman, 2001).

Some have attributed the disconnection experienced by African-American, Native American, and Latino students from mathematics to the failure of traditional curriculum to appeal to these cultures (Frankenstein, 1990; Lloyd, 2001). Students from these racial groups in math classes tend to experience "cultural conflict" or "cultural dissonance" as a result of lessons that they perceive to be contributing to the marginalization of their own home cultures while promoting the acceptance of dominant cultural norms (Bishop, 2001, p. 26). Alienating curricula play a role in promoting a perception among some groups of non-White students that equates academic success (especially in mathematics) to "selling out" or "acting white" (Collins-Eaglin & Karabenick, 1993, p. 3).

Appeals to Students' Cultures

One attempt at transforming the traditional mathematics curriculum so that it might be more effective in reaching students from non-dominant cultural backgrounds is known as culturally relevant pedagogy. Culturally relevant lessons appeal to students from diverse cultures by utilizing cultural referents and/or traditional learning styles of students from oppressed backgrounds (Wagner, Ray, Ecatoiu, & Rousseau, 2000). Not all lessons that utilize a students' home culture are considered "culturally relevant"; rather, these lessons must also meet the following criteria: "a) Students must experience success; b) students must develop and/or maintain cultural competence; and c) students must develop a critical consciousness through which they challenge the status quo of the current social order" (p. 160).

Many mathematicians, math teachers, and math students possess "only a limited understanding of what and how [cultural] values are being transmitted" through the discipline (Bishop, 2001, p. 24). Culturally relevant math lessons work against this ignorance by reversing the trend in traditional mathematics curricula to divorce mathematics from its cultural roots. They promote honest analysis of math's cultural influence by explicitly appealing to the ways in which mathematical ideas are continuously developing under the influence of cultural expectations and assumptions, as well as the ways in which mathematics classrooms can be used to promote inequity and intolerance (Adam, Alangui, & Barton, 2003).

The successes of innovative lessons that appeal to diverse cultures in improving students' attitudes towards classroom subject matter have been well documented. Ladson-Billings (1995) performed a three-year study in which she profiled nine successful teachers of African-American students in nine different elementary and middle schools. These teachers were selected for the study on the basis of student achievement as well as recommendations by administrators, parents, and students. Though she did not find "similarities in their teaching" as she had expected, Ladson-Billings discovered common ground in the "the philosophical and ideological underpinnings" of each teacher (p. 162). All the teachers took the direction for their lessons from their strong relationships with their students, developing lessons that incorporated the knowledge students gained from their lives outside of class and showing value for students' home cultures and languages. Ladson-Billings (1995) describes the way that each teacher utilized the culture of the students in their classes while teaching high quality lessons. For example, Gertrude Winston welcomed students' cultures into her fifth grade classroom by recruiting a diverse group of parent volunteers to teach about the skills that they used in their daily lives. The "artists or craftspeople in residence" came for 1 to 2 hours and taught about diverse skills including carpentry, playing basketball, and baking (p. 161). Winston built on each visit by connecting the skills taught by parents to the science, history, math, and language arts lessons the students were studying. Ladson-Billings details how the cultural appeals made by Ms. Winston and the other teachers who took part in the study positively influenced student test scores, engagement in the classroom community, and overall attitude towards school and learning (Ladson-Billings, 1995).

Lloyd (2001) conducted a five-year study that "aimed to show teachers alternative classroom practices to better meet the needs of students," particularly students from oppressed racial backgrounds, in science and math (p. 2). The focus of her work involved encouraging schools to promote the learning of all students through lessons that showed connections between "science and math and students' lives" (p. 15).

Lloyd (2001) concluded that one of the most important factors in improving the attitudes of students toward school was the degree to which administrators and teachers in the school were "risk-takers" (p. 16). The most successful educators were those who more fully embraced innovative and culturally relevant lessons. Students interviewed for this study focused on the skill of their teachers in engaging them as the most important factor affecting their attitude towards the class. Students in classes where lessons were not explicitly connected to their lives were much more likely to have a negative attitude towards their math and science classes than students whose teachers "put science [or math] in the world" (p. 13).

The Algebra Project, an initiative to improve the access of low-income African-American students to high quality algebra curricula, gives another example of a program that successfully integrates cultural relevance with innovative pedagogy to produce positive results in student achievement and engagement. The project, which was developed by civil rights activist Robert Moses, has been implemented in both rural and urban areas with great success. Through the program's integrative approach, students begin to feel a connection to the material (Davis & West, 2000, p. 2). The high level of engagement that the program develops is evident in comments like this one from David, a thirteen year old Algebra Project participant from Weldon, North Carolina: "I'm a math literacy worker. I speak math. I do math. I work with math," (Moses & Cobb, 2001, p. 192). The program achieves such success by working with educators and community members to develop lessons that are based on knowledge from the community. One such lesson in an Algebra Project school in Boston compared addition and subtraction of positive and negative numbers on the number line to traveling on the city's subway. Rather than ignoring or dismissing students' home cultures, Moses invited his eighth-grade students to bring their knowledge of the public transit system into the classroom in order to more deeply understand the ways in which addition and subtraction are analogous to this kind of straight line travel. In each Algebra Project community, educators, parents, and community members come together to find ways in which the specific cultural knowledge of members of that community can be incorporated in the teaching of algebraic concepts (Moses and Cobb, 2001).

The Case for Math History

One specific cultural referent available to educators who want to create culturally relevant math lessons is the history of the discipline. Lessons on the major events that helped form "mathematics" as a subject and the individuals who contributed to those events can meet the criteria and goals of culturally relevant pedagogy (Furinghetti, 1997).

Teaching math history serves students by "humanizing" the discipline, making the topics more accessible by connecting them to individuals and individuals' experiences (Bartolome, 1994, p. 173). Knowledge of math's history helps students understand the logical thinking patterns behind the discipline, these students tend to possess a deeper understanding of the material (Bartolome, 1994). In addition to deeper conceptual understanding, students who learn about the human component of the creation of math systems show signs of improvement on attitude scales (McBride and Rollins, 1977).

Furinghetti (1997) used a case study approach to analyze math history lessons taught in four European secondary and university classrooms. The students in the sample came from a variety of backgrounds, and historical concepts were integrated differently in each case. The teachers used research projects, references in lectures, and optional assignments to invite students to consider the history of the discipline and the role different groups of people have played in constructing the subject. Despite their different approaches, all four teachers reported the positive effect of these lessons on students' engagement in the class as a whole. Math history in each case helped develop more positive attitudes in students by showing "mathematics as powerful, accessible, connected, and evolving" (Wilson and Chauvot, 2000, p. 643).

Math History and Situated Cognition

Other researchers and psychologists have written about the benefits of "situated cognition," which works against "the functionalist belief in mind-body dualism" (Kirshner &Whitson, 1997, p. 4). This psychological theory recognizes the connections between individuals' ability to learn information and its connection to a specific "socio-cultural context" (Kirshner &Whitson, 1997, p. 4). By connecting math learning to the problems that have directed its development, educators can help students situate the learning of math concepts in the context from which the ideas developed.

Historically contextualized lessons have the added benefit of inviting the participation of modern learners to see themselves as part of the larger "community of practitioners" who have participated in the construction of mathematical ideas (Lave & Wenger, 1991). The extent to which students of color have internalized notions of mathematics as a field by and for White people suggests their deep disassociations from this community (Moody, 2004). Any survey of math history reveals the reality that individuals from Africa, Latin America, and the Middle East have made key contributions to the innovation of modern mathematical systems (Jones, 1989). This implies that the phenomenon of disassociation from mathematics observed in students from oppressed racial backgrounds is, in part, a result of dramatic oversights in the way students have come to understand math's development. Culturally relevant math history lessons can play a role in promoting a more positive attitude toward math in students who have an improved sense of the way math has developed "across generational boundaries" and the contexts that lead to those developments (Kirshner & Whitson, 1997, p. 5).

Math History and Critical Pedagogy

By emphasizing the role that non-White individuals have played in the creation of mathematics, math history lessons can challenge the way students have traditionally understood mathematical thinking. These lessons can meet the goals of culturally relevant pedagogy by encouraging students to critique the traditional way in which the history of the discipline has been constructed (Frankenstein, 1990). This approach draws on the idea of "critical pedagogy," based on the work of Paulo Friere (2000) and many African-Americans who taught during the civil rights era of the 1960's. These educators established a new way of thinking about the goal of education: not only did they believe that their lessons should empower individuals to achieve success, they saw education as an avenue of group empowerment that would lead to the dramatic restructuring of society's inequitable institutions (Ladson-Billings, 1995).

Math history lessons that address the goals of critical pedagogy will encourage students to ask questions about the roles racism and White supremacy have played in constructing a history that often omits contributions by people of color. By utilizing the diversity that exists in the discipline's history, math teachers can encourage critical thinking about the dominant culture by asking students to engage diverse cultures and examine the motivations behind institutional ignorance of those cultures (Alangui & Barton, 2003).

Math History and Role Model Development

Another consistent discovery in literature pertaining to the negative math attitudes of students from oppressed backgrounds is that relationships with adults who students want to emulate can play a role in encouraging stronger connections with school (Wolcott, 2001). In a study of students from Black Caribbean backgrounds in 13 British schools, Demie (2005) cited the development of role models who have achieved success in math and math related fields as one of the five most important features contributing to the promotion of positive attitudes toward the discipline. Wolcott (2001) detailed dramatic shifts in the attitudes of young women resulting from programs aimed at supplying them with role models with whom they were likely to identify in math and science related fields. Another study dealing with students who have experienced racial oppression found that one of the distinguishing characteristics between African American youth who became involved in gang activity and those who did not was the presence-or absence- of role models who had achieved success through academics (Taylor, Lerner, von Eye, Bobek, Balsano, Dowling, & Anderson, 2003).

Certainly, students' inability to interact with historical figures will limit the effectiveness of history lessons to appeal to the benefits associated with role model development; however, teachers can mediate against these limitations by presenting figures from history with whom students are more likely to identify culturally and providing them with ample opportunity to learn about the meaningful aspects of their lives. The overwhelming success of role model development in improving students' attitudes toward academics and school mathematics suggests that an important benefit of culturally relevant math history lessons would be to increase the number of personalities with which students interact, thus increasing the likelihood that students will develop role models who have experienced success in math (Jones, 1989).

Research Question

The research outlined above suggests that the act of re-membering mathematics--reconstituting math history to include the diverse individuals who have contributed to its construction-- can play a role in improving the attitudes of certain groups of students towards the discipline. The topic of this study stems from the goals of NCTM (2000) to reach out to students from underserved background, the success of culturally relevant classroom strategies in improving students' attitudes toward academics, and the links between math history and the cultures of oppressed racial and ethnic groups. It seeks to add to the growing body of research explaining the effects of lessons that use innovative teaching techniques to serve the increasingly diverse group of students attending schools in the US by exploring the following question: What are the effects of culturally relevant math history lessons on students' attitudes towards the discipline?

Methodology

This study explored the proposed question through three methods of data collection: open ended student interviews, classroom observation, and a five-question Likert scale survey. These data collection processes allowed the researchers to gain insight on the overall effect of math history lessons on students' attitudes as well as perspective on what aspects of those lessons were most effective for each participant. The sample size is too small to allow for highly generalizable conclusions based on quantitative data, but the qualitative analysis of students' reactions did provide valuable information for educators who are looking for ways to implement this type of lesson in their classroom.

Sample

Participants in this study were students in a non-honors level Algebra 2 class at a high school in central North Carolina with a majority African American student population. All the students in the class were recruited and only those who did not give their consent or missed more than two of the history lessons were excluded from participating. The final group of participants numbered fifteen. Ten of the participating students were African-American, three White, and two Latino. Seven of the participants were female and the rest were male.

This sample worked well for several reasons. First, all the students in the class had passed Algebra 1 and Geometry, so they had learned enough about math to make connections between historical topics covered in the lessons for the study and mathematical topics covered in those courses. Additionally, there were three racial groups represented in the class, and a majority of the students were non-White. These demographics allowed the researcher to analyze the reactions of students from a variety of different cultural backgrounds, while maintaining a focus on the reactions of students for whom the lessons were most culturally relevant.

In order to preserve the confidentiality of the participants, pseudonyms have been used throughout this paper whenever a student is mentioned.

Data Collection Process

The consenting students in the class participated in two individual interview sessions. During the interviews, students answered a series of open-ended and Likert scale questions intended to gauge their attitude towards mathematics in one of three domain-specific scales. Two of these scales were taken directly from the work of Fennema and Sherman (1976) regarding gender differences in students' attitudes toward math. The first, the Attitude toward Success in Math scale was designed "to measure the degree to which students anticipate positive or negative consequences as a result of success in mathematics" (p. 325). Questions relating to this scale focused on understanding how students reacted to success in math and what factors they saw as playing a role in that success. The second attitude scale, entitled the Mathematics Usefulness Scale, was designed by Fennema and Sherman to "measure students' beliefs about the usefulness of mathematics currently and in relationship to their future education, vocation, or other activities" (p.326). The questions that were used to analyze students' attitudes in this domain focused on the relevance of mathematics to students' lives outside of the classroom.

The final scale used for this research is based on Fennema and Sherman's Mathematics as a Male Domain scale. The researchers created this scale in order to gauge "the degree to which students see mathematics as a male, neutral, or female domain" (p. 325). These researchers used this scale to do important work with regard to gendered assumptions about the relative ability of males and females in mathematics and attitudes of students toward the gendered conceptions about the appropriateness of advanced study in mathematics. Since our study was focused on the differences of students across racial divisions rather than gender divisions, this scale was modified to ascertain students' attitudes towards Mathematics as a White Domain. Study questions that measured students attitudes with regard to this scale involved understanding students' assumptions about the racial identities of those who developed mathematics as well as those who succeed in it today. Questions pertaining to this scale were modeled very closely on those of Fennema and Sherman's "Male Domain Scale". The scope and size of this study made it difficult to judge the validity and reliability of the modified scale for the purposes of data analysis. However, the scale was assumed to have acceptable reliability and validity because the scale and items used to measure it were so similar to the original Fennema and Sherman scale.

Each of the three scales was addressed in all sections of the data collection. Student comments during observations and interviews were coded according to which scale they addressed and the students' level on the scale based on her/his comment. The survey was composed of one question pertaining to students' "Attitude toward success in math" and two questions each on the other two scales.

Following the initial interview, the lead researcher taught a series of five lessons over a period of four weeks on the contributions to the development of mathematics of African, African-American, Latin American, and Middle Eastern individuals. The lesson series began by introducing the topic of math history as the study of the problems that arose through the daily experience of human beings in a hunter-gatherer setting, and progressed into some of the more modern problems that have challenged individuals in recent centuries. Below are the five lesson titles and a brief description of the major activities for each, the National Council of Teachers of Mathematics standard that the lesson addressed is listed at the end of each description (see appendix for a more detailed description of the lessons including some activities and the North Carolina Standard Course of Study Algebra 2 objective that the lesson met).

- Number Systems: Students discussed the need to express quantity in exact terms and how this need might have related to life early in human communities. They also discussed the evolution of numbers towards more exact quantities and great complexity). Finally, they examined one later number system developed by the Mayans and used systems of equations to determine what symbols in the Mayan system represent in the Arabic system. (NCTM (2000). Number and Operations Standard. Students should understand numbers, ways of representing numbers, relationships among numbers, and number systems.)
- African Engineering and the "Pythagorean" Theorem: Students took measurements as they constructed a stair-step pyramid. They used the measurements to write Pythagorean equations and verify the validity of the Pythagorean Theorem. They then wrote quadratic equations and inequalities which they could use to make predictions about the size of other pyramids. Students considered whether or not the Greeks were actually the first society to recognize this theorem about the sides of right triangles as the modern name of the theorem suggests. (NCTM (2000). Connections Standard. Students should recognize and use connections among mathematical ideas;

understand how mathematical ideas interconnect and build on one another to produce a coherent whole; recognize and apply mathematics in contexts outside of mathematics.

- Mathematicians in North America: This lesson focused on Thomas Fuller and Benjamin Banneker, two Black mathematicians who lived in the US in the 18th century. The major activity in the lesson asked students to use their knowledge of quadratic function to calculate the lengths of buildings with given areas and their spatial reasoning to arrange the building to create a layout of Washington D.C., as a group of individuals which included Banneker had done before the city's construction. (NCTM (2000). Problem Solving Standard. Students should build new mathematical knowledge through problem solving; solve problems that arise in mathematics and in other contexts; apply and adapt a variety of appropriate strategies to solve problems; monitor and reflect on the process of mathematical problem solving.
- Geometric Mathematical Understanding: This lesson focused on the work of Euclid and Hypatia, two mathematicians who (while working in Alexandria, Egypt) developed mathematical concepts through the construction of segments, angles, and areas. In this lesson, students "translated" identities contained in Euclid's *Elements* from their geometric articulation into more modern mathematical language of equations with variables and numbers. (NCTM (2000). Representations Standard. Create and use representations to organize, record, and communicate mathematical ideas; select, apply, and translate among mathematical representations to solve

problems; use representations to model and interpret physical, social, and mathematical phenomena.

- The Algebraic Breakthrough: This lesson focused on the work of al-Kwharizmi, an Arabic mathematician who worked in Baghdad in the 8th and 9th centuries C.E. and contributed to the development of modern Algebraic identities. Students compared al-Kwharizmi's articulation of math concepts with that of Hypatia as well as with their modern representations. (NCTM (2000). Algebra Standard. Students should understand patterns, relations, and functions; represent and analyze mathematical situations and structures using algebraic symbols; and use mathematical models to represent and understand quantitative relationships.

After the series of lessons, follow up interview sessions were held with the participating students. These interviews were similar to the ones that took place at the onset of the study, with students providing information about their attitudes toward math through open-ended and structured data collection methods. In addition to asking students to reconsider their attitudes in each of the three scales measured at the beginning of the study, post-lesson questions explored the characteristics of the lessons and/or students that contributed to observed shifts in student attitudes.

Analysis

The responses of the students in both interview sessions were coded in order to highlight major themes and overall shifts that occurred in the attitudes of individual students. In addition, a t-test was used to analyze whether or not a significant difference existed between the means of student responses for each question on the survey before and after the lessons. Finally, data collected through reflective analysis of the lessons was used to critically evaluate the lesson plans, curricular materials, and teacher pedagogies employed during the lessons and explore the extent to which the lessons were effective and relevant to the students.

Results

In order to determine whether or not a significant change had occurred with respect to the three attitude scales involved in the study, survey questions were categorized according to which scale they addressed. Students' responses to each question were then assigned numerical values, a response of "strongly disagree" denoted by 1 and "strongly agree" denoted by 5, with the higher scores indicating a more positive attitude. The means of the responses for each question were then analyzed using a t-test for significance. There was no significant difference between the mean student responses on any of the five questions before and after the students were taught about the history of mathematics; however, the standard deviation of the means was quite large in each case. These statistics suggests that students tended either to strongly disagree or strongly agree with the survey items. While the average of these responses fell close to the middle of the Likert scale in each case, this does not seem to be an accurate representation of students' actual attitudes. For this reason, qualitative data provides a more useful interpretation of students' overall response to the lesson series. For each attitude scale, the data compiled during student interviews does suggest that learning math history had some affect on students' attitudes.

Table 1: Student Attitude Scales ($n = 15$)				
Attitude scale measured	**Pre-lesson survey mean (SD)**	**Post-lesson survey mean (SD)**	**t**	**P (2-tailed)**
Attitude towards success in math	2.40 (1.35)	2.60 (0.91)	-0.612	0.550
Mathematics Usefulness (Question 1)	3.80 (1.14)	4.00 (0.76)	-0.642	0.531
Mathematics Usefulness (Question 2)	3.53 (1.30)	4.00 (0.93)	-1.825	0.089
Mathematics as a White Domain (Question 1)	1.53 (0.91)	2.00 (1.00)	-1.240	0.235
Mathematics as a White Domain (Question 2)	2.47 (0.99)	2.23 (1.08)	0.613	.550

Quantitative data on students' Attitudes toward Success in Math came from their response to the survey item: "When I do well in math, I usually attribute the success to good luck." The difference in mean responses to this item before and after the math lessons was -0.2 with a paired standard deviation of 1.26. The average response of 2.4 before and 2.6, suggests that students in the sample were not likely to exhibit a tendency to attribute success solely to good luck (a hallmark of students with negative attitudes towards success) either before or after the lessons (t (14) = -0.612, p=.55).

During the initial interview of the study, students were asked to reflect more deeply on their views with regard to success in math. Thirteen of the 15 participants (87%) cited "hard work" as the main factor contributing to their success in math. These student responses suggested a high degree of agency with regard to mathematical success; however, this sense of agency did not to correlate with confidence in the subject. Students who responded in this way were quite critical of their own mathematical ability. Implicit in their statements about the value of hard work in math class was a self critique of their past work ethic. An example of this kind of statement in an initial interview came from an 11th grade, African-American student named Russ:

> "Math doesn't come easily to me. I've got to study hard. I've got to want it. I'm not studying nearly enough this year and it shows in my grades."

Russ's comment suggests that his notions of agency in mathematics encourage self blame rather than self efficacy and that his overall attitude toward success in math may be more negative than one might conclude from quantitative data alone. In follow up interviews, students were much more likely to exhibit a genuine sense of ownership with regard to their success accomplishing mathematical tasks. "It was our decision how to build D.C.," one student, Eboni, said when describing her favorite lesson of the history series-North American Mathematicians-in which students used area equations and spatial reasoning to construct a plan for how to place major buildings and public spaces in the US capitol. The smile on her face made it clear that she had experienced success in the activity and that she felt responsible for that success.

Survey results in the second attitude scale used in this study, the Usefulness of Math scale, were similarly inconclusive. This data came from students' responses to two survey items: 1) "I use math skills (other than arithmetic) from time to time during my daily life" and 2) "I feel comfortable talking about math in front of others". The initial survey mean scores for these items were 3.80 and 3.53 (see Table 1). These scores suggest that most students seemed to show a belief that math has important applications to outside-of-class contexts and that it was generally acceptable to talk about these concepts. Means for the follow-up survey were slightly higher for each question (4.0 and 4.0), but the differences were not statistically significant ($t(14) = -0.64, p = 0.531$ and $t(14) = -1.82, p = 0.089$).

As with the first scale, qualitative data revealed some important shifts in students' attitudes in this area that are not evident in the survey results. Before the lessons, most students (73%) expressed a general feeling that "math is everywhere" and that the subject has important applications outside of school. However, when pressed, they were unable give meaningful examples of times when people use math skills in their lives outside of class. One 11th grade African-American student, Stokely, articulated ideas that were typical of the sample in his initial interview. "We all use math everyday," he asserted in response to a general question about his attitude toward math, but he paused when asked to talk about some specific ways he uses math thinking skills. "Sports, television, food, the police department…you know, all that stuff uses math," he said. Stokely's response suggests that he has been told about the importance of math to his life, but that he had not connected math thinking skills such as quantitative expression, analysis, or spatial reasoning with any specific outside-of-school tasks. Math history lessons provided students with an opportunity to connect mathematical concepts with solving specific problems that people have faced in history. Participants engaged lessons about how past mathematicians have solved problems such as how to articulate quantities, build large structures, and plan cities. In follow-up interviews, most students were able to back up assertions of math's usefulness with examples of out-of-school tasks that people use math to complete. Over half of the students interviewed after the lessons (8 of 15, 53%) were able to give specific examples of why we need math to be able to talk about quantities, shapes, and areas in order to solve problems faced by humans in society. This specific knowledge suggests that students had a more developed sense of the Usefulness of Mathematics as a result of participating in the lesson series.

Survey data on students' attitudes towards Math as a White Domain came from their response to the following survey items: 1) "In general, students from some racial and ethnic backgrounds are more likely to pick up math concepts easier than students from others because of an ability they were born with" and 2) "Almost all important discoveries in math were made by Europeans or White Americans." The means of students' responses (M_1=1.53 and M_2= 2.00, see Table 1) on the initial survey suggest that they did not enter the study with the idea that race was a determining factor in an individual's ability to excel in math. Follow-up survey results seem to suggest that students continued to reject the idea that math is a White domain after learning about math history (mean score on the follow-up survey for question 1 equaled 2.47 and mean score on the follow-up survey for question 2 equaled 2.23). Again, these results do not show a significant difference between the two means ($t(14) = -1.24, p = 0.235$ and $t(14) = 0.61, p = 0.550$).

In the initial interview session, students were reluctant to talk about the idea that people of certain races might be more or less successful in math than others. "Race has nothing to do with it," one White 10th grader, Maureen, responded in an angry tone to a question asking for her opinion about the abilities of members of different racial groups in math. Only two students in the sample suggested that race might be a factor in determining a person's ability to succeed in math when asked directly. Those students, both African-American, admitted that they had witnessed different achievement levels in their classes along racial lines, but refused to go into detail about those differences.

Another question in this interview seems to point to the fact that, while students were reluctant to talk about their assumptions regarding race and math ability, these assumptions continue to play a role in shaping their view of math and individuals who excel in math. When asked to guess where most historical math discoveries were made, 9 students (60% of the total sample) said Europe, East Asia, or both. Of the remaining three students who responded to this question, 2 (13%) said North America and 1 (7%) said North and South America. No student in the survey mentioned Africa or the Middle East as possible birthplaces of the subject. This suggests that students have a limited understanding of where mathematical thought originated (since individuals in these geographic location were vital in the construction of the discipline) and that students do not associate these places with excellence in mathematics.

These guesses reveal the fact that students have some sense of awareness about the achievement levels of people in different racial groups in this country, and that they feel comfortable making assumptions based on that awareness. One 12th grade Latina student whose parents immigrated to the US from México, Desiree, laughed upon hearing the question and exclaimed, “Well, [math] certainly didn’t come from México.” Desiree’s explanation of the statement revealed that it was not based on knowledge of México’s history. Her statement was rooted in the dominant cultural view that Latino students have less mathematical ability than students from other racial groups. Her school experience had taught her to devalue the mathematical knowledge of individuals from Latin America, a view that impacted her attitude regarding the math ability of those who identify as Latino in her classes. This statement, which revealed her willingness to make generalizations about the math ability of Latin Americans, stood in stark contrast to her previous assertions that race did not play a role in determining an individual’s mathematical aptitude.

In the follow-up interviews, some students were more willing to talk about their racial assumptions. Eight of the 15 students (53%) said they were “surprised” that most of the mathematicians highlighted in the lessons had come from Africa, Latin America, and the Middle

East. Several African-American students talked at length in these interview sessions about their frustrations with dominant cultural assumptions that regarding mathematical ability of Africans and African-Americans. Sherry, an 11th grade African-American participant expressed her awareness of assumptions that are made about Black people's math ability: "sometimes people say we didn't have anything to do with it [creating math], that it was all different people." Several other African-American students reported learning about the role of African and African-Americans in math for the first time in lesson series:

> "I knew our people were smart, but I didn't know a lot of people from Africa knew how to do Math like that."
>
> "I used to think that it was only White people who invented math, but really its not just White people…everybody played a role in making math what it is today"

These statements suggest that the math history lessons were effective in helping some students understand and develop their attitude of Math as a White Domain.

Discussions

The results of the study suggest that students' attitudes did improve somewhat in each of the three categories measured as a result of lessons in math history; however, these changes were not pronounced and the benefits of such changes in attitude were not evenly distributed across the entire sample. Certainly, the (relatively) short time period of the study and constraints on the lessons should be considered as limitations to their effectiveness. Students engaged in only three and a half hours of instruction in math history over a period of four weeks-- far less time than is spent on other units. The nature of the study mandated that lessons were added into the pre-planned curriculum of the cooperating instructor, so lessons occurred somewhat sporadically in the absence of a strong sense of continuity between them and students' other traditional Algebra 2 lessons. Additionally--and more importantly in terms of the implications of this study--the lessons imperfectly addressed the goals of the three theories that formed the basis for interest in teaching math history. By understanding the ways in which these particular math history lessons did and did not address the ideals of situated learning, role model development, and cultural relevance, educators can find ways to develop curricula in math history that have an even stronger impact on students' attitudes toward the discipline.

Situated Learning:

> "I got to learn why I need to take Algebra 2…why we're doing it and everything…and who made it. Cause I thought somebody just named it Algebra 2," Christian, African-American, 11th grade participant.

The goal of situated learning is to promote the kind of connections and sense-making evident in Christian's statement above. By learning a little bit about the background of algebraic thought, Christian was able to discover justification for why he was enrolled in the Algebra 2 course. Christian was not the only student who experienced this benefit. Eight of the 15 students interviewed noted that the math history lessons helped them understand how math developed in the context of outside-of-class problems, thus suggesting that they succeeded in promoting the contextualization of student learning.

Additionally, the activities in which students participated as a part of the math history seemed to have played an important role in encouraging students feel connected to what Lave and Wagner (1991) called the larger "community of practitioners" of mathematics. Only two students in the initial interview identified with the label "mathematician," but seven reported feeling "like a mathematician" when they were completing assignments in math history lessons.

Each of these students cited the hands-on, inquiry-based nature of the lessons as a major factor in promoting this feeling. For these students, the act of situating learning had a positive impact on their attitude toward the discipline as well as their understanding of the concepts.

Unfortunately, the lessons did not forge these connections in the minds of all students. Several students continued to possess vague conceptions of the use of mathematics. When asked in the follow-up interview to describe "what a mathematician does," Artesha, an African-American 11th grader, had this to say: "It's like a magician, but instead of using magic and stuff, they use math." Evident in this and other statements by students in follow-up interviews was the idea that math remained separate from their lives and unrelated to the kinds of things the people do "in the real world."

Teachers could help students form more meaningful ideas about how to use math by explicitly addressing the connection between student assignments and mathematicians' work. One of the weakest points of each lesson taught for this study was the fact that time for review and assessment was often limited. Too often, the instructors allowed time to run out without bringing the class back together to discuss hands-on activities and helping students forge the kind of connections between mathematical concepts and outside of class applications that about half the participants missed.

Role model development theory:

> Researcher: "Which historical figures did you most identify with?"
>
> Billy (African American, 12th grade participant): "I really liked learning about al-Kwharizmi"
>
> Researcher: "Why?"
>
> Billy: "'Cause I really like saying his name."

The above conversation reveals the limitations of the math history lessons taught as a part of the study in promoting meaningful role model development. When asked to talk about whether or not they identified with historical figures in the lessons, only three students were able to describe figures with whom they connected in some meaningful way. Students' confusion about the meaning of "identifying with" historical figures is evident in Billy's comment. He mistook the general positive feeling toward al-Kwharizmi that he felt because his name was unique for identification with this historical figure as a real person. This and other comments by the students during their interviews suggest that survey data with regard to this concept may be misleading. The mean student response to the survey item "I could see connections between the historical figures and societies about which we learned and myself and my own society" was somewhat high. However, students' inability to articulate their understanding of those connections suggests that most students, like Billy, were not referring to the kind of connection necessary to promote role model development.

The fact that these lessons focused on mathematicians who lived long ago in cultures quite different from that in the modern US seems to have been the major limiting factor in the lessons' ability to engender role model development. There do seem to be some ways to overcome this obstacle in the context of math history lessons. One method would be to include more modern mathematicians in the unit-a task that could be more easily accomplished in a longer math history curriculum. Secondly, instructors could find ways to encourage students to learn more about the lives of the mathematicians in the hopes that this knowledge would help them connect with the figures on a more human level. While these methods both seem reasonable, neither would ensure the kind of role model development that has been shown to improve students' attitudes toward academics.

Instructors might consider including additional culturally relevant lessons in their courses in order promote more opportunities for students to develop math role models. One activity that is likely to encourage this sense of identification involves following the “artist or craftspeople in residence” model described by Ladson-Billings (1995). Instructors who invited “mathematicians in residence”--individuals who were connected to, but not a part of local school communities--into the classroom to describe the ways they use math in various outside-of-school contexts might work well alongside math history lessons to create environments that stimulate role model development in all students.

Culturally Relevant Pedagogy:

> “I didn’t think [Africans, Latin Americans, Middle Easterners, and African Americans] did all that math and stuff back in the day…they done things that I didn’t think they could do…[Knowing this] makes me want to keep learning and push myself on and get all the math I can get,” Candice, African American, 9th grade participant

The final theory that the math history lessons in this study addressed, though imperfectly, was that of culturally relevant pedagogy. Candice’s statement suggests that, for her, the history lessons did address two of Ladson-Billings’ three requirements for this kind of teaching: “students experience success” and “students develop and/or maintain cultural competence” (1995, p. 160). Her reflection reveals the fact that she successfully engaged notions of how math developed. Additionally, her admission that she did not know of the contributions of those groups of people to the development of the discipline prior to the lessons suggests that they encouraged the development of her “cultural competence,” those skills that will help her understand culture and its relationship to power (Ladson-Billings, 1995, p.160).

Data collected from students in follow-up interviews as well as assessments collected from the lessons overwhelmingly point to the success of students in engaging and understanding the concepts that were part of the history lessons. Students’ work shows that they all successfully interpreted Mayan numbers, constructed pyramids, designed innovative models of Washington D.C., and understood the conceptual developments that lead to the creation of what we think of as geometry and algebra. Each student was able to share something she/he learned during the lessons in post-lesson interviews. Another marker of the success experienced by students in these lessons was their willingness to share ideas with one another in the classroom. Fourteen of the 15 students interviewed described themselves as “comfortable” talking about math and participating in the math history lessons.

Candice’s experience with regard to developing cultural competence seems to have been typical of the sample as well. The mean of student responses on the post-lesson survey item 12, “I learned new things about the role people of color have played in creating math” was quite high. In follow-up interviews, 11 of the participants spoke of ways they developed their understanding of the non-White cultures discussed in the lessons or confirmed previous positive views of those cultures. Additionally, the data on students’ attitudes in terms of the Math as a White Domain scale, which suggested that students better understood their feelings in this area as a result of the lessons, shows that the unit successfully met the goals of developing cultural competence.

The third and final aspect of culturally relevant lessons was addressed inadequately in the lessons taught as a part of this study. To qualify truly as culturally relevant, lessons must encourage students to "develop a critical consciousness through which they challenge the status quo of the current social order" (Ladson-Billings, 1995, p. 160). Candice's comment quoted at the beginning of this section reflects the lessons' incomplete fulfillment of this requirement. Her comment focused on her own relationship with math and math history. Conspicuously absent from her analysis is any critique of the way the history she has learned has been constructed to downplay and disregard the roles of those non-White cultures in creating math. She recognized the problems with not knowing this history, but failed to question why she had not learned it. Stokely, another African-American participant, made a similar comment: "we get less credit for what we actually did." Truly successful culturally relevant lessons would have encouraged students to come to this realization *and* confront the role that institutional racism has played in creating the phenomenon to which Stokely referred.

In order to meet fully the goals of culturally relevant pedagogy, instructors must encourage students to make connections between the history they knew, the history they learned, and the influence of racist institutions and institutional practices in creating differences between the two. In the lesson series taught to the student participants, there were two excellent opportunities to have this conversation. As part of the lesson on Egyptian pyramid building, students were asked to write about whether or not they thought (based on their own experience constructing pyramids) that African people knew the "Pythagorean" Theorem centuries before Pythagoras lived in ancient Greece. The instructor could have encouraged a critique of the current social order by asking students to think about some possible explanations for why Pythagoras continues to get credit for the development of this concept. At another point in the lesson series, students saw two paintings of Euclid, a mathematician who lived in Alexandria and wrote one of the foundational books of modern geometry. The first showed a dark-skinned figure with thick hair performing measurements with a compass. The second, a painting by the Italian Renaissance artist Rafael, was of a White man teaching other White people on the steps of a large building suggestive of Greek architecture. The instructor noted the differences between the skin color of the individual in the two pictures and asked whether or not students believed that students in Egypt would have looked like the ones in the picture; however, he did not ask them to analyze the pictures in a way that encouraged them to make a meaningful anti-racist critique of the two portrayals of Euclid. In order for lessons to function as truly culturally relevant, teachers must seek out opportunities like these to highlight the racist construction of historical figures and ask students to reflect on the meaning of these cultural representations in their own lives.

Conclusion: The Need to Re-member the History of Mathematics

> "Remembering is never a quiet act of retrospection. It is a painful re-membering, a putting together of the dismembered past to make sense of the trauma of the present." (Bhabha, 1991, p. 7)

Many African American, Latino, and Native American students in the United States are in the midst of traumatic school experiences (Lloyd, 2001; Peng, Wright, & Hill, 1995; Thomas, 2000). The solution to this trauma, according to the postcolonial theorist Homi Bhabha, must include an effort by educational institutions to connect students from these racial groups with the past from which they have been alienated (Bhabha, 1991). In math, educators have an opportunity to reconnect students with an empowering history while covering the basic concepts of the discipline in a way that makes them meaningful and engaging (Jones, 1989).

Today's teachers, administrators, and researchers have the opportunity to transform the traditional way in which educational institutions have quietly "remembered" a math history composed predominantly of contributions by Europeans and White Americans by re-membering math history to include the cultures, personalities, and innovations of non-White individuals who played crucial roles in developing today's mathematical systems.

This study detailed the experiences of one teacher trying to accomplish this goal. While by no means perfect, the lessons in this study were taught in a way that encouraged the contextualization of mathematical learning while addressing some of the goals of role model development theory and culturally relevant pedagogy. Despite the imperfections of the lessons and other constraints of the study, participating students displayed signs of genuine change with regard to each of the three attitude scales tested. These modest but meaningful results should serve as an encouragement to other educators who are striving to make math meaningful by facilitating connections between course material and their students' lives. The results show that by incorporating the history of mathematics in non-White cultures in the secondary classroom, educators can help develop more positive attitudes in their students and effectively address the goals of NCTM's equity principle (NCTM, 2000).

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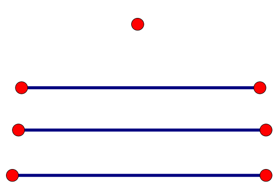
Appendix: Lesson Plans and Handouts

Lesson #1: What do numbers do?
North Carolina Standard Course of Study objectives for Algebra 2: 1.02: Define and compute with complex numbers. 2.10: Use systems of two or more equations or inequalities to model and solve problems; justify results. Solve using tables, graphs, matrix operations, and algebraic properties
Imagine you and your class are in an early hunter/gatherer society one member of the group is gone by her/himself for several days/hours and comes back with a piece of fruit that no one in the community has seen before…
What kinds of questions would you ask the scout?

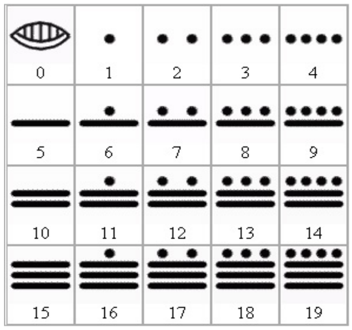
Mayan Numbers
The Mayans had an intricate number system which they used to develop a precise calendar and engineer massive structures and cities. Can you use the facts below to decipher their symbols and “translate” them into modern numbers?
Fact 1: Archaeologists know that there 3 famous temples in the Mayan city of Palenque (located in what is now southern México). Beside the symbol for temple they found this symbol in some Mayan writing describing the city.

Fact 2: Records suggest that Waterlily Jaguar was the 7th ruler of the city of Copan (located in present day Honduras). This symbol is written frequently next to his name.

Fact 3: There seems to have been an important festival on the 16th day of one Mayan month in Chichen Itza (located on the Yucatan peninsula in modern day México). Priests from across the empire wrote of this festival using this symbol.



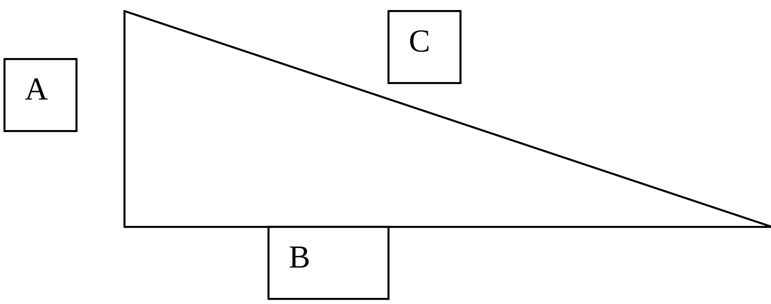
1. Use these facts to “translate” our numbers 1-19 into the Mayan number system.
2. Once you’ve translated the numbers create a few addition problems. Notice how Mayans might have “carried digits” the when performing arithmetic.



These are the first digits of the Mayan number system. Visit the links in this packet for more information about doing arithmetic with Mayan numbers.

Lesson 2: African Engineering and the "Pythagorean Theorem"
NCSCOS Objective 2.02 Use quadratic functions and inequalities to model and solve problems; justify results
The "Pythagorean" Theorem says that the square of one short side of a right triangle plus the square of the other short side equals the square of the longest side.

Refer to the following picture for a representation of this important theorem.



Pythagorean Theorem:

$A^2 + B^2 = C^2$

Level on which the ramp is resting	Number of blocks used to construct that level	Base distance (on ground level)	Height of the top of the ramp	Length of the Ramp	Pythagorean Equation
1	16				
2	9				
3	4				
4	1				

1. Your group is Khufu's team of engineers to build the Great Pyramid. You know that the pharaoh has asked you to build a pyramid that is 480 feet tall. He has asked you to try to figure out how long the ramp needs to be in order to build this pyramid.

a. Write an equation to find the length of the ramp. Use “Y” to represent the length of the ramp and “X” to represent the base distance.
   Y = ________________________
b. Graph this equation in your calculator.
c. Make a recommendation to Khufu about how long the ramp should be. **Remember**: the shorter the base length the steeper the ramp will need to be and the harder it will be to drag stones up it. Write your recommendation below.

Lesson 3: North American Mathematicians

NCSCOS Objective 2.02: Use quadratic functions and inequalities to model and solve problems; justify results

Directions: On the grid provided construct a model of the layout of Washington D.C. given the following dimensions for the following major landmarks and buildings. Once you have completed the design, trace it onto an overhead projector transparency and prepare to present your design to the class. You must write the dimensions for each building and public area on their transparency.

Capitol Building: 175,170 square feet-approximately 50 blocks

Washington Monument: 262, 755 square feet- 80 blocks

White House: 200,000 square feet- 70 blocks

One Public Park or open space: 105600 square feet-100 blocks

Grand Avenue (this space became the National Mall after it was built): 2,112,000 square feet- 10 blocks by 20 blocks (total number of blocks filled in: 200)

Lesson 4: Geometrical Mathematical Understandings

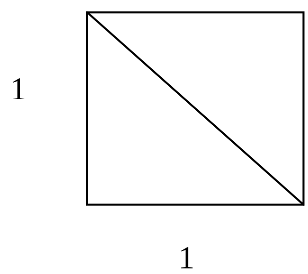
NCSCOS Objective 2.07: Use equations with radical expressions to model and solve problems. 1.03: Operate with algebraic expressions (polynomial, rational, complex fractions) to solve problems.

What is “the square root of two”?

Directions: Below are 3 situations that may involve $\sqrt{2}$. Does each statement or drawing represent $\sqrt{2}$ correctly? Write a sentence explaining the thinking behind your answer.

1. One of the numbers between 1.414213 and 1.414214

2. The length of the **diagonal** of the square below:



3. The positive solution for X in the equation:

$$X^2 = 2$$

What was Math in Alexandria?

Math translations from Hypatia’s language to modern math language

Elements (in translation), Euclid

1. Book II: Proposition 4: “If a straight line segment is cut at random, the area of the square on the whole is the same as the area of the two squares on the segments and twice the area of the rectangle contained by the segments.”

How would Hypatia (math professor in Alexandria who was born around C.E. 370) have presented this concept to her class?

How do we write this idea in our “math language” today?

Lesson #5: The Algebraic Breakthrough

NCSCOS Objective 1.03: Operate with algebraic expressions (polynomial, rational, complex fractions) to solve problems. 2.02: Use quadratic functions and inequalities to model and solve problems; justify results

In his work, al-Khwarizmi used the following terminology to create six standard forms of what we now know as “quadratic” and “linear” equations.

“Squares”: a variable squared, ex: x^2, $4x^2$, $19x^2$
“Roots”: a variable or a number times a variable, ex: x, 2x, $\sqrt{19}\,x$
“Numbers”: any number, ex: 3, $\frac{2}{3}$, $\sqrt{31}$

“Translate” 3 of al-Kwharizmi’s 6 “forms for equations” into equations that we might use in a modern Algebra class.

1. Squares equal to numbers.

2. Squares and roots equal to numbers.

3. Squares and numbers equal to roots.

Give an example of a mathematical symbol that you have discussed in your Algebra 2 class that **could not** be represented using a geometric shape?