Math in the City: Connecting Mathematics and Culture

Irene M. Duranczyk
duran026@umn.edu
University of Minnesota, General College
Barbara Leapard
Joanne Caniglia
Elaine Richards
Eastern Michigan University

Abstract
This article summarizes a presentation given at the National Council of Supervisors of Mathematics annual conference in Philadelphia, PA April, 2003. It was an endeavor sponsored by Eisenhower Higher Education Professional Development Grant Project Number (020290-206), *Math in the City*, Detroit, Michigan 2001-2002. The project involved pre-service teachers exploring the urban environment while designing mathematics curriculum to support the Michigan Curriculum Framework—Mathematics Content Standards and Benchmarks for elementary through secondary (K-12) education. The sociocultural theoretical base for the project precedes the description of the activities and resources used and developed to create *Math in the City*. Examples of how a sociocultural theory model can be used to integrate ethnomathematics into the content, pedagogy and assessment of K-12 education are given.

Math in the City: Connecting Mathematics and Culture

Can we see mathematics in our world? Can we create opportunities for pre-service teachers and in-service teachers to explore their worlds and discover that math is everywhere and that the layers of mathematics can unfold for the first grader as well as the twelfth grader through familiar venues? Visiting cemeteries entrenched with history, retracing the historical roots of music in our culture, exploring museums laden with artifacts and visual representations of times past, and enjoying walking tours of city architecture and infrastructure can provide adventures in mathematics. Ethnomathematics embodies this journey—linking students' diverse ways of knowing and learning and their culturally embedded knowledge base with academic mathematics. Ethnomathematics can assist pre-service teachers by having them question and reflect on their own personal journeys in order to become more aware, more critical, more appreciative, and more mathematical self-confident, and in so doing, to be empowered to change their visions of mathematical knowledge and teaching. Using a sociocultural theory model, the journey of *Math in the City* began.

The sociocultural theory model which has its roots in Kolb's (1984) experiential learning model has been adapted for mathematics by Nelson-Barber and Estrin (1985) and Moses and Cobb (2001), into a pedagogical format to explore, develop, and interface students' experiences with academic mathematical knowledge. The four step Kolb experiential learning model involves: (a) participation in a common event, (b) individual and group reflections on that experience, (c) individual's and group's abstract learnings, postulates, and truths from the experience, then (d) they apply the information abstracted to new situations. The sociocultural model is structured around (a) participation in a common event, (b) individuals capturing the experience or event in their own language and in pictorial representation, (c) individuals and groups reflecting on this experience forming their intuitive understanding, then only after students have drawn their intuitive understanding of the event and have mathematized (uncovered all the possible ways mathematical knowledge enhanced the experience) their experience do we move forward to (d) translating this experience into structured mathematical language or symbolic representation, and (e) exploring possible axiomatic knowledge (Duranczyk et al., 2004). This article uses this sociocultural model to describe *Math in the City*—guiding pre-service and in-service teachers through multicultural, urban experiences and culminating in the translation of these activities into K-9 curricular materials addressing the *Principles and Standards for School Mathematics* (2000) by the National Council of Teachers of Mathematics and the *Michigan Curriculum Framework (MCF) Content Standards and Benchmarks* (1998) (see Figure 1).

MATHEMATICS CONTENT STANDARDS AND BENCHMARKS LESSON PLAN

I. Standard and Benchmark (NCTM and MCF):

Benchmark Clarification: (In your own words what does this Benchmark mean?)
Instructional Example: (Create a meaningful problem that accompanies the Detroit visit.)
MEAP-like item: (List one problem from the Michigan Education Assessment Program that is close to this topic.)
Web-Based Resources: (Be very specific about the URL.)
Textbook References: (Site the page and the textbooks from the Porter Room 100.)

Figure 1 - Students' rubric for preparing lesson plans or modules

The Ethnomathematics Curriculum Process

In an effort to embrace, honor, and celebrate multiculturalism in the mathematics curriculum process, *Math in the City* was designed as a professional development project integrating math and culture while exploring K-9 mathematics content standards, presenting inclusive pedagogical approaches and modeling alternative assessment techniques.

Content Integration

For bonding math and culture into the curriculum, seven techniques were used: (a) presenting mathematics as a cultural product, (b) providing experiences linking real world mathematics with school mathematics, (c) highlighting mathematical traditions that survived colonization, (d) highlighting mathematical content that can be drawn from daily activities, (e) looking for cultural elements and activities that may serve as starting points for doing and elaborating mathematics in the classroom, (f) encouraging critical mathematics education that enables students to reflect on the reality they live in and empowers them to develop and use mathematics in an emancipatory way, and (g) emphasizing and analyzing the influences of sociocultural factors on the teaching, learning and development of mathematics.

Pedagogical Integration

Merging math and culture into classroom pedagogy involved using the sociocultural model while giving emphasis and attention to: (a) linking students' real world understanding of mathematical ideas with academic mathematics multiple representations (verbal, numerical, graphical, and symbolical), (b) connecting mathematical ideas to previous knowledge and experiences, (c) connecting mathematical ideas to real world interests, experiences, and empowerment, (d) presenting a variety of cultural, historical algorithms within their cultural, historical context and connecting them to present day algorithms, mathematical insights, and their multiple and independent origins, (e) giving time for, and placing value on, reflection for uncovering possible axiomatic knowledge and related applications, and (f) acknowledging, honoring, and valuing many possible ways to present and explore mathematics while promoting accurate standard mathematical symbolic notation and representations.

Assessment Integration

The convergence of math and culture into assessment was an integral component of *Math in the City*. Assessments (a) measured the key mathematical ideas that were most important for students to learn, (b) enhanced learning and supported good instructional practice, (c) supported every student's opportunity to learn important mathematics, (d) respected multiple measures to assess student progress (tests, quizzes, projects, interactive activities, oral presentations, etc.), (e) allowed for negotiation in assessment, (f) included projects based on students' interests, (g) used portfolios designed to track students' growth and accomplishments, and (h) used authentic applications to demonstrate mathematical knowledge and skills.

City Explorations

Pre-service and in-service teachers explored mathematics in Detroit, Michigan with the support and cooperation of The Detroit Historical Museum and its talented docents. Incorporating professional, interactive story-living workshops and community tours, pre-service teacher and in-service teachers explored (a) the journey of John Freeman Walls and other slaves as they sought freedom though the underground railroad; (b) the development of a self-sufficient community for Afro-Americans within Detroit during segregation; (c) the history of the Motown sound of the 1960's; (d) the history of the Tuskegee Airmen, the first African-American flying unit—the 99th Fighter Squadron during WWII; (e) Elmwood Cemetery, Detroit's oldest and first interracial and interdenominational cemetery; and (f) the Great Fire of 1805, which temporarily destroyed the infrastructure of the city of Detroit. Below is an account of just a few of these experiences and the ethnomathematics curriculum that was explored through these venues.

Math in Music

For our series on math in music, students were given background information on Paradise Valley and Motown. Historical information was discussed before embarking on a bus tour of Paradise Valley in Detroit and a site visit to Hitsville USA. A docent from the Detroit Historical Society delivered a running commentary as we explored the area centered on the near east side of downtown Detroit which was also known as Black Bottom in the 1920's. Among other Black-centered businesses and entertainment venues, this area was the center of the development of jazz and blues in Detroit. The road tour ended with the site visit to Hitsville USA, which was Motown Studio A and now houses the preserved studio, original furnishings, and three floors of historical materials capturing the birth, growth, and move of the Motown sound to California. At our next class session, a week later, students were asked to talk about their experiences. Students were then given time to think about mathematizing their experience. What aspects of the road tour and site visit could be enhanced by exploring mathematical ideas? Students generated many ideas. We also prepared project activities ranging from (a) designing reed and brass instruments from straws, using fractions to mark and achieve an octave of sounds; (b) creating string instruments from a florist box and rubber bands or string and using measurement and fractions to fret and tune instruments for a octave of sound; (c) using internet interactive activities involving permutation and combination to create a fugue; and (d) discovering other resources on the internet that students could use to explore the history of music in Detroit and discover other interactions between mathematics and music (see Figure 2). Students were then encouraged to work in groups or individually to prepare their project for this unit. Their project involved designing three lesson plans, called modules, for K-3, 4-6, 7-9 students depicting mathematics in music and the music history of Detroit. Their projects needed to follow the rubric given and have all the ancillary materials attached so that this unit was ready to teach (see Figure 1). These curricular materials were used to evaluate students' progress.

Mathematics in Music Web Sites

Math in Music lesson plans
http://educ.queensu.ca/~curr/units/PattnPlay.pdf
http://www.math.niu.edu/~rusin/papers/uses-math/music/
http://www.teachervision.com/lesson-plans/lesson-10340.html
http://www.teachervision.com/lesson-plans/lesson-10339.html
http://www.teachervision.com/lesson-plans/lesson-4862.html
http://www.teachervision.com/lesson-plans/lesson-4851.html
http://www.teachervision.com/lesson-plans/lesson-10343.html
http://www.teachervision.com/tv/printables/0876283849_237.pdf
Web site for the history of Black music / musicians in Detroit - Paradise Valley and Hastings Street
http://detnews.com/2002/detroit/0202/27/s04-426440.htm
http://www.freep.com/news/metro/qnjourn6.htm
Mozart, music, math, dice
http://www.cwi.nl/~zsofi/mozart/mocamps.html
http://www.cwi.nl/~zsofi/mozart/
Interactive Web site for Math and Music
http://imagine.xs4all.nl/bram/mozart/
http://www.riverdeep.net/current/1999/10/100299.music_math.jhtml
http://www.studyworksonline.com/cda/content/explorations/0,,NAV2-95_SEP1237,00.html
Worksheets of math and music
http://www.pbs.org/jazz/classroom/printerfriendlyfractionsworksheet.html
http://www.pbs.org/jazz/classroom/printerfriendlyonebeat.html
http://www.pbs.org/jazz/classroom/printerfriendlyrhythms.html

Figure 2 - Websites for students to explore math and music

Math in the Underground Railroad

Exploring math involved in the Underground Railroad was accomplished through two different venues: John Freeman Walls Historic Site in Ontario, Canada; and the Second Baptist Church of Detroit, Michigan. The tour of the Walls Historic Site featured docents who were the direct descendants of the original Walls family. This family played a pivotal role in the Underground Railroad by helping African-Americans who had escaped from slavery to establish new lives in Canada. Many students purchased the book, The Road That Lead to Somewhere (Walls, 1980) a biographical, historical fiction capturing the Walls story from slavery in North Carolina to establishing homesteading opportunities at the end of the Underground Railroad in Ontario, Canada.

The docents for the tour of the Second Baptist Church of Detroit helped to explain the church's role in the Underground Railroad as one of the last stops on the Railroad before slaves were smuggled to Canada. In addition to visiting the museum and the church, *Follow the Drinking Gourd* (Knight, 1999), a film concerning the Underground Railroad, was shown. This film showed how slaves used the celestial system to travel from plantations in the southern region of the United States to the north. It also showed how quilts were used for communication for the Underground Railroad. After visiting these historical sites, students used ideas from geometry, measurement, fractions and decimals to design quilts and maps—two of the important features of the Underground Railroad. An example of a lesson plan based on this unit is captured in Figure 3.

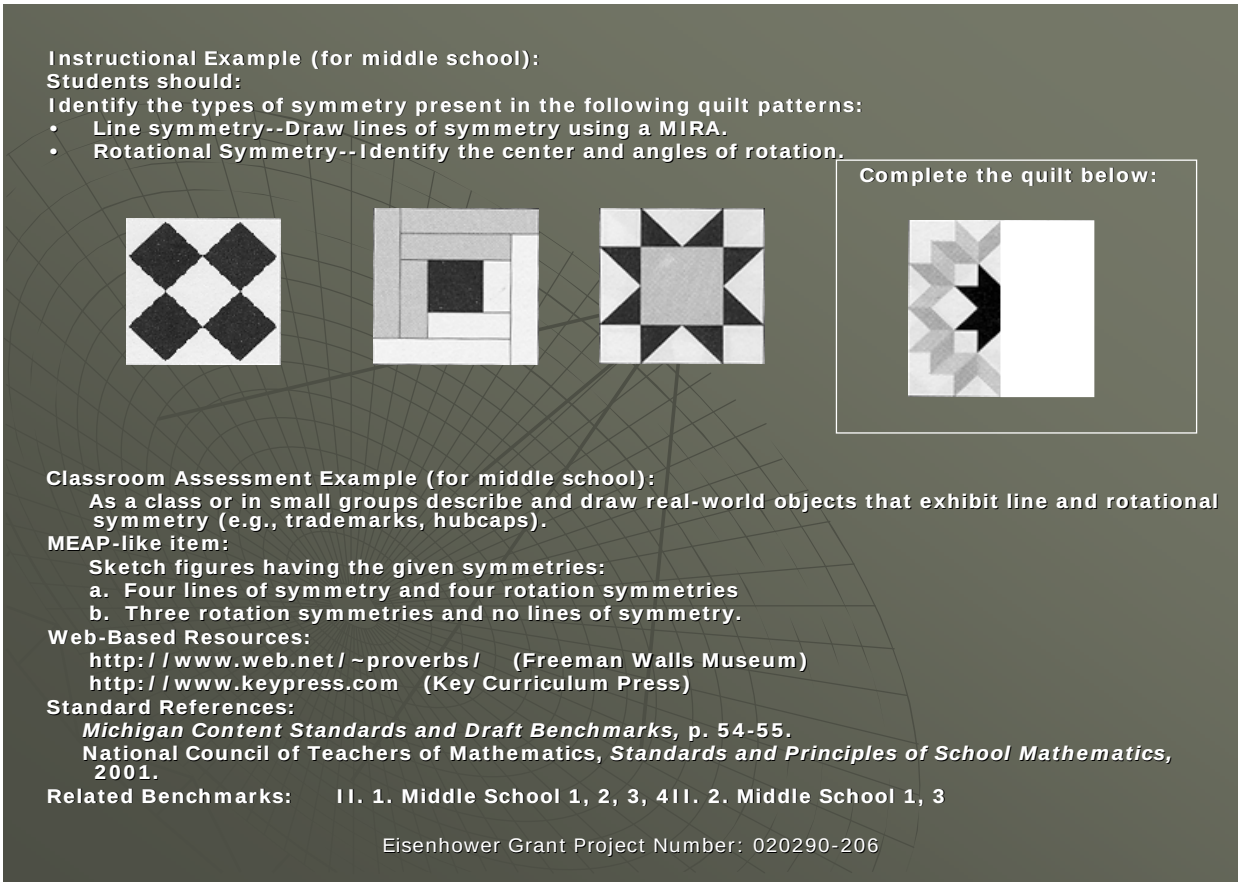

Figure 3

Internet resources found to support the unit on the Underground Railroad were compiled and are listed in Figure 4.

The Underground Railroad Web Addresses

Quilts codes, routes north, drinking gourd song etc.
http://www.beavton.k12.or.us/greenway/leahy/ugrr/awards.htm
http://quest.arc.nasa.gov/ltc/special/mlk/gourd2.html
http://www.ea.pvt.k12.pa.us/htm/Units/lsDevon/DFormSS/UGRRcodes.htm
http://www.hgtv.com/hgtv/cr_quilting_blocks/article/0,,HGTV_3299_1374077,00.html
Underground Railroad sites
http://www.cr.nps.gov/nr/travel/underground/ugrrhome.htm
http://www.nationalgeographic.com/features/99/railroad/
http://www.education-world.com/a_sites/sites004.shtml
http://www.esu3.k12.ne.us/districts/millard/centmidd/vertlib/pathrailroad.html
http://www.farmlib.org/fundr.html
Underground Railroad Activity in Southwestern and Southeastern Michigan
http://lcweb.loc.gov/bicentennial/propage/MI/mi-06_h_upton1.html
http://www.sos.state.mi.us/history/museum/explore/museums/hismus/prehist/civilwar/undergro.html
The Fugitive Slave Act and the Underground Railroad
http://www.math.buffalo.edu/~sww/0history/hwny-ugrr.html
American Slave Narratives
http://newdeal.feri.org/classrm/classlp.htm
http://www.si.umich.edu/CHICO/sos/new/index.html
http://education.ucdavis.edu/NEW/STC/lesson/socstud/railroad/contents.htm
National Parks Conservatory - Retracing the Route to Freedom
http://www.npca.org/walk.html
Other lesson plans
http://www.ptamerica.com/quilts.htm
http://www.cmsdnet.net/trc/plans/undergroundrailroad.htm
http://www.educationworld.com/a_curr/curr195.shtml
http://www.kinderart.com/across/afamslavequilt.shtml

Figure 4 - Websites for students to explore math and the Underground Railroad

Math in the Air

The Tuskegee Airmen National Museum in Detroit, Michigan was dedicated to the members of the 99th Fighter Squadron, the first African-American flying unit, during World War II. Docents for the Tuskegee Museum were airmen of the fighter squadron. Besides regaling students with stories about their activities as airmen, they also demonstrated for the students how important mathematics was for their survival. References to the phrase the whole nine yards—an ammunition belt feeding the machine gun in Supermarine Spitfire—drew laughter from the young audience. After touring the museum, students returned to class and worked on paper airplane and helicopter constructions. The students then discussed the mathematics involved in the construction such as geometry and measurement, and competitively tested the airplanes and helicopters for speed and distance. Figure 5 contains many of the websites which were used to further explore mathematics, flight, and the history of The Tuskegee Airmen.

Math, Tuskegee Airmen, and Airplanes

History of Tuskegee Airmen
http://www.wpafb.af.mil/museum/history/prewwii/ta.htm
http://tuskegeeairmen.org/
http://www.coax.net/people/lwf/tus_air.htm
http://www.waterholes.com/~dennette/models/ww-ii/redtails.htm
http://www.blackaviation.com/blackhistory.html
http://www.cr.nps.gov/museum/exhibits/tuskegee/airoverview.htm
http://www.nps.gov/tuai/
http://www.newseum.org/warstories/interviews/mp3/journalists/bio.asp?ID=26
http://www.geocities.com/Pentagon/Quarters/1350/

Math and aviation websites
http://www.cis.yale.edu/ynhti/curriculum/units/1988/6/88.06.07.x.html
http://www.cis.yale.edu/ynhti/curriculum/units/1988/6/88.06.11.x.html
http://www.cis.yale.edu/ynhti/curriculum/units/1990/7/90.07.02.x.html
http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Mathematics/.index.html
http://spacelink.nasa.gov/Instructional.Materials/Curriculum.Support/Mathematics/X.Gliders/.index.html
http://www.sd76.ab.ca/curlinks/graphing/Paper_Planes/PaperPlanesMathCurrData.htm

Design your own airplane on-line
http://www.planemath.com/planemathmain.html
http://illuminations.nctm.org/index_d.aspx?id=323

Paper plane designs
http://www.mcshane.org/planes/
http://www.paperairplanes.co.uk/
http://www.geocities.com/EnchantedForest/Creek/8015/
http://users.bigpond.net.au/mechtoys/plane.html
http://www.josephpalmer.com/planes/Airplane.shtml
http://users.bigpond.net.au/mechtoys/paper.html
http://www.bestpaperairplanes.com/

Figure 5 - Websites for students to explore math in the air

Math in the Cemetery

During the tour at Elmwood Cemetery, docents gave very detailed background stories of prominent African-Americans buried at the cemetery during the last century. As the tour progressed, students were asked to think in terms of the mathematics-based ideas they could use in their lesson plans. Statistics based on the ages and genders of those buried in the cemetery was one of the major mathematical concepts that many of the students considered. In addition, the three-dimensional geometric shapes of many of the unique monuments, statues, and headstones were of great interest for students. Determining the available square footage left for burial in the cemetery was suggested by several students.

During the tour students were divided into groups in order to explore different areas of the cemetery and to capture the unique characteristics of their particular plots. When they returned to the classroom, they used Excel to determine statistics such as mean, median, and mode to calculate typical life spans during the variety of time periods surveyed. They graphed trends over units of time. As far as the geometric shapes were concerned, students designed activities for children to learn the names of, and the characteristics for, each of the shapes. One such discovery was a forty-foot-high obelisk, estimated to be a 4-ton monument. Some resources used to create other classroom activities centered around the cemetery theme are listed in Figure 6.

Cemetery Math - Elmwood Cemetery

Elmwood Cemetery
http://www.michmarkers.com/Pages/S0453.htm
http://www.findagrave.com/cgi-bin/famousSearch.cgi?mode=cemetery&FScemeteryid=447
http://www.detnews.com/history/elmwood/elmwood.htm
http://www.rims.k12.ca.us/ugr/ugr_1999/day4/elmwood.html
http://www.geocities.com/genealogymi/elmwoodmap.html
http://www.geocities.com/michhist/elmwoodcem.html

Math and Cemeteries
http://www.wside.k12.il.us/pes/cemetery.htm
http://research.soe.purdue.edu/challenge/DeadStuff/activity.htm
http://www3.uakron.edu/edcourse/ci/owens/math/pdf/interdisciplinary
http://research.soe.purdue.edu/challenge/DeadStuff/Pre-Activity.htm
http://www.ancestry.com/library/view/news/articles/1326.asp
http://alliance.la.asu.edu/internetclass/ExampleLesson1.html
http://www.mdw.army.mil/fs-a11.htm
http://www.cmsdnet.net/alliance/dozierka/weblesson.htm
http://www.angelfire.com/ky2/cemetery/wecker.html
http://mathforum.org/t2t/message.taco?thread=220&message=2
http://www.angelfire.com/ky2/cemetery/math.html

Figure 6 - Websites for students to explore math in the cemetery

The Poster Project Display

All participants were required to keep a portfolio of the inquiry-based field trips and submit fifteen learning modules incorporating real-world mathematics activities with the field-based experiences. Journal entries, including a mathematics autobiography, were assigned for students to reflect on appropriate pedagogical approaches for teaching field-based mathematics content. The culminating activity for *Math in the City*, "The Poster Project Display," provided a final evaluation of the course projects, as well as dissemination of the project to the university community.

"The Poster Project Display" combined the visual representation of the fieldtrips with interactive conversation about the project. Each student prepared a colorful, sometimes interactive, tri-fold poster highlighting one *Math in the City* field experience and orally presented the display to an audience of peers, educators, and visitors in the university library. The poster session offered a lively way to reveal the hands-on mathematics course-project and took pre-service teachers beyond the classroom-learning environment. Mathematical shapes and dimensions discovered at Detroit's Elmwood Cemetery were recreated in a three-dimensional tri-fold poster. Mathematical calculations used in music were illustrated featuring Motown's Hitsville USA. Mathematics used in aerospace came alive in several displays representing the Tuskegee Airmen National Museum visit. Guests to "The Poster Project Display" quickly became active mathematics as participants analyzed and discussed baseball statistics, aerodynamics of paper airplanes and bridge-construction facts. The displays were rich with information about the chosen site, and the posters presented various levels of mathematics that could be used in the mathematics classroom. The posters were eye-catching using charts, diagrams, web-sites, drawings, photographs, and other media, such as light and sound, to create interest and generate conversation as guests browsed the booths. "The Poster Project Display" successfully communicated the goals and purpose of the *Math in the City* course-project in an interactive, experiential learning format (see Figure 7).

Figure 7 - The Poster Project Display

Summary

The possibilities for conducting a program such as *Math in the City* are endless. Encouraging other teachers or professional development administrators to uncover mathematics can happen in any urban, suburban, or rural area. Walking tours, visits with elders of the community, historical cemeteries—the landscape can be rich with stories that can be mathematized. The sociocultural theory model provides a rich framework to explore and connect mathematics with culture. We challenge you to help mathematics to come alive for students and teachers K-16. The depth and breath of mathematics was abstracted from real experiences. Our challenge is to create more opportunities and bridges for the many individuals who do not see the connections and interrelations between academic mathematics and life.

References

Duranczyk, I. M., Staats, S., Moore, R., Hatch, J., Jensen, M., & Somdahl, C. (2004). Introductory-level college mathematics explored through a sociocultural lens. In I. M. Duranczyk, J. L. Higbee, & D. B. Lundell (Eds.), *Best practices for access and retention in higher education* (pp.43-53). Minneapolis, MN: Center for Research on Developmental Education and Urban Literacy, General College, University of Minnesota.

Knight, D. (Producer/Director/Editor), & Christopher, R. (Writer). (1999). The underground railroad: Connections to freedom and science. [Video cassette]. Washington DC: National Aeronautics and Space Administration.

Kolb, D. A. (1984). *Experiential learning: experience as the source of learning and development.* Englewood Cliffs, NJ: Prentice-Hall.

Michigan Department of Education. 1998. *Michigan curriculum framework content standards and benchmarks.* Lansing, MI: Author

Moses, R. P. & Cobb, C. E. (2001). *Radical equations: Math literacy and civil rights.* Boston, MA: Beacon Press.

National Council of Teachers of Mathematics. (2000). *Principles and standards for school mathematics.* Reston, VA: Author.

Nelson-Barber, S. & Estrin, E. T. (1995). *Culturally responsive mathematics and science education for native students*. San Francisco: WestEd.

Walls, B. E. (1980). *The road that led to somewhere.* Windsor, Ontario: Olive Publishing.