Gliding through T

Students develop skills as twenty-first century learners and researchers by using Timeglider™ to explore famous mathematicians in a culturally responsive manner.

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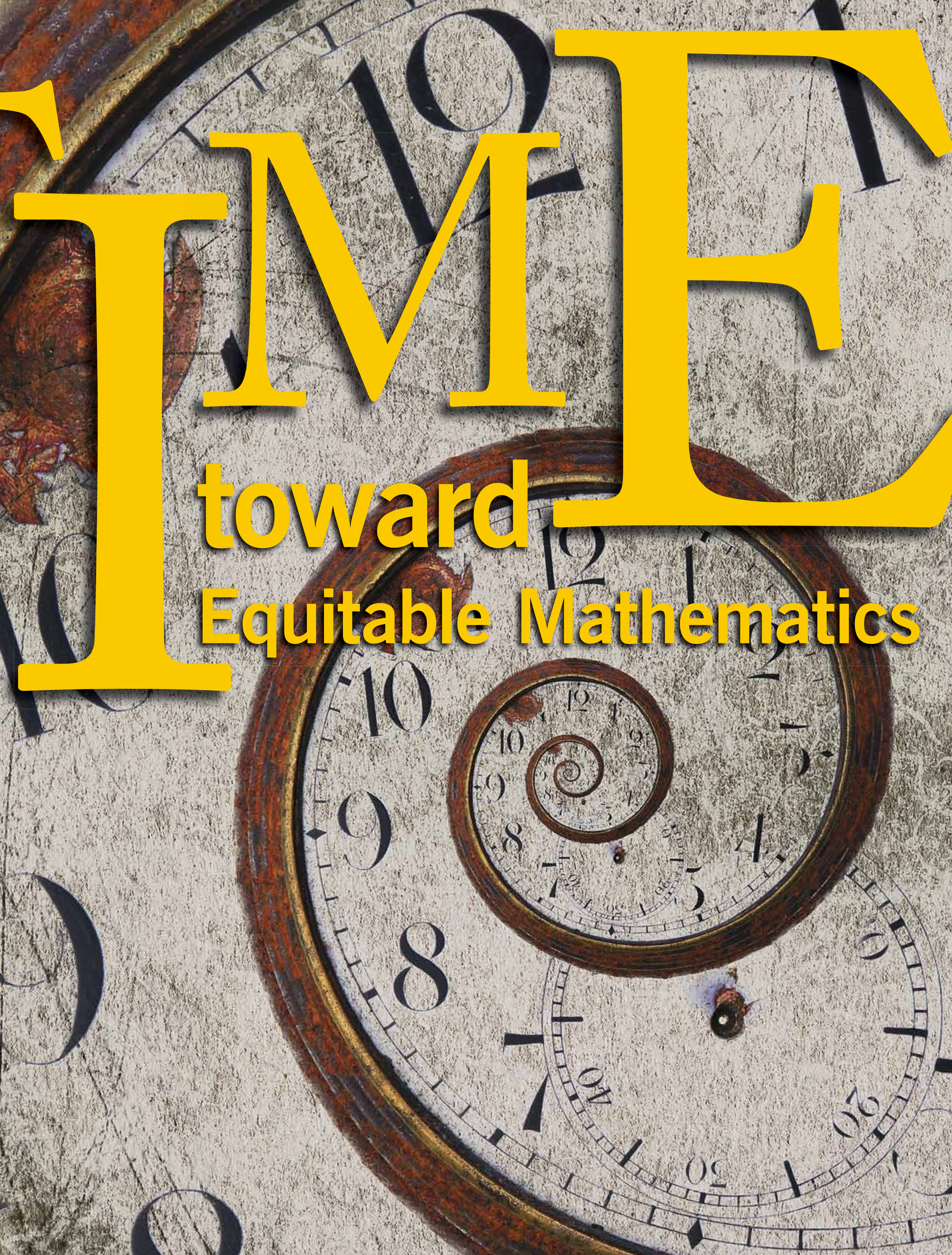
AUDRIUS PRIVEDA/THINKSTOCK

What does a mathematics lesson that is intended to promote equity strive to achieve? If a middle-grades mathematics teacher thought, "I would like to create a lesson that is equitable," what type of work would students engage in? What would be the desired outcomes resulting from students' participation in the activity?

The 2008 NCTM Position Statement on Equity calls for students to "have access to and engage in challenging, rigorous, and meaningful mathematical experiences" and to "build a relationship with mathematics that is positive and grounded in their own cultural roots and history" (NCTM 2008, p. 1). One way that teachers ensure that students receive an equitable education is by helping them develop twenty-first century knowledge and skills (NRC 2012). Larmer and Mergendoller (2010) argued that adept twenty-first century learners use technology effectively; *Principles and Standards for School Mathematics* (NCTM 2000) also posited that technology is essential for teaching and learning mathematics. Proficient twenty-first-century learners also possess media literacy, in that they know how to critically analyze online information to determine its worth, validity, and usefulness (Livingstone 2004; Potter 2012). Cultivating twenty-first-century learners to prepare them for college and careers also aligns with the goals found in the Common Core State Standards for Mathematics (CCSSI 2010).

With these educational objectives in mind, I designed a project intended to support students' growth as twenty-first-century learners and promote equity in learning mathematics. The activity aimed to increase students' cultural understanding of the development of the field of mathematics, enhance their technological knowledge through the use of the Web 2.0 tool Timeglider™, and strengthen their media literacy skills with analytical online research. I titled the assignment, "Influential Figures in Mathematics: An Overview with Web 2.0."

TIME toward Equitable Mathematics



A DESCRIPTION OF THE ACTIVITY

Students completed this project toward the end of the school year after statewide standardized testing had concluded. Approximately 100 seventh-grade students, divided evenly across my four separate class periods, were given this assignment. Each class period lasted one hour.

After I reviewed the project guidelines and grading rubric with students, we convened in one of the school's computer labs for three successive days. Students chose an influential mathematician to research and then used Timeglider to create a timeline of significant life events and mathematical contributions (see **fig. 1**). Timeglider, a free online tool, allows users to create multifaceted and interactive timelines. Students incorporated the traditional biographical information found on a standard timeline but were also able to download relevant equations, graphics, pictures, and links to outside sources (see **fig. 2**).

Although a variety of free web-based timeline programs exist (e.g., Tiki-Toki, Dipity®), Timeglider requires students to use proportional and spatial reasoning as they build their product. A scale from 1 to 100 can display certain events more prominently than others, depending on the significance of the event. A zoom feature requires users to determine a focus level that is proportional to the lifespan of the mathematician and accounts for the number of events on the timeline. Images downloaded onto timelines must be proportional with their relative importance and fit within the viewing window (see **fig. 1**). At the onset of the assignment, to ensure that the projects had a suitable aesthetic appearance, I demonstrated on the Timeglider website how failure to use proportional reasoning affects a timeline.

Fig. 1 Students must use proportional reasoning to determine the appropriate zoom level for their timelines and to fit pictures and event titles within the viewing window.

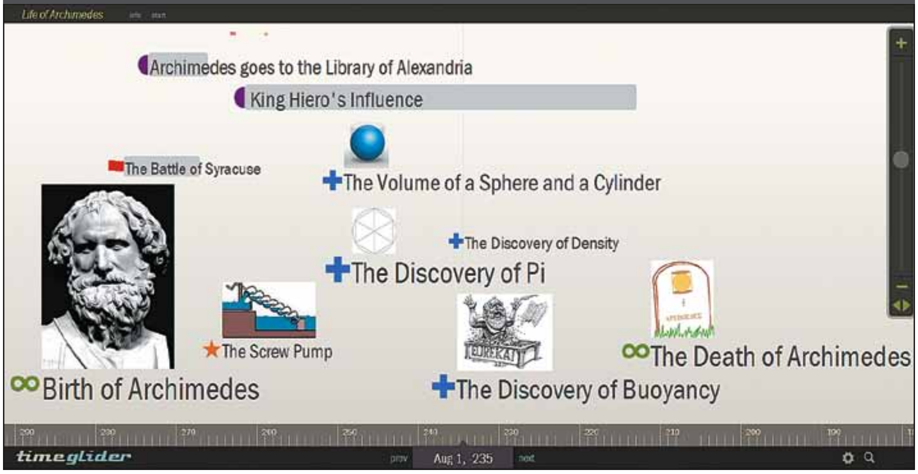
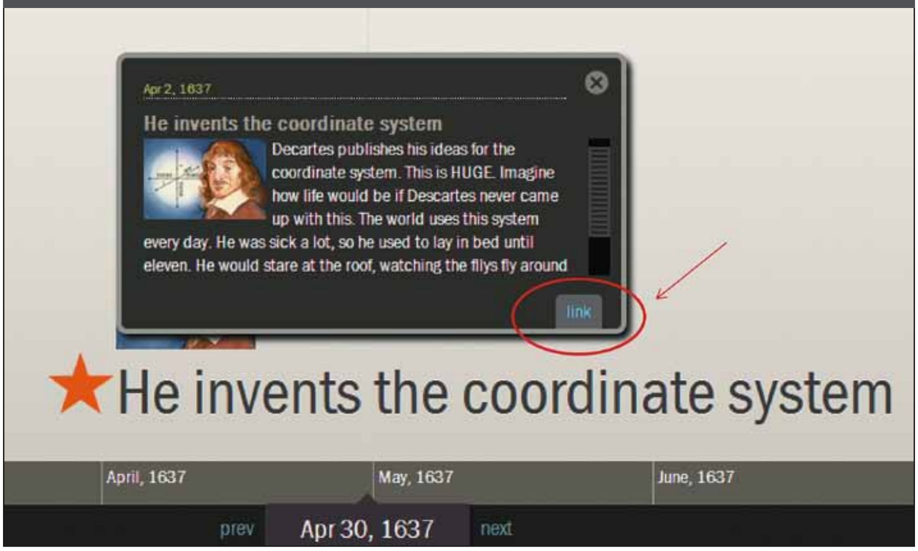


Fig. 2 Clicking on an event title on a Timeglider timeline opens a text box that displays more detailed information about the event. This student also inserted a link to a YouTube video that described how René Descartes (1596–1650) developed the coordinate plane.



In the computer lab, students accessed various websites to gather information about their mathematician. First, they explored a variety of influential mathematicians to determine whom they might like to study in depth. Students typically experienced little difficulty choosing a mathematician who interested them. However, if they were unable to select someone or if another student chose the person they wanted, I had a list available and made suggestions based on my knowledge of the student.

After making their selection, students critically read an array of online material about their choice. They cross-referenced one source of information against another to ascertain what information held the most historical validity. Then they synthesized the most reliable information and inserted it into their timeline. I provided prompts for students to consider as they sifted through their online reading to promote their sense of media literacy and research acumen (e.g., "Who is the author of this webpage?" and "What motives might this author have for writing?"). Students used higher-order thinking skills (Anderson et al. 2001) to complete this activity as they evaluated the credibility and content of the online information they found; synthesized their research into a cohesive body of knowledge; and created an attractive, informative timeline.

After completing their timelines, students used the classroom's interactive whiteboard to share a brief overview of their Timeglider projects with the entire class. Presentations lasted two class periods, so the entire project encompassed five one-hour class periods. However, presentations began on a Monday, so some students worked on their projects over the preceding weekend, which gave them a total of five days to complete their projects.

During their presentations, students explained the most significant contributions their mathematician had made, including any obstacles this person overcame. I wanted students to see the mathematicians as real people rather than distant, fictional characters with whom they had nothing in common. The mathematicians were presented in chronological order. After each presentation, we added the mathematician's name to a large timeline drawn on the board in the front of the room. Students also placed an asterisk on a large world map drawn on the board to denote the individual's birthplace. Blue asterisks represented male mathematicians; red, female mathematicians.

After all the presentations were given, the class discussed connections. I asked, "As you look at the timeline and the world map, what do you notice? Do you see any patterns or recurring themes?" Students noticed the few names scattered between the years 2000 B.C. and the year 0, most of which belonged to Greek mathematicians, such as Pythagoras, Euclid, and Archimedes. They noted the lack of names during the Dark Ages in Europe, from A.D. 476 to 1000. The only names on the timeline during this time period belonged to men from Arab countries, such as Muhammad ibn Musa al-Khwarizmi. Students realized that Arab countries did not experience a Dark Ages period as did Europe and that many advances within the field of mathematics occurred in the Arab world during this time.

Creating equitable learning experiences for students is more than a nice idea or a new trend in mathematics education; it is an ethical and moral pedagogical responsibility.

Mathematical progress began to spread in Europe as European travelers, such as Leonardo of Pisa (Fibonacci), visited Arab countries and brought back newfound mathematical knowledge. Students noticed the abundance of names on the board from the 1400s to 1900s, especially from 1400 to 1700. We discussed why the Renaissance—the "rebirth" of learning—occurred in Europe and how advances in mathematics stemmed from Renaissance thinkers studying the work of such ancient Greek mathematicians as Pythagoras and Euclid.

Students made several observations during the discussion that allowed us to address equity in mathematics. Some students acknowledged the paucity of females and non-Westerners represented on the timeline and world map. No names on the board belonged to mathematicians from Central or South America. I alluded to the ancient Aztec, Inca, Maya, and Olmec civilizations, all of which built elaborate pyramids, and asked students, "Didn't these civilizations use math for their architecture? Why, then, did no one research a famous mathematician from this part of this world?" Most students had not heard of al-Khwarizmi, even though he is often referred to as the Father of Algebra. I questioned the class: "Given al-Khwarizmi's influential role in the development of algebra, why do you think that you have never heard of him?"

It surprised students to see so few American mathematicians represented on the world map, until they recalled that the United States is a relatively young country. We pondered aloud the differences between patriotism and ethnocentrism. This series of didactic exchanges fostered intellectual discourse, piqued students' curiosity, challenged their paradigms, and heightened their awareness of issues involving equity and social justice (Bartell 2013; Wager and Stinson 2012). Gregson (2013) urged teachers to "talk openly with students about complex social problems that might be explored with mathematics" to stimulate their interest and incite their desire to pursue mathematical knowledge as a means to achieve their goals and solve societal problems (p. 193).

EVIDENCE OF LEARNING AND EQUITY

Students wrote a summary explaining what they learned from the project and described their experience using Timeglider. I wanted to determine how a research project that required students to use a Web 2.0 tool influenced their motivation and interest in the assignment. I also wanted to see how their understanding of math changed as a result of the activity and if the project facilitated what Fink (2003) described as a *significant learning experience*. Significant learning experiences transform the way students view themselves, others, and the world. Students responded to the following two writing prompts:

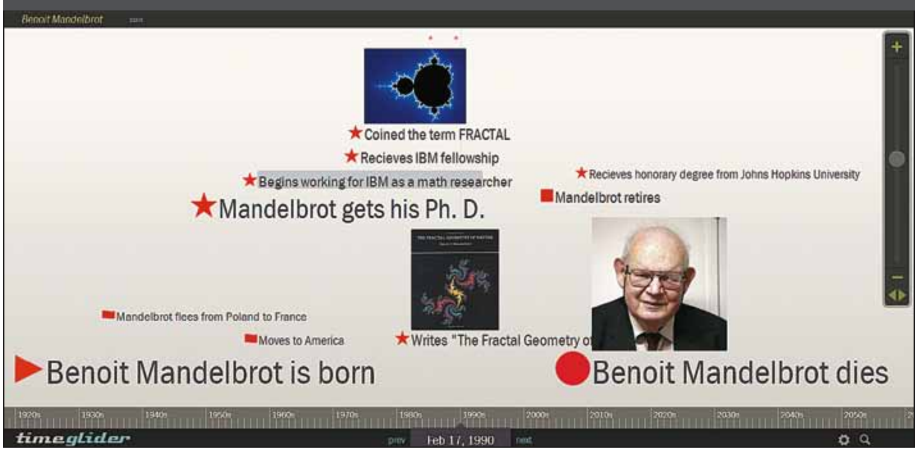
- Who do you think is the most influential, or important, mathematician and why? Which mathematician do you think has had the most enduring impact within the field of mathematics or on society as a whole?
- How did your understanding of math change as a result of this assignment? Consider your experience researching the mathematician you chose and your experience seeing your classmates' presentations.

The following are two student observations:

> I think Emmy Noether was an influential mathematician because she was one of the first women to be widely recognized and respected for her mathematical theories. In the 1920s and 1930s, she was discriminated against as a female and as a Jew. When she died, Albert Einstein wrote a letter to the *New York Times* stating that she was 'the most significant creative mathematical genius thus far produced since the higher education of women began.' So I think she is a very important mathematician.

> I think that Leonardo of Pisa, or Fibonacci, was the most important mathematician, because, after he returned from studying in northern Africa, he introduced the base ten number system to Europe. This helped replace the inefficient Roman numeral system used throughout Europe at the time. In the thirteenth century, Fibonacci introduced the Western world to the Hindu-Arabic number system, which helped pave the way for the Renaissance, and that changed everything.

Fig. 3 Students often researched mathematicians of their same culture, ethnicity, or gender. For example, a Jewish student chose to study the life of Jewish mathematician Benoît Mandelbrot (1924–2010), who fled from Poland to Paris in 1936 to escape Nazi persecution.



The seventh-grade students who participated in this activity attended an ethnically diverse suburban middle school. The school's student population was approximately 38 percent Caucasian, 22 percent African American, 20 percent Asian, 15 percent Hispanic/Latino, and 5 percent multiracial, which underscored the importance of providing culturally responsive curricula. Many students researched mathematicians whose cultural roots resembled their own (see **fig. 3**). An Asian student, who researched Muhammad ibn Musa al-Khwarizmi, wrote:

> I think Muhammad al-Khwarizmi is the most important figure because he is considered the Father of Algebra. Most of what we have learned this year is algebra, and he invented things we've studied, like the Distributive Property. His work also contributed to the Hindu-Arabic base ten number system that spread throughout Europe in the 1300s and 1400s.

Students from Middle Eastern countries experienced feelings of pride and renewed dignity as they realized that someone with whom they shared a cultural heritage influenced the curriculum they studied throughout the school year. In another summary, an Indian student described how inspired he was to learn about Indian mathematician Srinivasa Ramanujan, given that Ramanujan was born into poverty and was largely self-taught.

Students' summaries suggested that the project accomplished the intended objectives and engendered a significant learning experience. Through their research, presentations, class discussion, and reflective written responses, students made connections among mathematics and history, geography, culture, religion, politics, and science. They gained a global awareness of how advances within the field of mathematics developed through time, were inextricably bound to the cultural milieu and historical context in which they occurred, and contributed to modern-day society.

PROMOTING SELF-EFFICACY AND IDENTITY DEVELOPMENT

According to social cognitive theory (Bandura 1986, 1997), students can learn through vicarious experience (i.e., observing models). For example, “observing success in others who are similar” increases students’ self-efficacy and achievement in mathematics (Schunk and Richardson 2011, p. 16). In this activity, studying mathematicians whose gender or cultural heritage reflected their own enhanced students’ self-efficacy as mathematical learners. For instance, many female students indicated in their summaries that they found Ada Byron (see **fig. 4**), Emmy Noether, and Ingrid Daubechies to be particularly meaningful to them.

Students’ ability to identify individuals within the school environment (e.g., peers, teachers) who are similar to them predicts their academic engagement and achievement (Steele 1997, 2003; Voelkl 2012; Whaley 2012). Students who cannot identify themselves within the school environment often look to sources outside the classroom to develop a positive self-concept; consequently, they often disengage from school (Skinner and Pitzer 2012; Steele 1997, 2003). This project enabled students to more readily identify themselves within the academic setting because they could see themselves vicariously through the mathematicians they studied or otherwise learned about during their classmates’ presentations.

What students believe about their identity as math students, or what Bishop (2012) referred to as their “mathematics identity” (p. 35), impacts their disposition toward learning mathematics (Zollman, Smith, and Reisdorf 2011). It is important that teachers nurture all students’ mathematics identity in light of disproportionately low female, African American, and Hispanic/Latino enrollment in advanced high school and college mathematics courses and in science, technology, engineering, and mathematics (STEM) career fields (Burke and Mattis 2007; Griffith 2010; O’Brien, Martinez-Pons, and Kopala 1999). Learning experiences, such as the type described in this article, bolster female and minority students’ self-efficacy, increase their mathematical knowledge, and change the way they view themselves as math students. Such experiences help open the door, so that students can then pursue advanced mathematics classes and STEM-based careers (Aguirre, Mayfield-Ingram, and Martin 2013; Cobb and Hodge 2002, 2011; Nasir and Cobb 2007; Turner et al. 2013).

Fig. 4 Students enjoyed learning about influential female mathematicians, such as Ada Byron, Lady Lovelace (1815–1852).

REFLECTION

This project promoted equity and enabled students to find meaning in mathematics. Students developed greater proficiency as twenty-first century learners through their critical online research and use of Timeglider technology. They realized how multiple cultures throughout history contributed to the field of mathematics and how these contributions influenced the concepts they learned throughout the school year. They saw and learned that although women did not have equal access to learning or the same educational opportunities as men, when given the chance, they produced mathematical innovations that benefited society. They discovered valuable mathematical advances generated by members of their respective gender and culture, which, in turn, transformed how they viewed themselves as math students.

Creating equitable learning experiences for students is more than a nice idea or a new trend in mathematics education; it is an ethical and moral pedagogical responsibility. However, engaging students in mathematical tasks that are both “challenging” and “grounded in their own cultural roots and history” (NCTM 2008, p. 1) can be a delicate endeavor and difficult to achieve (Bartell 2013; Gregson 2013; Wager and Stinson 2012). This project did not teach a specific mathematical algorithm, skill, or procedure. It did, however—

- extend students’ prior knowledge of certain mathematical concepts, such as pi and the Cartesian plane, including their historical and modern-day applications;

- introduce students to advanced concepts that they might eventually study more in-depth and, in turn, pique their curiosity (e.g., Euler's formula and Mandelbrot's fractal geometry);
- strengthen students' skills as twenty-first-century learners; and
- illuminate their respective culture's stitch within the fabric of mathematical knowledge.

Collectively, these learning outcomes fostered equity in mathematics education by deepening students' appreciation for the subject and enhancing their sense of self-efficacy and identity as mathematical learners.

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REFERENCES

Aguirre, Julia, Karen Mayfield-Ingram, and Danny Martin. 2013. *The Impact of Identity in K–8 Mathematics: Rethinking Equity-Based Practices.* Reston, VA: National Council of Teachers of Mathematics.

Anderson, Lorin, David Krathwohl, Peter Airasian, Kathleen Cruikshank, Richard Mayer, Paul Pintrich, James Raths, and Merlin Wittrock. 2001. *A Taxonomy for Learning, Teaching, and Assessing: A Revision of Bloom's Taxonomy of Educational Objectives*. New York: Longman.

Bandura, Albert. 1986. *Social Foundations of Thought and Action: A Social Cognitive Theory.* Englewood Cliffs, NJ: Prentice-Hall.

———. 1997. *Self-Efficacy: The Exercise of Control*. New York: Freeman.

Bartell, Tonya Gau. 2013. "Learning to Teach Mathematics for Social Justice: Negotiating Social Justice and Mathematical Goals." *Journal for Research in Mathematics Education: Special Equity Issue* 44 (January): 129–63. doi:http://dx.doi.org/10.5951/jresematheduc.44.1.0129

Bishop, Jessica Pierson. 2012. " 'She's Always Been the Smart One. I've Always Been the Dumb One': Identities in the Mathematics Classroom." *Journal for Research in Mathematics Education: Special Equity Issue* 43 (1): 34–74. doi:http://dx.doi.org/10.5951/jresematheduc.43.1.0034

Burke, Ronald J., and Mary C. Mattis, eds. 2007. *Women and Minorities in Science, Technology, Engineering and Mathematics: Upping the Numbers*. Northampton, MA: Edward Elgar Publishing.

Cobb, Paul, and Lynn Liao Hodge. 2002. "A Relational Perspective on Issues of Cultural Diversity and Equity as They Play Out in the Mathematics Classroom." *Mathematical Thinking and Learning* 4 (2): 249–84. doi:http://dx.doi.org/10.1207/S15327833MTL04023_7

———. 2011. "Culture, Identity, and Equity in the Mathematics Classroom." In *A Journey in Mathematics Education Research: Insights from the Work of Paul Cobb*, edited by Erna Yackel, Koeno Gravemeijer, and Anna Sfard, pp. 179–95. New York: Springer.

Common Core State Standards Initiative (CCSSI). 2010. Common Core State Standards for Mathematics. Washington, DC: National Governors Association Center for Best Practices and the Council of Chief State School Officers. http://www.corestandards.org/assets/CCSSI_Math percent20Standards.pdf

Fink, L. Dee. 2003. *Creating Significant Learning Experiences: An Integrated Approach to Designing College Courses*. San Francisco, CA: Jossey-Bass.

Gregson, Susan A. 2013. "Negotiating Social Justice Teaching: One Full-Time Teacher's Practice Viewed from the Trenches." *Journal for Research in Mathematics Education: Special Equity Issue* 44 (January): 164–98.

Griffith, Amanda L. 2010. "Persistence of Women and Minorities in STEM Field Majors: Is It the School That Matters?" *Economics of Education Review* 29 (6): 911–22.

Larmer, John, and John R. Mergendoller. 2010. "Seven Essentials for Project-Based Learning." *Educational Leadership* 68 (1): 34–37.

Livingstone, Sonia. 2004. "Media Literacy and the Challenge of New Information and Communication Technologies." *The Communication Review* 7 (1): 3–14.

Nasir, Na'ilah Suad, and Paul Cobb, eds. 2007. *Improving Access to Mathematics: Diversity and Equity in the Classroom.* New York: Teachers College Press.

National Council of Teachers of Mathematics (NCTM). 2000. *Principles and Standards for School Mathematics.* Reston, VA: NCTM.

———. 2008. NCTM Position Statement on Equity in Mathematics Education. http://www.nctm.org/about/content.aspx?id=39817

National Research Council (NRC). 2012. *Education for Life and Work: Developing Transferable Knowledge and Skills in the 21st Century*. Washington, DC: National Academies Press.

O'Brien, Virginia, Manuel Martinez-Pons, and Mary Kopala. 1999. "Mathematics Self-Efficacy, Ethnic Identity, Gender, and Career Interests Related to Mathematics and Science." *The Journal of Educational Research* 92 (4): 231–35. doi:http://dx.doi.org/10.1080/00220679909597600

Potter, W. James. 2012. *Media Literacy*. 6th ed. Thousand Oaks, CA: Sage Publications.

Schunk, Dale H., and Kerri Richardson. 2011. "Motivation and Self-Efficacy in Mathematics Education." In *Motivation and Disposition: Pathways to Learning Mathematics*, edited by Daniel J. Brahier and William R. Speer, pp. 13–30. Reston, VA: National Council of Teachers of Mathematics.

Skinner, Ellen A., and Jennifer R. Pitzer. 2012. "Developmental Dynamics of

Student Engagement, Coping, and Everyday Resilience." In *Handbook of Research on Student Engagement*, edited by Sandra L. Christenson, Amy L. Reschly, and Cathy Wylie, pp. 21–44. New York: Springer.

Steele, Claude M. 1997. "A Threat in the Air: How Stereotypes Shape Intellectual Identity and Performance." *American Psychologist* 52 (6): 613–29. doi:http://dx.doi.org/10.1037/0003-066X.52.6.613

———. 2003. "Race and the Schooling of Black Americans." In *Understanding Prejudice and Discrimination*, edited by Scott Plous, pp. 98–107. New York: McGraw-Hill.

Timeglider/Mnemograph. Timeglider (software). timeglider.com

Turner, Erin, Higinio Dominguez, Luz Maldonado, and Susan Empson. 2013. "English Learners' Participation in Mathematical Discussion: Shifting Positionings and Dynamic Identities." *Journal for Research in Mathematics Education: Special Equity Issue* 44 (January): 199-234. doi:http://dx.doi.org/10.5951/jresematheduc.44.1.0199

Voelkl, Kristin E. 2012. "School Identification." In *Handbook of Research on Student Engagement*, edited by Sandra L. Christenson, Amy L. Reschly, and Cathy Wylie, pp. 193–218. New York: Springer. doi:http://dx.doi.org/10.1007/978-1-4614-2018-7_9

Wager, Anita A., and David W. Stinson, eds. 2012. *Teaching Mathematics for Social Justice: Conversations with Educators.* Reston, VA: National Council of Teachers of Mathematics.

Whaley, Arthur L. 2012. "Effects of Ethnic/Racial Identification on Case-Based Learning Outcomes in a Psychology Course at a Historically Black College/University." *Journal of Cognitive Education and Psychology* 11 (1): 79–93. doi:http://dx.doi.org/10.1891/1945-8959.11.1.79

Zollman, Alan, M. Cecil Smith, and Patricia Reisdorf. 2011. "Identity Development: Critical Component for Learning in Mathematics." In *Motivation and Disposition: Pathways to Learning Mathematics*, edited by Daniel J. Brahier and William R. Speer, pp. 43–53. Reston, VA: National Council of Teachers of Mathematics.

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