Chapter Nine

Rethinking Art in Mathematics and Science

Jeff Sapp

INTRODUCTION

I didn't come to art naturally. I taught high school math and middle school math and science for years before I ever considered art as a comrade. Two things caused me to embrace art. First, I noticed how students valued artistic expression in how they dressed and put themselves together each day, how they decorated their textbook covers and notebooks, and how they doodled during lectures. Secondly, I increasingly became aware that when I did anything artistic—whether it was through assigning graphic organizers, using posters with colored markers for students to show comprehension, incorporating music as a way to show the relevance of math, or showing pictures of Fibonacci patterns in nature—whatever artistic outlet I used suddenly increased attention, motivation, and comprehension. I became a STEM teacher increasingly intrigued by the power of art. I wanted to learn more.

In many ways the arts continue to be an equity issue for children. I currently work with California State University Dominguez Hills' Urban Teacher Residency (UTR) and Transition to Teaching (TTT) programs that place math and science teachers in the lowest performing schools in Los Angeles Unified School District (LAUSD). One of the goals is to get competent and dedicated educators to stay in these high-needs schools, as there is a high attrition rate for professionals. The arts are around, but the drive in many schools is still singularly focused on increasing standardized test scores. Period. In the schools I work with, many of which are in working class areas, the arts are often considered the "fluff" mentioned earlier. I was intrigued to

Table 9.1. Percentage of K-8 Students in After School Art Programs

What is the percentage of K-8 students in after school arts programs?	
Households that make under $15K	= 6%
$15–30K	= 9%
$30–50K	= 14%
$50–75K	= 20.3%
$75K+	= 30%

find a study that looked at arts and affluence (McMullen, 1968). What the study found was that the wealthier the household the more the children in that household were given opportunities to immerse themselves in art.

Okay, so what do wealthier households know about art that I don't know and how will it benefit students? For one, students who study art have higher grades, score better on standardized tests, have better attendance records and are more active in their communities. Why? One reason is that the arts change the brain by strengthening students' ability to focus, keep their attention on a task, delay gratification, and manage their emotional states of patience, flow, and self-discipline. These are all skills that our LAUSD students need desperately and I was "in" about the power and impact of art and have spent years integrating art into mathematics and science.

STORY OF SUCCESS

Ladson-Billings (1995) coined the term *culturally relevant pedagogy* and defined it as a way of teaching that "not only addresses student achievement but also helps students to accept and affirm their cultural identity while developing critical perspectives that challenge inequities that schools (and other institutions) perpetuate" (p. 469). I certainly saw this play out well with one of my university student-teacher candidates. He taught in a predominantly Latino community (98% of his high school students were Latinos) and he developed a set of primary documents showing Mayan mathematics. Because it was his own culture as well as the culture of most of his students, and because he hand-drew beautiful and intricate pieces highlighting various contributions of the Mayans, he stated, "I could actually see my students literally lean in to math for the first time. Honestly, I've never seen my students be more engaged and curious about math as I did the day I used my set of primary documents." The personal and cultural aspects of his set of primary documents—a set that beautifully affirmed his and his students' cultural identity—unleashed a number of critical questions from his students: "Why have I never seen this before in a math class?" "Who writes the math books and why did they leave us out?" "What else are they not telling us?" "How can we find out more about what the Mayans did?" A group of students decided to explore these questions with their teacher after school and then report back to the class. Over the course of several years, this has led to the walls of the classroom becoming an exploration of "mathematics outside the textbook," as the students have named it.

CONNECTION TO MULTICULTURAL EDUCATION/ MULTICULTURAL CURRICULUM TRANSFORMATION

The critical multicultural aspects of these sets of primary documents lie in students questioning, confronting, and challenging why their cultural identity groups might not be represented in mathematics and science, what Gay (2004) refers to as "curriculum desegregation." The engaging reality that their identity group is suddenly visible in an otherwise invisible curriculum is simply the hook, but not the reason for the use of these primary documents. One teacher showed numerous women in the historical canon of science, most of whom students had never heard of before. The teacher listens for the "Why?" question and can facilitate conversations around patriarchy, misogyny, and sexism—conversations not often happening in math and science classrooms. This further moves the teaching of mathematics and science to an "equity pedagogy" that Gay (2004) describes as an education that "places value on *how* to effectively teach diverse students as well as *what* to teach them." Furthermore, besides curriculum desegregation and equity pedagogy, there is a humanizing pedagogy surrounding the use of these primary documents as well. This humanizing pedagogy can be seen by students' responses to seeing their cultural identities in the classroom, but perhaps more so by looking at more personal aspects of important people in the mathematics and science canons. One teacher, for instance, included the love letters written between Charles Darwin and his partner Emma Wedgwood, with whom the father of evolution spent over forty years with and raised ten children alongside (Burkhardt, 1994). No one in the class had ever heard of Wedgwood or that Darwin had children. Suddenly, Darwin was a person and not just a topic (Buber, 1971). A humanizing pedagogy moves topics from an "it" (an object) to a "thou" (a subject).

CONCRETE EXAMPLES IN STEM MULTICULTURAL CURRICULUM TRANSFORMATION

Primary documents and sources are snippets of history and life. They are often incomplete and come with little context and, consequently, they require students to be analytical, to examine sources thoughtfully, and determine what else they need to know to make inferences from the materials. Primary documents and sources also help students relate in a personal way to events of the past and help them come away with a deeper understanding of history as a series of human events, often of which they themselves are a part. Many textbooks today are full of colorful visuals that are nothing more than window dressing. Teachers can go far beyond window dressing and have students focus on the symbols and metaphors in editorial cartoons, dramatic qualities of photographs, the potential of images to make abstract ideas and concepts become concrete, and interrogate the implicit biases and stereotypes in certain images. Used these ways, the implementation of primary documents in mathematics and science easily meet many curriculum standards required of professional educators today.

Inviting students to bring in their personal "funds of knowledge" (Moll, 2005) allows for important family and community conversations to occur. It never ceases to surprise me when students bring in primary documents related to a topic we are studying and I find out that they have a close relative who has played a key role in the topic at hand, like a recent student who shared that his uncle is a Nobel Prize–winning chemist.

One of the reasons students are thrilled to be creating primary documents themselves is the availability of technology today. Students can scan photographs and documents, leaving the originals safe at home. They can print famous documents—easily accessible through dozens of museum archives online—and use sepia tones and different paper stock to make them look and feel authentic. I stand in awe of the creative power that becomes unleashed when I invite students to create documents around a mathematics or science topic.

Anticipatory Activities and Primary Documents

Anticipatory activities are meant to elicit curiosity, provoke questions, and activate students' background knowledge. I find them a wonderful place to infuse art with mathematics and science. A favorite anticipatory activity involves creating a set of primary documents around a concept as a way to introduce and intrigue students about the topic. This anticipatory activity is meant to grab students and "hook" them into a topic they've been reluctant about in the past. Some of the primary documents are hand drawn, others are photographs that are printed out on photo paper so as to make them feel more authentic, others are printed on card stock, and some are soaked in tea to give them both an aromatic and textural feel. Students go wild for the visual and kinesthetic feel of these documents and, even more so, they feel like they're pryingly getting into someone else's personal property, which engages them in math and science in ways I've not seen before.

I teach methods courses for math and science teachers. It is the work of our beginning math teachers that I wish to share with you. As always, the quality of work students provide inspires me. The ones in this chapter are examples that demonstrate how mathematics can be infused with elements of race, ethnicity, and gender.

Curriculum Overview

This particular assignment was left open and broad so as to invite as much creativity as possible. The only requirements were these:

1. Create a minimum of ten primary documents.
2. Place a notation on the backside of each document giving as much content as possible about it.
3. You must vary the documents so that the set contains different visual and tactile pieces to engage your peers. For instance, some photographs, use different stocks of paper, soak a document in tea, burn the edges of one, hand write or draw others.
4. Write a one-page description of how the documents fit within your teaching.
5. Place all items in a large self-contained envelope.
6. Be sure to make a copy of your work to keep as you'll be donating the set you hand in "to the cause."

Curriculum Specifics

What I love about the first primary document below is that Jessica included an actual example of a simple quipus as well as the photograph of an older example with more cords. I love the color-coded visual and accompanying explanation because simply reading the description I can see the values, but it's even more fun to kinesthetically handle an actual quipus.

The next set of primary documents introduces five great women of mathematics in a way that would reach reluctant readers as well as reluctant mathematicians. Students learn about Maria Gaetana Agnesi, Caroline Herschel, Florence Nightingale, and Sofia (or Sonya) Kovalevskaya. This pink set of documents was presented as a booklet that students could easily flip through and Veronica mentioned that she "created several sets so that when my students finished their seatwork, they could flip through these and learn about these great women." I love how she wrote in the voice of each of these important women.

In figure 9.3 you see the work of Jose, who hand-drew these original, intricate drawings. He was so engaged with this activity because it invited him

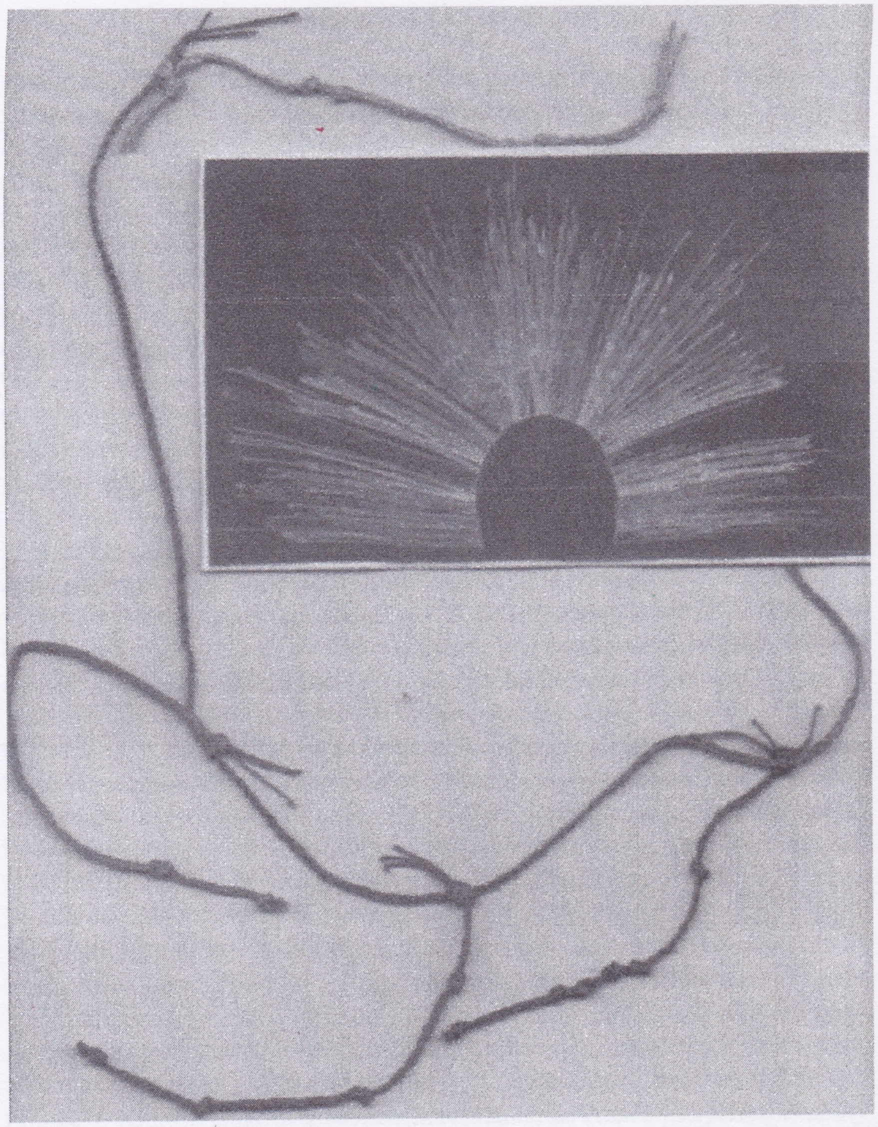


Figure 9.1. Set of primary documents on *Ancient Number Systems*. Created by Jessica Guyon. Written on the back: Quipus or khipus (sometimes called talking knots) were recording devices used in the Inca Empire and its predecessor societies in the Andean region. A quipu usually consisted of colored, spun, and plied thread or strings from llama or alpaca hair. It could also be made of cotton cords. The cords contained numeric and other values encoded by knots in a base ten positional system. Quipus might have just a few or up to 2,000 cords. Each cluster of knots is a digit, and there are three main types of knots: simple overhand knots, "long knots" consisting of an overhand knot with one or more additional turns, and figure-of-eight knots. In the Aschers' system a fourth type of knot—figure-of-eight knot with an extra twist–is referred to as an "EE." A number is represented as a sequence of knot clusters in base 10. The example is a simple example where the blue cord represents 41, the red represents 111, the turquoise represents 1, and the yellow represents 22.

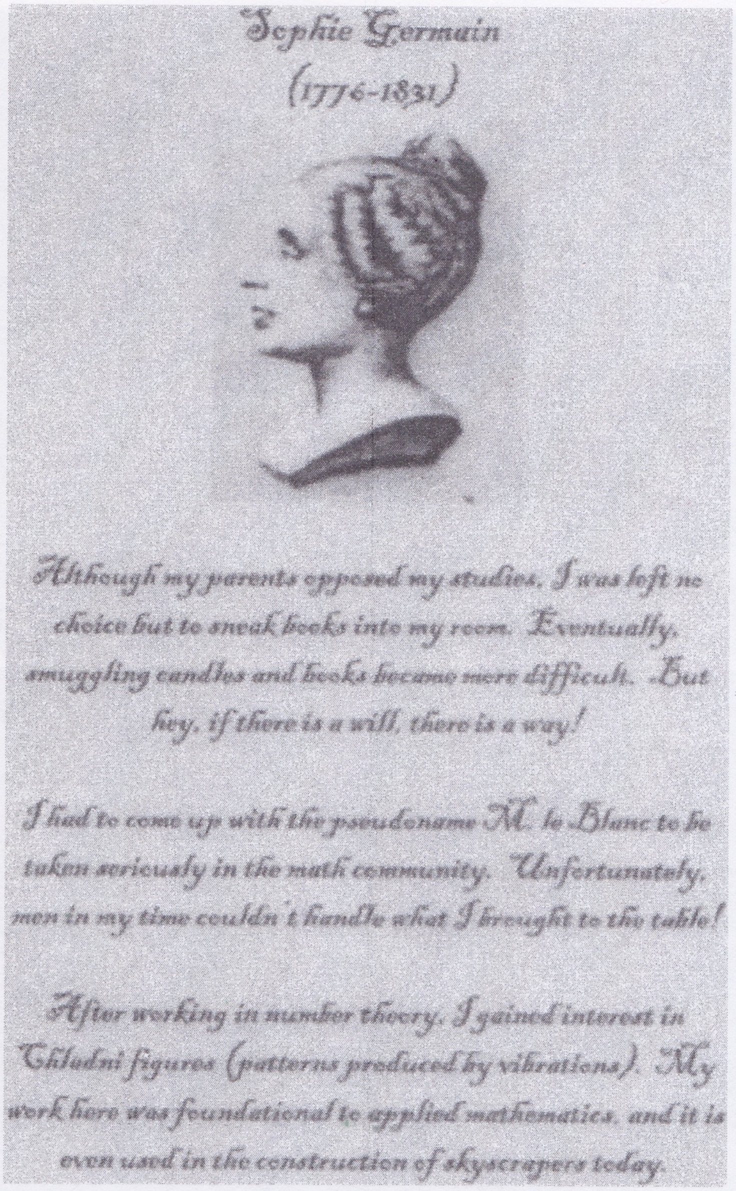
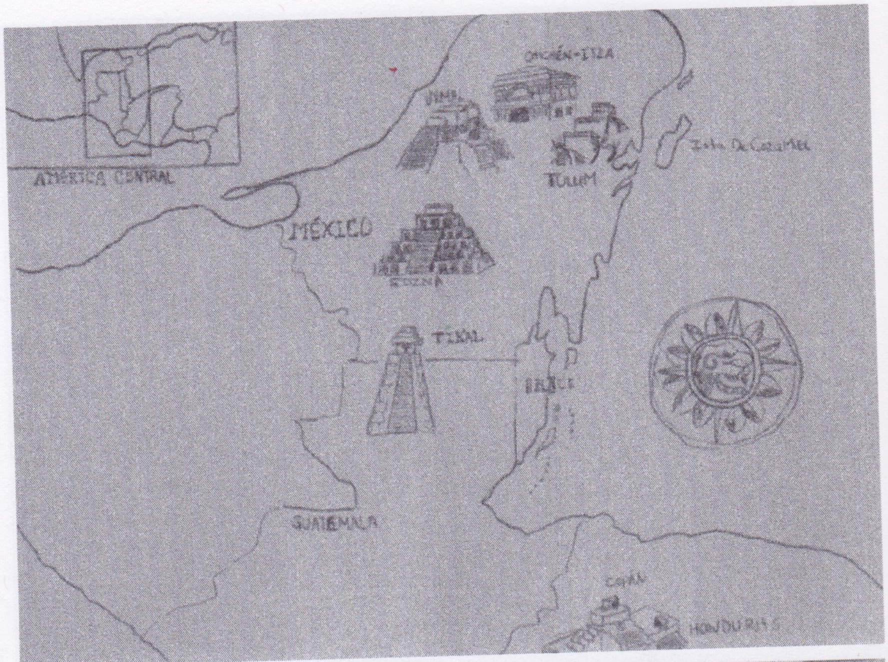


Figure 9.2. Set of primary documents on *Famous Women Mathematicians You Probably Never Heard of*. Created by Veronica López. What it says: Sophie Germain (1776–1831) "Since my parents opposed my studies, I was left no choice but to sneak books into my room. Eventually, smuggling candles and books became more difficult. But hey, if there is a will, there is a way! I had to come up with the pseudo name M. le Blanc to be taken seriously in the math community. Unfortunately, men in my time couldn't handle what I brought to the table! After working in number theory, I gained interest in Chladni figures (patterns produced by vibrations). My work here was foundational to applied mathematics, and it is even used in the construction of skyscrapers today."



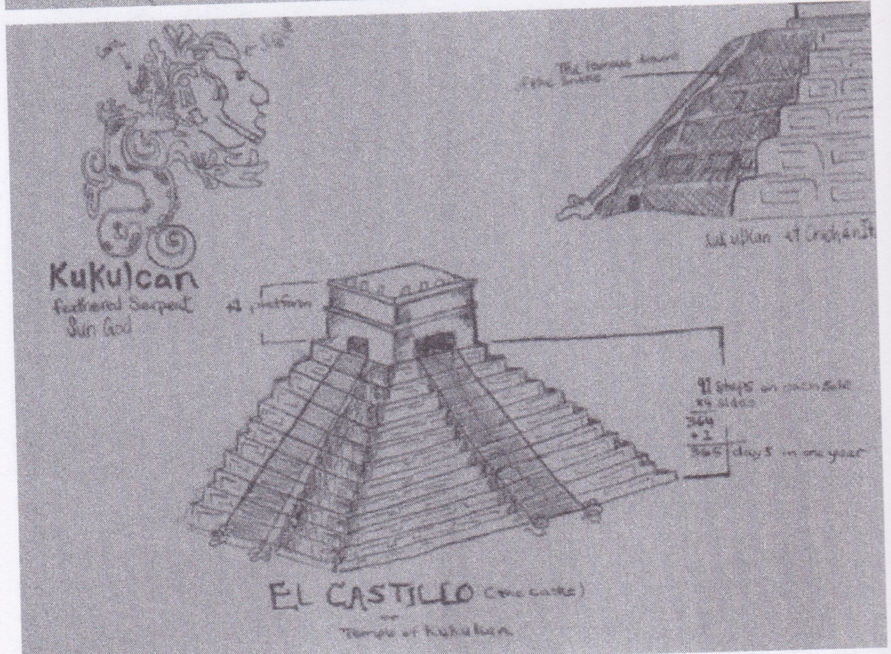


Figure 9.3. Set of primary documents on *Mayan Mathematics*. Created by Jose Antonio Casillas. Top: What it says on the back: The map of Central Mexico and the main pyramids of the Mayans. Bottom: What is says on the back: The Temple of Kukulcan was built 91 steps high. It had 4 sides bringing it to a total of 364 (91 x 4 = 364) plus the top platform to a total of 365. The temple was a calendar for the Maya and served as a guide for the Maya to harvest and plant.

to show how his own cultural heritage has impacted mathematics. They were drawn on hard stock paper.

Figure 9.4 adds the culture of many of this teacher's students into mathematics. Sheeveta stated that she works "with a Latino population of 98%, so I knew these documents would make a good engagement activity to teach students about distant descendants from their culture and how they used math during that time." I particularly liked what she did with the Mayan Dresden Codex (figure 9.5) by dipping the crinkled paper into tea to give it both smell and texture.

Figure 9.6 includes a simple, but effective idea of making a Xerox copy of a document and then posting the copy onto cardboard in an effort to give the document texture. Jessica and the others created comprehensive packets of primary documents on the Mayans and it was one of the more popular sets to create.

In figure 9.7, it is the intention of the educator, January, that she "show these to students to show how different the number systems were in the past from different cultures and different countries. We think that it's important that students see how the numbers evolved over time." KC writes that he'd use the documents to "help students gain an historical and cultural perspective on the history of math." Over a dozen different cultures were represented in their documents.

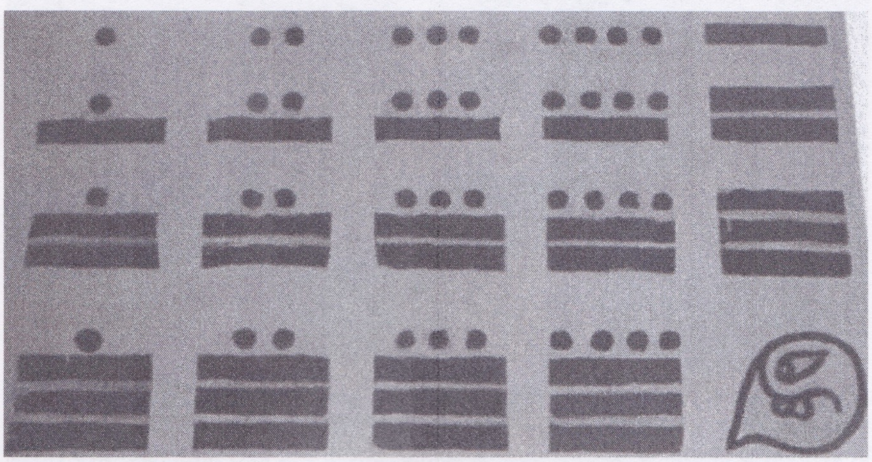


Figure 9.4. Set of primary documents on *The Cultural Histories of the Aztecs and Mayans.* Created by Sheeveta M. Jackson. What it says on the back: Maya numerals (otherwise known as Mayan numerals) were a vigesimal (base-twenty) numeral system used by the Pre-Columbian Maya civilization. The numerals are made up of three symbols: zero (shell shape), one (a dot), and five (a bar).

Figure 9.5. What it says on the back: The Mayan Dresden Codex is the oldest known book written in the Americas. This is the document that contains the Mayan numerals of bars shells (meaning "zero"), dots (meaning "one"), and bars (meaning "five"). The Dresden Codex also contains amazingly accurate astronomical tables.

Figure 9.6. Set of primary documents on *Ancient Number Systems.* Created by Jessica Guyon. What it says on the back: The Mayan had a second Number System that they used for dating buildings and on calendars. This would be a more formal system rather than a number system used for calculation. The numerical glyphs can be seen on monuments and codices as normal-form (bar-and-dot) glyphs, or as glyphs known variously as head-variant glyphs or portrait glyphs. Portrait glyphs are just that, portraits of the gods that are the integers. They're also called head variants because only the head is shown. In the vast majority of cases, only a portion of the head is shown, although full heads do exist.

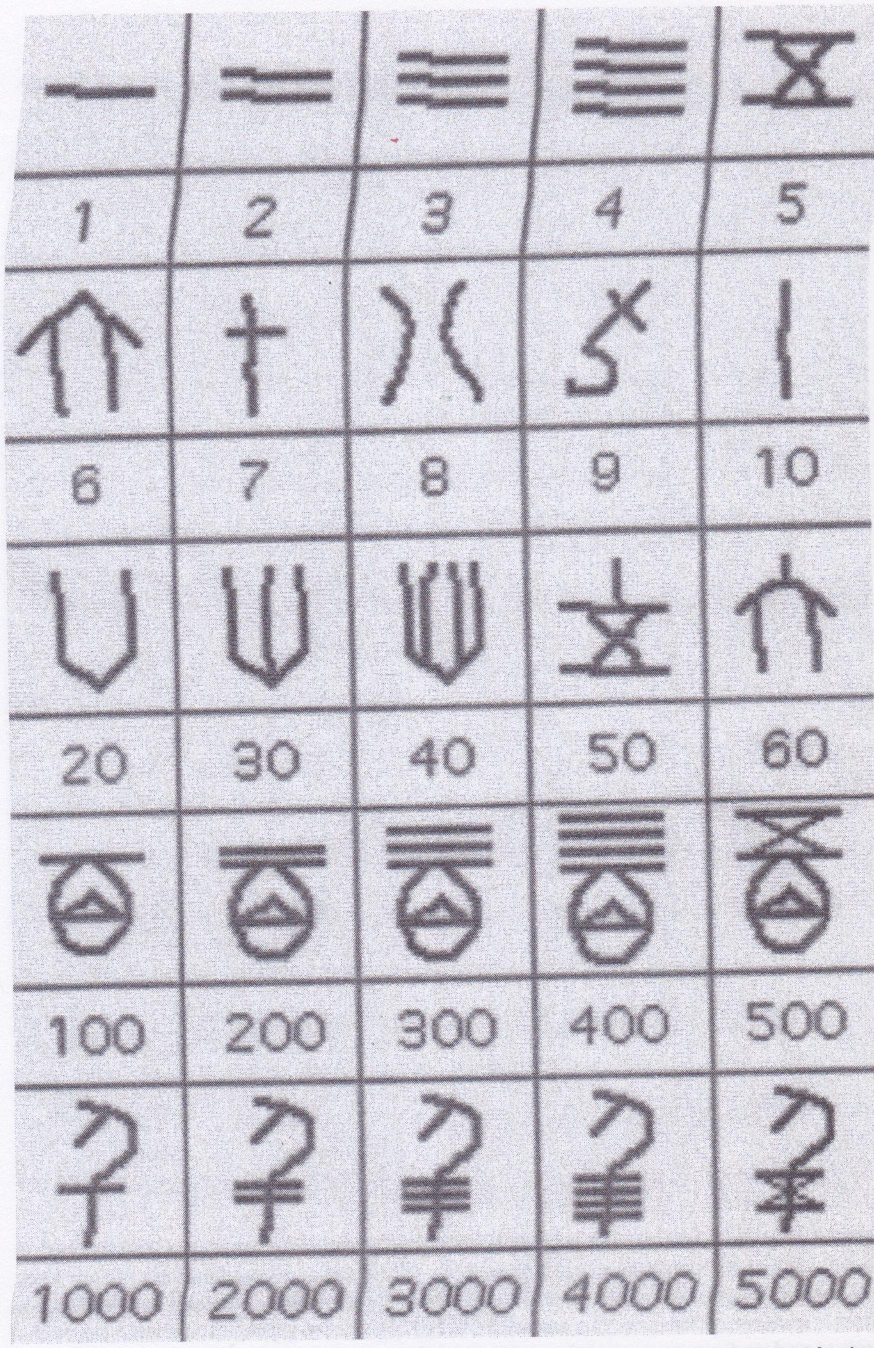


Figure 9.7. Set of primary documents on *The Evolution of the Counting Numbering System*. Created by January Camero and K. C. Gobble. What it says on the back: Chinese Numeral Systems. The Chinese had one of the oldest systems of numerals that were based on sticks laid on tables to represent calculations.

Figure 9.8. Set of primary documents on *The Evolution of the Counting Numbering System*. Created by January Camero and K. C. Gobble. What it says on the back: A cuneiform tablet of Babylonian mathematics depicting the Pythagorean theorem. The tablet shows an approximation of the square root of 2 in the context of Pythagoras' theorem for an isosceles triangle. The original tablet is in the Yale Babylonian Collection.

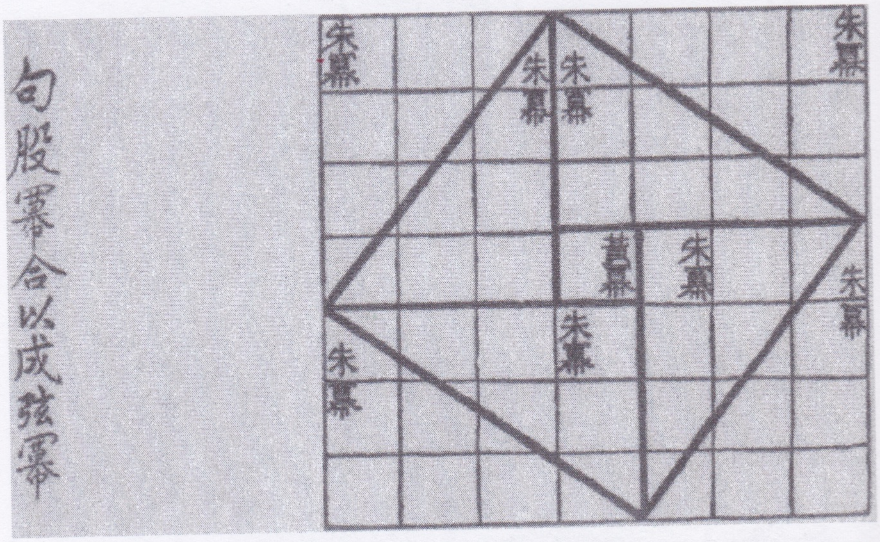


Figure 9.9. Set of primary document on *The Pythagorean Theorem*. Created by Jazmin Rodríguez and Chris Torres. What it says on the back: A photo of a famous book named The Pythagorean theorem, a 4,000 year history. It goes through the development of the proof by Pythagoras.

After creating their primary documents, January and KC were approached by a peer in our class who offered to reconstruct their work using clay. Because of this collaboration January and KC now have a clay representation of their work for their classrooms. This is just another extension of what is possible when educators begin to focus on artistic expressions in the history of mathematics.

The best cut comes of this assignment is the diverse collection of documents the educators gathered, from ancient art, various proofs from different cultures and times, and selections from important books. Jazmin Rodriguez states, "Showing ancient documents to my students gave them a sense of credibility of how the Pythagorean theorem proof was created. It was really interesting to see my students excited and engaged when they saw realistic copies of the primary sources. This introduction was a great way to start the conceptual lesson and engagement. My students were able to debrief after they analyzed the documents and write a paragraph of the importance of such documents and formulas."

Chris Torres uses his set of primary documents as a self-discovery activity. "The only thing I tell them is that the Pythagorean theorem deals with triangles. The reason for why I don't give them the theorem is because they

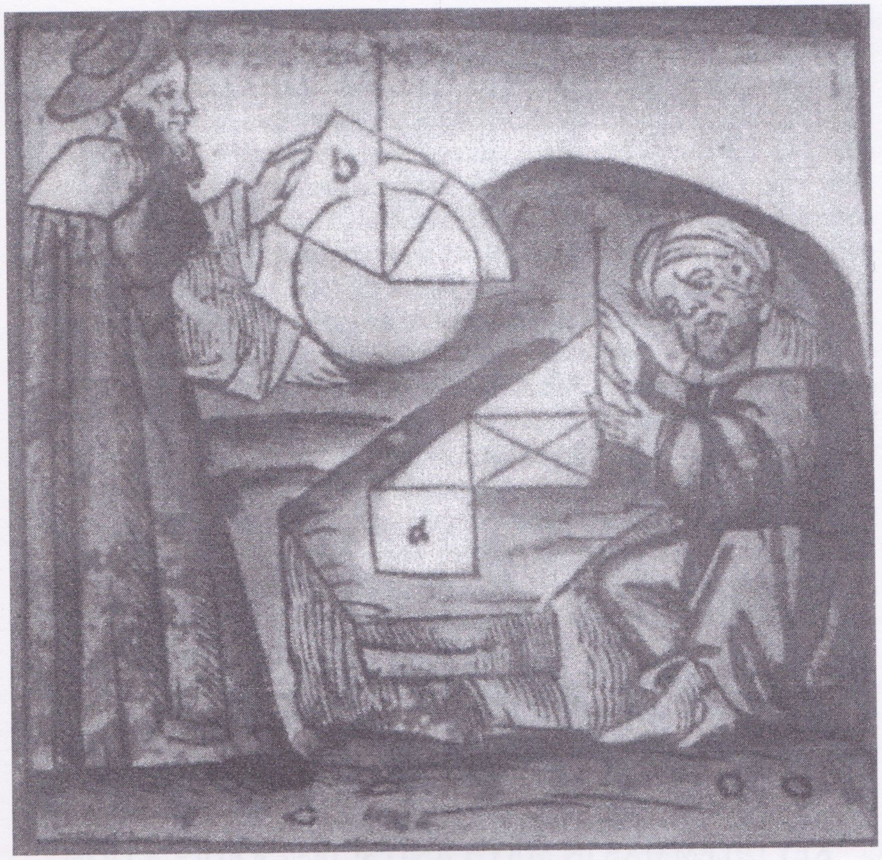


Figure 9.10. What it says on the back: Chinese Pythagorean Theorem proof.

will discover it with this primary document self-discovery activity I've prepared for them."

REFLECTION BRIDGE

The one area of concern I've seen in regards to having students create a set of primary documents is the couple of students who simply go to, say, Google Images and print out a few blurry black-and-white images and turn them in. I've found that to make this assignment really work that they need a rubric of what is expected of them. I mentioned earlier the six requirements I created so that the assignment is well framed, the last of which is, "Be sure to make a copy of your work for yourself as you'll be donating the set you hand in 'to the cause.'"

This last part—donating a set "to the cause"—has been integral in growing this strategy to be more than I could have ever dreamed it might be. For one, over the course of several years of doing this, I have students pick the same topics over-and-over again, resulting in me having dozens of primary documents on a single topic, say Pythagorean's Theory. One student will do a document in such a creative way that I replace that one item in my collection with that best example and, over the course of years I have collected a large, outstanding group of primary documents on many topics. It's much better and more creative than I would have done myself. These "best practices" examples become the models that students work towards or, in many cases, try to best! This past year has seen something new again when, suddenly, students started making 3D models instead of paper documents. One student used clay to make an original set of fossils. Another student used Q-Tips as bones to make elaborate skeletons.

I believe that this kind of assignment where students are asked to blend the rigor of their academic work with the brilliance of their aesthetic creativity has the potential to create what I refer to as "heirloom assignments." I know this because I still have a wild rose that I drew in my sixth-grade science curriculum. It hangs in my hallway reminding me that some assignments are worth keeping. I believe that these sets of primary documents have the potential to become academic heirlooms.

KEY DILEMMAS IN MATH AND SCIENCE EDUCATION

The key dilemma I've come across centers on the question, "What is STEAM?" Many schools are just now getting STEM programs up and running and have trouble conceptualizing how art fits into STEM. Then there is the definition of art itself, which depending on whom you are speaking can mean many different things. Upon hearing me talk about STEAM on our campus, one of my dearest colleagues sent me the following email: "Can I share a pet peeve about the STEAM thing? I feel that arts questions and outcomes differ from STEM questions and outcomes (except at the highest levels), and I think that what is really being employed are visual thinking strategies, rather than the arts. I think it is great to advocate for young people to learn visual thinking in STEM, but to seemingly include the arts gives the mistaken impression that arts education is happening. I fear that this practice will allow program directors to say, 'We're doing the arts already' and the little remaining support for true arts programming will disappear." Scientists, technology people, engineers, mathematicians, designers, artists, educational theorists, and teachers may all have different ideas and definitions of what constitutes "art." This merits more conversation for educational communities to form a definition of the arts in STEAM.

SUMMARY

The primary documents are simple and highly effective ways to use art as a way to reflect the historically rich impact of various cultures and genders on mathematics. Too often, the STEM education our students are offered is a domesticating education that gives them a functional literacy only. Infusing art, culture, and gender into STEM is one more step toward a more empowering mathematics, a kind of math literacy that is personal and relevant and allows students to see themselves situated in the grand conversation of mathematics. As feminist poet Adrienne Rich (2011) reminds us:

> When those who have the power to name and to socially construct reality choose not to see you or hear you, whether you are dark-skinned, old, disabled, female, or speak with a different accent or dialect than theirs, when someone with the authority of a teacher, say, describes the world and you are not in it, there is a moment of psychic disequilibrium, as if you looked into a mirror and saw nothing. (p. 218)

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