5

GHANA

Adinkra Symbols

Lindsay Poirier, Ron Eglash, and Bill Babbitt

Location The Western African nation of Ghana

"Partnering with math teachers and Adinkra artists in Ghana has been a crucial part of my work as a computer science graduate student, as I attempt to create software that can reflect the sophistication and beauty of indigenous knowledge. From developing an algorithm for drawing logarithmic curves to animating the carver's hand, math helps me move between these two worlds of hand-crafted tradition and high-tech computation."

—Bill Babbitt (at left, talking with Adinkra expert Gabriel Boakye)

Context

Adinkra symbols are prevalent throughout Ghana. They are the traditional symbols of the Asante (also known as Ashanti) culture, which developed in the country's central region. Each symbol represents an ideal or belief, along with a proverb held by the Asante people. For instance, the symbol in figure 5.1 is called *Akokonan* ("the leg of a hen"); it represents mercy and nurturing, as it recalls the proverb "The hen steps on her chicks but does not hurt them."

Fig. 5.1. *Akokonan:* "The Leg of a Hen"

What we know of the origins of Adinkra is based on Asante oral history. It states that Adinkra has its roots in Gyaman, an African kingdom that began in medieval times and was located in the present country of Ivory Coast (Côte d'Ivoire). At that time, spiritual leaders and royalty wore cloth stamped with the symbols to important ceremonies. In the early nineteenth century, the Gyaman people attempted to copy the Golden Stool, the Asante's symbol of absolute power. In a resulting military conflict, the king of the Gyaman, Nana kofi Adinkra, was killed. Nana Osei Bonsu-Panyin, the *Asantehene* (Asante king), took his opponent's Adinkra cloth as a trophy. With this, the Asante claimed the art of stamping cloth with Adinkra symbols.

Today, the most common use of Adinkra is still in textiles. The Asante use a traditional stamping process to create cloth that is worn to ceremonies and festivals (as shown in fig. 5.2). The colors of the cloth and the symbols it features represent the sentiments of the event. At funerals, for instance, individuals will adorn themselves with black, brown, or brick-colored cloth that is stamped with symbols pertaining to mortality or religion.

Fig. 5.2. Stamped Adinkra cloth

In order to stamp the fabric, symbols are carved into a calabash and attached to bamboo sticks for a grip. Adinkra designers produce their own ink by shaving the bark of a Badie tree *(Bridelia ferruginea),* pounding it, soaking it, and then boiling it. This results in a thick black ink called *Adinkra aduru,* or Adinkra medicine. Cloth is then laid out along a table, and the stamps are dipped in the ink and then pressed down on the cloth an equal distance apart. In Twi (or Akan), the language of the Asante, *Adinkra* translates to "good-bye"; accordingly, cloth stamped with Adinkra symbols was at first often worn to funerals. Over time, the traditions surrounding Adinkra have evolved. Today, symbols can be seen in architecture, sculptures, pottery, and even incorporated in company logos, providing a profound significance to the objects on which they are placed. While the original symbols are still used, new symbols and meanings are constantly being developed.

One of the most interesting aspects of Adinkra design is how the symbols incorporate elements of geometry. Students may enjoy learning how to pronounce the Twi words that represent four possible geometric transformations: *adane* (ah-DAWN-eh) means "reversed image," or reflection; *ketowa* (KET-wah) and *keseye* (ke-SEE-yah) mean "smaller" and "larger" and relate to dilation, which can be a size change in either direction; *ntwaho* (en-TWA-hoe) is the word for "spinning," or rotation; and *twe* (TWEE) is the word for "pulling an object" that relates to translation.

The Adinkra symbol shown in figure 5.3 is called is called *Funtunfunefu Denkyemfunefu* ("the Twin Crocodiles"). It represents democracy and unity in diversity and is based on the proverb "They share one stomach and yet they fight for food." In this symbol, we can see reflection (where one side of the symbol mirrors the other side) along the vertical and horizontal axes.

In *Aya* ("the Fern," shown in fig. 5.4), the leaves gradually become smaller as the fern grows upwards, representing the dilation that can be seen in an actual fern. This symbol represents endurance and resourcefulness. In figure 5.5, we can see rotation in the symbol *Nkontim* ("the hair of the Queen's servant"), which represents service and loyalty. In this symbol, each of the four arms of the spiral are rotated and repeated about a center point.

Translation can be seen in *Ntesie–Mate Masie,* a symbol (fig. 5.6) that represents knowledge and wisdom and is based on the proverb "Deep wisdom comes out of listening and keeping what is heard." Each circle in the symbol is identical to the other but shifted vertically or horizontally to a new position.

Fig. 5.3. *Funtunfunefu Denkyemfunefu:* "The Twin Crocodiles"

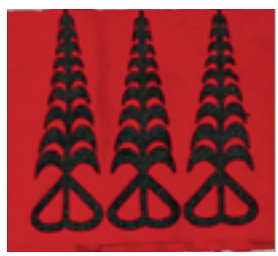

Fig. 5.4. *Aya:* "The Fern"

Fig. 5.5. *Nkontim:* "The Hair of the Queen's Servant"

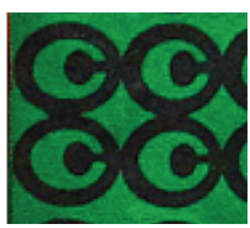

Fig. 5.6. *Ntesie–Mate Masie:* "I have heard it and kept it"

Kindergarten–Grade 3

Objectives

Students will create their own Adinkra stencils. They will use them to explore calculating area using the operations of addition and multiplication.

Materials

- Sheets of colored paper (8 × 10 inches)
- Plastic resealable bags filled with 24 paper squares (2 × 2 inches)
- Glue
- Inch rulers

Standards Met in This Section
Common Core State Standards—Measurement and Data
Measure areas by counting unit squares (square cm, square m, square in, square ft, and improvised units). Relate area to the operations of multiplication and addition. Find the area of a rectangle with whole-number side lengths by tiling it, and show that the area is the same as would be found by multiplying the side lengths. Multiply side lengths to find areas of rectangles with whole-number side lengths in the context of solving real world and mathematical problems, and represent whole-number products as rectangular areas in mathematical reasoning (3.MD.6 and 7, National Governors Association Center for Best Practices and Council of Chief State School Officers [NGA Center and CCSSO] 2010, p. 25).
NCTM Standards—Measurement
▲ explore what happens to measurements of a two-dimensional shape such as its perimeter and area when the shape is changed in some way (NCTM 2000, p. 170).

Introduce

Adinkra symbols are designs created by the Asante people and used to decorate many items of daily use in Ghana. Adinkra cloth is beautifully designed cloth stamped with patterns of symbols, often ones that represent things seen in nature such as trees, ferns, and animals. Each symbol has a specific meaning and a proverb related to it.

Asante artists carve Adinkra stencils from gourds and then use these stencils with handmade dyes to place patterns on an area of cloth they are designing. You can imagine how much calculation the artist needs to use as he or she decides on the size and shape of the stencil design, where to locate the designs to produce the desired pattern, and how many designs are needed to cover the surface of the cloth they are stenciling.

Explore and Create

1. Show students several photo examples of Adinkra cloth, asking them to pay particular attention to the geometry of the patterns. Explain that each design represents a particular image, object, or idea to the Asante people who produce and wear the cloth. Explain that a proverb (such as those mentioned in this chapter's Context section) accompanies each design and reminds those in the community of an important cultural concept. Discuss proverbs and ask your students what they think several of the Asante proverbs actually mean. Explain that an artist covers or "tiles" an area with a specific design and must know where to place the designs and how many will be needed to cover the cloth as intended. Asante artists are expert at designing and placing patterns across the cloth they decorate so that entire areas become patterned.

2. Divide the students into pairs, and give each pair an 8 × 10-inch sheet of blank colored paper and a plastic bag with 24 white paper squares measuring 2 inches square. Ask students to estimate how many squares will be needed to completely cover the paper's surface. Ask them to then begin placing and gluing the squares so that the entire surface of the colored paper is covered.

3. Discuss with students the concept of area, making sure to focus on the concept of area rather than on the formula for finding an area. How many students counted the squares to determine their answer? Did any students do this differently? Can any students suggest a faster way of calculating area other than by counting? Encourage divergent and flexible thinking.

4. Introduce the terms *length, width, area,* and *perimeter.* Discuss the concept of using a variable to represent a particular term (i.e., l = length or w = width). As students work within their teams and as a whole class, ask them to write a sentence describing how they would tell a friend to find the area of a surface when using a specific dimension. Together, have the class translate these word sentences into a formula they can apply when calculating the areas of differently shaped surfaces.

Apply and Extend

- Refer back to the discussion you had with your students as you guided them to discover a formula for calculating area of a two-dimensional surface. Ask the students what would happen to the previously calculated area if the stencil pieces they were using were now doubled. Have them construct one 4-inch square (4 × 4) with their 2 × 2-inch squares. Note how many of the 2 × 2-inch squares are used. How many 2 × 2-inch squares are needed to make one 4-inch square? When the dimension of a shape is doubled, does this mean that the area also becomes twice as large? If students are asked to increase to triple the dimensions of the original 2 × 2-inch square, what do they predict would happen to the area? What have they discovered?

- Remind the students of the number of 2 × 2-inch squares they previously used to tile their colored paper. Ask them to draw 4-inch squares to tile another sheet of colored paper and compare the number of 4-inch squares needed with the number of 2 × 2-inch squares used. What did they discover? What possible explanation could there be for this result?

Summarize and Assess

Discussion Questions

Q We now have a better understanding of the way that Adinkra artists calculate area and how they determine how many designs will cover an area of cloth. In what other ways do these artists use math?

Grades 4–8

Objectives

Students will explore the presence of transformational geometry—reflection, dilation, rotation, and translation—in indigenous design and, as a result, gain a more thorough understanding of geometry's relationship with nature. They will collaborate in groups to distinguish how the transformations are portrayed in a variety of Adinkra symbols and will then have an opportunity to design their own symbols, incorporating a variety of transformations. Using an online applet, students will graph their design, providing a connection between transformational geometry and coordinate graphing.

Materials

- Web page with "Adinkra Grapher" applet at http://csdt.rpi.edu/african/adinkra/index.html
- Poster board
- Markers
- Notebook paper and pencil
- Graph paper
- Ruler
- Protractor
- Compass

Standards Met in This Section
Common Core State Standards—Geometry
Describe the effect of dilations, translations, rotations, and reflections on two-dimensional figures (8.G.3, NGA Center and CCSSO 2010, p. 56).
NCTM Standards—Geometry
▲ describe sizes, positions, and orientations of shapes under informal transformations such as flips, turns, slides, and scaling; ▲ examine the congruence, similarity, and line or rotational symmetry of objects using transformations; ▲ draw geometric objects with specified properties, such as side lengths or angle measures; ▲ use visual tools such as networks to represent and solve problems; ▲ use geometric models to represent and explain numerical and algebraic relationships; and ▲ recognize and apply geometric ideas and relationships in areas outside the mathematics classroom, such as art, science, and everyday life (NCTM 2000, p. 232).

Introduce

Adinkra symbols are representations of beliefs and values held by the Asante people of Ghana. Many of these designs draw on aspects of nature, and they often incorporate elements of geometric transformations such as reflection, dilation, rotation, and translation. Through a study of these designs, we can gain an understanding of how these transformations embody aspects of the natural world. In this exercise, students will have an opportunity to design a symbol using these transformations, allowing them to creatively portray their own connection with nature.

Explore and Create

1. In pairs, have students navigate to the "Transformational Geometry" page under the Culture section of the web page listed in the Materials list. Have students read through the pages on each transformation, noting how transformational geometry is present in Adinkra symbols.

2. Separate the class into four groups. Assign each group a geometric transformation—reflection, dilation, rotation, or translation. Hand each group a piece of poster board, and instruct the students to create a poster on their geometric transformation. The poster should include a definition of the transformation and at least three examples of Adinkra symbols that incorporate it. (For a collection of Adinkra symbols, navigate to http://www.adinkra.org/htmls/adinkra_index.htm.) For each symbol they choose, have students draw the symbol, write its literal meaning, and write its symbolic meaning.

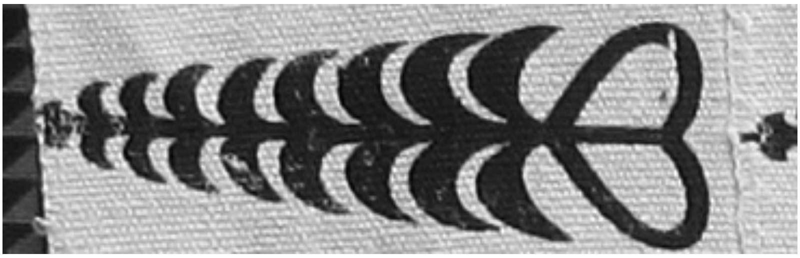

Fig. 5.7. *Aya:* "The Fern"

3. Have the groups present their posters. As each group presents the symbols on their poster, ask the entire class to suggest what element of nature the symbol represents and how the geometric transformation can be seen in that element. For instance, if students were presenting *Aya,* the fern (fig. 5.7), they would describe how the dilation that can be seen in the symbol's leaves depicts the dilation in the leaves of an actual fern.

4. Tell students to think about their own values and possibly identify an element of nature that somehow depicts these values. On sheets of paper, have students incorporate linear shapes and arcs to design their own symbol that depicts these values. Their symbols should also incorporate at least one of the geometric transformations.

5. After they complete their initial sketches, have the students use a ruler, a protractor, and a compass to plot their designs on a piece of graph paper. Have the students record the coordinates for each point of their design on the graph paper. Also have them record the radius and angle of each arc.

6. After plotting their design on graph paper, have students navigate to the "Math Software" section on the Adinkra Grapher web page (as shown in fig. 5.8). Have the students use the applet to plot their symbol.

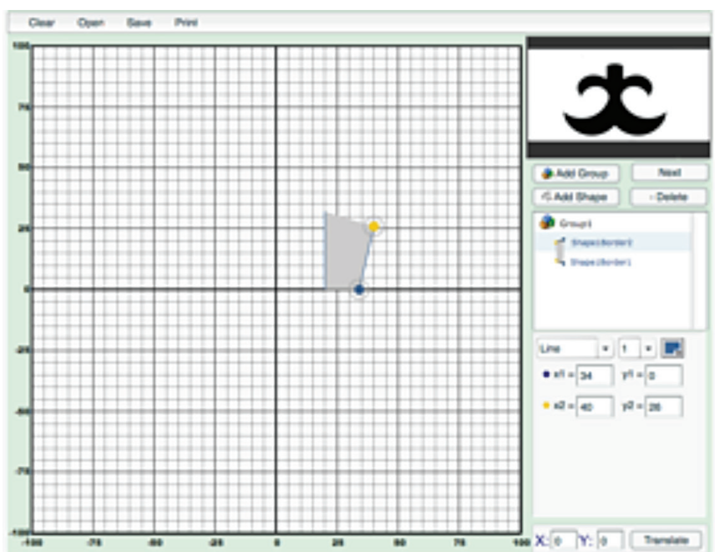

Fig. 5.8. Example of "Math Software" page

Apply and Extend

- Have students print out their designs and share them with the class. Ask students to describe the shapes and arcs within their symbol, along with the elements of transformational geometry that it incorporates. Have students also share the values that their symbol represents and how they created the design to represent those values. If a design is related to an element in nature, have the student describe the connection.
- Have students attempt to recreate their design using the "Programming Software" section on the Adinkra Grapher web page. Ask to students to describe what they had to do differently to plot their design on the graph using programming concepts.
- For homework, ask students to record ten instances of transformational geometry that they see in nature or in their homes. Have students share their findings during the following class.

Summarize and Assess

Discussion Questions

Q Did many of the symbols incorporate more than one element of transformational geometry? Which transformations were often paired, and why do they complement each other?

Q How does knowledge of transformational geometry make it easier to measure and place shapes on the graph? Explain your thinking.

Grades 9–12

Objectives

Students will explore and model scaling factors with arithmetic sequences such as the Fibonacci numbers. They will also model scaling with geometric sequences, such as squaring reflecting examples as found in both nature and African design. Students will use an online applet to study and create Adinkra patterns reflecting designs found in nature and the Asante culture.

Materials

- Web page with "Adinkra Grapher" applet at http://csdt.rpi.edu/african/adinkra/index.html
- Grid paper
- Ruler and protractor

Standards Met in This Section
Common Core State Standards—Modeling
The basic modeling cycle involves (1) identifying variables in the situation and selecting those that represent essential features, (2) formulating a model by creating and selecting geometric, graphical, tabular, algebraic, or statistical representations that describe relationships between the variables, (3) analyzing and performing operations on these relationships to draw conclusions, (4) interpreting the results of the mathematics in terms of the original situation, (5) validating the conclusions by comparing them with the situation, and then either improving the model or, if it is acceptable, (6) reporting on the conclusions and the reasoning behind them (NGA Center and CCSSO 2010, pp. 72–73).
Common Core State Standards—Geometry
Use coordinates to compute perimeters of polygons and areas of triangles and rectangles. (G-GPE.7, NGA Center and CCSSO 2010, p. 70) Apply geometric methods to solve design problems (e.g., designing an object or structure to satisfy physical constraints or minimize cost; working with typographic grid systems based on ratios) (G-MG.3, NGA Center and CCSSO 2010, p. 78).
NCTM Standards—Geometry
▲ use trigonometric relationships to determine lengths and angle measures; and ▲ understand and represent translations, reflections, rotations, and dilations of objects in the plane by using sketches, coordinates, vectors, function notation, and matrices (NCTM 2000, p. 308).

Introduce

As part of their cultural practice, the Asante of Ghana often wear cloth stamped with the symbols called Adinkra to ceremonies and festivities. Artisans carve symbols into pattern blocks, which are then coated with a black dye and the pattern is pressed onto the cloth. The patterns denote important images, often illustrating things found in nature that remind the wearer and those who see the cloths of proverbs important in the Asante community.

Many of the shapes in Adinkra symbols are logarithmic spirals. It's easy to see why when you realize that many Adinkra shapes are inspired by nature, and natural processes are often expressed in logarithmic spirals. The first two examples (figs. 5.9 and 5.10) represent a ram's horns and a bird's foot, both the result of growth curves in nature. In the third symbol (fig. 5.11), the bumps down the middle are related to the knuckles on a fist, representing the concept of power. The proverb that inspired it means "Only god has the power of life"—but how do you represent the concept of "life" in general? For the Adinkra artisans, the symbols involving life always use the arc of a logarithmic spiral, as they have generalized that spiral as a geometric abstraction of the essence of biological growth.

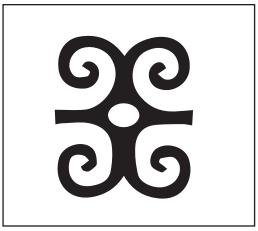

Fig. 5.9. *Dwennimmen:* "Ram's horns"

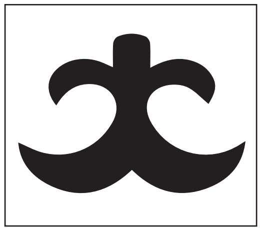

Fig. 5.10. *Akokonon:* "Hen's foot"

Fig. 5.11. *Gye Nayme:* "Except God"

Contemporary scientists who model the development of biological shapes, or "morphogenesis," also use logarithmic spirals. One way to generate those shapes mathematically is with Fibonacci numbers. (As it happens, Leonardo Fibonacci, the medieval Italian mathematician who devised his sequences, was himself educated in northern Africa.) For instance, in modeling a plant's growth we may compare growth at fixed time intervals and by the amount and direction of growth taking place. It is not unusual to find the results of such studies patterned closely to numbers in the Fibonacci sequence or modeling the creation of iterative golden sections. If the growth of an organism generates a curve, then a very simple model can generate a logarithmic spiral. Scaling factors are also apparent in designs where iterative patterns are scaled. When we look at a fern leaf, for example, we see a repetitive shaped pattern that either increases or decreases in size along the length of the leaf. These patterns of nature illustrating mathematical scaling are often incorporated into African design in art and architecture, and they provide a compelling example of the integration between culture, mathematics, and the natural world.

In the following activity, students will use the online applet to create patterns reminiscent of Adinkra patterns. They will study and create scaling factors to produce geometric transformations depicting the interplay between biological patterns and the cultural designs used in a community. Students will begin their exploration of spirals through a review of the Fibonacci numbers and their ratios. Before starting the activity, review with students how to build the sequence of numbers known as the Fibonacci sequence. A sequence with fourteen numbers should give students a good idea of how the sequence is built and sufficient numbers for further exploration (e.g., 1, 1, 2, 3, 5, 8, 13, 21, 34, 55, 89, 144, 233, 377). This review will then lead students to an investigation of scaling factors to include geometric squaring sequences.

Explore and Create

1. Begin with a discussion of Fibonacci sequences. Fibonacci patterns and numbers are found in many places in nature, and they are also often incorporated by cultures into art and design. Biologically, we can frequently see the successive terms of the Fibonacci sequence appearing in plants. As the plant grows from a small center, young buds move away from the populated area of the old buds to a new location where they are free to expand. This forms a spiral that has consecutive Fibonacci numbers such as spirals with counts of 8 and 13.

2. Have students explore the Fibonacci sequence found in some common, and easy to count, examples from nature. Students should begin by counting the spirals formed from lower right to upper left and record their findings in a chart like the one below (table 5.1). Real-life examples or photos may be used for the investigation.

Table 5.1
Counting spirals in nature

Cone flower	21	34
Daisy	21	34
Giant sequoia cone	3	5
Pine cone	5	8
Pineapple	8	13
Sunflower	55	89

3. Students are now familiar with the numbers of the Fibonacci sequence. Have students explore the golden ratio as they find the quotients of successive Fibonacci numbers. Encourage them to look for a pattern as they continue the exploration, and have them consider what number seems to be the limiting value.

Table 5.2
Dividing successive Fibonacci numbers

1/1	1
2/1	2
3/2	1.5
5/3	1.666…
8/5	1.6
13/6	1.625
21/13	1.615384615
34/21	1.619047619

The value of 1.61818… or $(1 + \sqrt{5}/2$, and symbolized by the Greek letter *phi*, is known as the *golden ratio.* This ratio appears over and over again in nature, art, music, and architecture.

4. Using the numbers from the Fibonacci sequence, have students construct a golden rectangle, either using grid paper or a computer application.

5. Have the students draw a rectangle that measures 55 by 89 units. Within this rectangle, have them construct a square that is 55 units on a side. This remaining rectangle is also a golden rectangle, one that measures 55 by 34 units. Repeat the process using squares of 34 units, 21 units, 13 units, and 8 units. Students should use a calculator to verify the ratios made from the Fibonacci numbers.

6. Have students connect the vertices of the squares to form a logarithmic spiral. A spiral is defined as a curve traced by a point that moves around a fixed point from which it continues to move away. Have students compare the logarithmic spiral to the Adinkra designs provided to them. Ask them to determine how many of the designs exhibit the logarithmic spiral and the associated golden rectangle.

7. Students should be able to design their own Adinkra-style designs using the information learned about golden rectangles and logarithmic spirals. An exciting way to do that is to use the Adinkra programming tool at http://community.csdt.rpi.edu/applications/17.

Apply and Extend

- Ask students to examine the following Adinkra design image (fig. 5.12). The design may remind them of a plant they have seen, such as a corn plant that has been laid on the ground.

Fig. 5.12. Leaves design

- As indicated, the height of the leftmost set of leaves is 5.25 inches. The height of the next set of leaves (moving to the right) is 4.75 inches. To calculate the scaling factor, the student must divide 4.75/5.25. The resultant scaling ratio is approximately 90 percent. That second set of leaves is therefore 90 percent of the height of the first set. Students should be able to see that there appears to be a constant rate of change as the progressive leaves to the right decrease gradually in height at a scaling factor of .90.
- Ask students to imagine they are artisans carving similar images and are aware of the role of scaling ratios in their designs. Ask them how many leaves should be on an image if they, as the designers, want the last pair of leaves to be no smaller than the tip of a carving chisel, which is 0.25 inches wide. Allow students to explore creating the designs they could make for Adinkra cloth through setting scaling ratios to produce their art.

- Encourage students to explore scaling ratios using the following web page in the suite of Culturally Situated Design Tools: http://csdt.rpi.edu/african/MANG_DESIGN/culture/mang_homepage.html. They should note the mathematical and physical similarities that connect these designs and artworks with African nature and culture.

Summarize and Assess

Discussion Questions

Q How do cultures incorporate images of their environment, including nature, in their artwork and design? Do you see such connections in your home community? What might it mean if you do or do not?

Q What do you consider to be a key insight that you have gained as a result of your interaction with these mathematical activities?

Co-Writers for This Chapter

Lindsay Poirier *wrote the Context, Kindergarten–Grade 3, and Grades 4–8 sections of this chapter. She is a PhD student in the Department of Science and Technology Studies at Rensselaer Polytechnic Institute. Her research critically examines the logics of computing and how it inflects social research conducted on "big data."*

Bill Babbitt *co-wrote the Grades 9–12 section in this chapter. He currently has the pleasure of working with colleagues on Culturally Situated Design Tools. The CSDTs offer an opportunity to improve student-learning outcomes by teaching mathematics and computer science concepts through cultural simulations. Additionally, Bill is a co-advisor for Albany Area Math Circle and an assistant coach for the Upstate New York American Regions mathematical League team.*

Featured Consultant for This Chapter

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