© 2012 THE BARNES FOUNDATION (4)

Framing Measurement: An Art Gallery Installation

An interdisciplinary activity connects mathematics and art from The Barnes Foundation museum in Philadelphia.

Sarah B. Bush, Karen S. Karp, Victoria Miller Bennett, Liz Popelka, and Jennifer Nadler

Mathematics teachers and art teachers were able to enthusiastically engage seventh- and eighth-grade students in an interdisciplinary activity focused on scaling, proportional reasoning, and measurement by recreating artwork from a famous private collection. Using the artwork from The Barnes Foundation in Philadelphia, Pennsylvania, the middle school's art teacher worked with students to help re-create the original paintings through the use of scale drawings and proportional reasoning. Then, in mathematics class, students used measurement to position the paintings in the school hallway to duplicate two gallery walls.

The art collection of The Barnes Foundation was amassed by Albert C. Barnes,

A Brief History of Albert C. Barnes

Albert Barnes grew up poor in Philadelphia but later became a successful businessman and pharmaceutical chemist. He made his fortune co-inventing *argyrol*, a compound used to fight infection in newborn babies as well as in injured World War One soldiers. Barnes's artwork was collected between 1912 and 1951 and included impressionist, postimpressionist, and early modern paintings as well as examples of African sculpture, Native American ceramics, Pennsylvania German decorative arts, old master paintings, jewelry, textiles, and ironwork. Barnes intended for the collection to serve in an educational capacity.

who worked with well-known educator John Dewey to develop an educational method for art appreciation that focused on artists' use of color, light, line, and space. Critical to this process was the study of unique displays of artwork, coined *ensembles* by Barnes, that were hung in a way meant to guide the viewer into looking at the elements of artistic composition. By looking at art from different time periods and geographic regions in the same wall display, Barnes thought that students would notice how the artists used similar processes in creating their work.

This activity meets the seventh-grade and eighth-grade standards found in the Common Core State Standards for Mathematics (CCSSI 2010), which state that students should "compute unit rates associated with ratios of fractions, including ratios of lengths, areas and other quantities measured in like or different units," (p. 48). It also speaks to the geometry domain, which states that students should engage in "reproducing a scale drawing at a different scale" (p. 49). Additionally, this activity addresses "attend to precision," number 6 of the Standards for Mathematical Practice, which states that mathematically proficient students "are careful about specifying units of measure" and "calculate accurately and efficiently" (p. 7). "Using appropriate tools strategically," number 5 of the Standards for Mathematical Practice, states that "mathematically proficient students consider the available tools when solving a mathematical problem" (p. 7). Moreover, this activity supports the essential understanding that "A ratio is a multiplicative comparison of two quantities, or it is a joining of two quantities in a composed unit" (Lobato and Ellis 2010, p. 18).

ACTIVITY 1: RE-CREATE A GALLERY WALL

This lesson consisted of two main activities: (1) the re-creation of two gallery walls of art from The Barnes Foundation and (2) a proportional reasoning task using two pieces of art. For the first activity, copies of the artwork from The Barnes Foundation, as well as each painting's dimensions, were given to budding student artists by the art teacher. For two weeks, approximately 40 seventh-grade students re-created the paintings from the two walls in the galleries. During the final two days, all 230 art students in sixth, seventh, and eighth grade contributed their finishing touches.

When the art was completed, had dried, and was framed, each student team (one seventh grader paired with two eighth graders from two math classes) was given a technical drawing (see **fig. 1**). This drawing contained estimates of the actual dimensions of the painting, the frames, and the spaces in between the art written in either metric or customary (English) units. Using the re-created paintings from art class, students used measurement and multistep calculations to install the two different ensembles on a large hallway wall in the school. **Figure 2** shows the completed installation.

Planning

The first step in planning required determining which ensembles of paintings from The Barnes Foundation we wanted students to reinstall. Although a collection of artwork from any museum or gallery could be used, we chose The Barnes Foundation in Philadelphia because its entire collection was in the process of being moved from the original suburban home and reinstalled in a new, specially designed museum downtown. This scenario made our task authentic and linked it to a real-world event. A Barnes Foundation newsletter contained an example of the technical measurements needed to precisely reinstall the paintings in the new location. This technical drawing was a catalyst for our event.

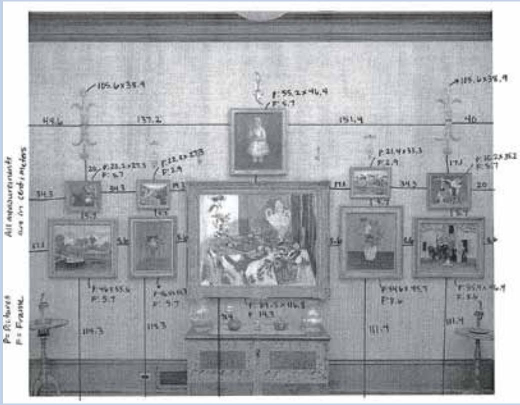
After we chose two ensembles from two galleries, all dimensions had to be determined (as shown in **fig. 1**), such as the painting and frame sizes, the space in between the paintings, and the distances to the floor from the frames. In our case, we were not given the exact dimensions, so estimations were gleaned from the photographs. We noticed that each wall contained a standard-size electrical outlet. Using the known dimensions of an outlet cover allowed a scale factor to be calculated. From there, measurements of each painting, frame, and space on the photograph of the gallery wall were multiplied by the scale factor to estimate all the dimensions. Originally, this measurement was calculated in inches and then converted to centimeters to create a metric version (see **fig. 1**). We wanted to implement this activity by the end of the school year to coincide with the opening of new The Barnes Foundation in Philadelphia, so we completed these conversion steps ourselves because of time constraints. However, this work would have been a meaningful task for students to complete.

Once we had calculated the dimensions of the paintings and frames, we needed to re-create life-size versions. The art teacher gladly accepted this task, and we gave her color copies of each painting from both ensembles. We screened the paintings in the two ensembles and replaced two nudes with other paintings from the collection. The art teacher then assigned teams of students, who cut white poster paper to the exact sizes for each piece of art, to re-create each of the twenty-one paintings. Using the color reproductions (available from most museums), students then spent about two weeks in art class drawing and painting. Next, frames that matched those in the ensembles were made from brown paper that had been cut to size and sponge painted a bronze color. To cut the frames accurately, an additional amount was added to the length (and the width) of the paintings to allow for mitered corners.

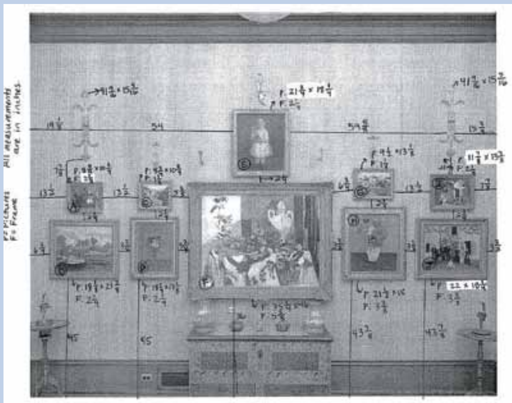
Eighth Graders Design a Gallery

For the eighth-grade class, the introduction to the painting installation began the day before the actual event. Students were told that they would work collaboratively with a class of seventh graders and were expected to help lead the groups. The older students worked hard but often

Fig. 1 A technical diagram was labeled with centimeters and inches; the use of both units of measurement was a topic of much discussion throughout the project.



(a)



(b)

Fig. 2 The technical diagram in **figure 1** became a gallery gracing a school hallway.

SARAH B. BUSH

Students position paintings on the wall to replicate the original gallery installation.

SARAH B. BUSH

struggled with mathematics. Although they were excited about their opportunity to lead mathematically, they were also nervous and asked questions to be sure that they would avoid "being in charge alone." Each pair of eighth graders was assigned to two different paintings that would hang in the school's "gallery."

The day of the project, students were given some background information about The Barnes Foundation, the history of the art collection, and the story of its relocation. The teacher then asked students about potential obstacles they could foresee when making sure the ensembles in the galleries were preserved in their original arrangements. Students examined photographs of the original property compared with the new modern building in Philadelphia and concluded that the new location was much larger.

"What if the rooms in the new spot are bigger?" one group asked.

"Great question," the teacher replied. "What if they are?"

"You'd have to know stuff like how far apart all the pictures are in the old place, so that if the new place is, say, twice as big, paintings might need to be twice as far apart in the new place," one student explained.

"Why?" the teacher asked.

"Because," she answered, "that would make it, oh. . . ."

"A proportion!" a boy from another group chimed in.

"Yeah," the student said. "Then the distances would be proportional!"

Once the teacher clarified for the students that the galleries needed to maintain the exact same dimensions in their new space, students focused on issues directly related to the measuring process. Overall, students were aware of potential problems before the paintings were removed from their original location, but discussions focused primarily on the lack of precision in measuring. For example, one student asked about measuring the space between paintings in inches rather than centimeters. The groups were given time to discuss this situation. Many students strongly believed that using two different units of measure would not work, but they did not know why. The teacher asked if students thought inches or centimeters were bigger and how the size of the unit affects the measurement. Students hesitated, so one group's members asked if they could grab rulers to compare.

After examining the rulers and discussing measurement, most groups concluded that the paintings would be too far apart in the new location if a change in units occurred because using inches instead of centimeters would result in larger distances between the paintings. The teacher asked them to consider the reverse. What would happen if the measurements were in inches and the paintings were hung in the new location based on centimeters? Students started seeing that these would be proportional but scaled down (or up), accordingly.

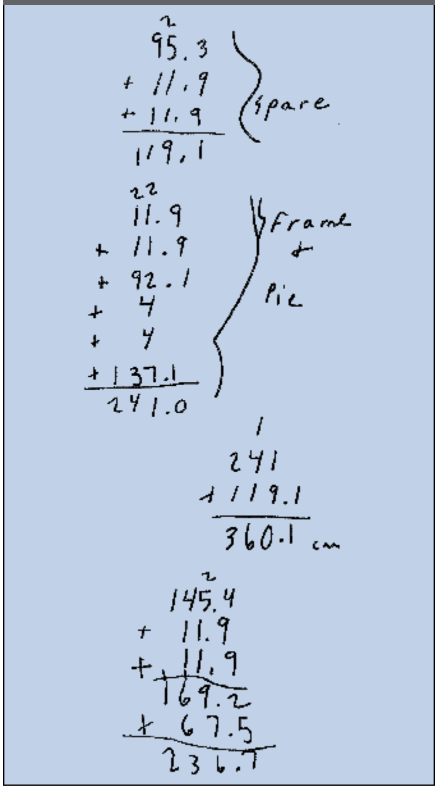
The teachers told the students they would be acting as staff of The Barnes Foundation, whose job it was to reinstall the artwork in the new location. They were also going to be given diagrams with correctly labeled measurements. Students viewed a copy of the technical drawing (see **fig. 1**) on the overhead projector and were slightly overwhelmed. They felt that, undoubtedly, the team that had placed the paintings probably had the same feelings of being overwhelmed. The teacher handed out diagrams to teams of students, reminding them of the paintings for which they were responsible and telling groups, "You will be measuring in inches" or "You will be measuring in centimeters." In response, one student said, "It's going to be messed up!" When asked why, the student responded "because we're not all measuring with the same stuff!" The teacher assured her that it was an "issue we should keep in mind as we work, and we'll come back to it later."

Armed with a variety of rulers and tape measures, the students headed to the hall where the artwork would be reinstalled. They examined the wall and their diagrams and developed a plan. The seventh-grade class would be joining them soon, and they would have to explain their tentative plan. To give the students an anchor to use as a landmark, the teacher hung the large centerpiece of each ensemble on the wall ahead of time. We recommended to students that the groups assigned to the paintings near the center of the wall go first, proceeding outward.

Seventh and Eighth Graders Install Art Together

Students were intentionally grouped heterogeneously, mixing the high-performing seventh-grade class with

Fig. 3 Cooper made precise computations.



SARAH B. BUSH

A student transfers a 2 in. × 2 in. section of a masterpiece, which becomes part of the final project, as shown in figure 7.

the struggling eighth-grade students. The seventh graders were purposefully given minimal background information to encourage the eighth graders in their groups to take a leadership role and guide the process. Once the seventh graders entered the hallway, the older students described the task and collaborated to develop a plan.

Two professors from local universities coordinated the order in which the paintings were hung by groups. A small stepladder was used to prevent too many groups from being at the wall in the same place at the same time. Other than this assistance, no other directions were given. Some groups needed to be grounded in how the measurements were to occur. “Do we measure from the molding or from the floor?” one group asked. Another group wanted to confirm that the technical drawings indicated space between the frames rather than space between the paintings. A few students were unsure how to read the measurements. One asked, “Is that 19.6 or 1 9/16?” She then confirmed, “That is not even 2 inches then.”

Because student teams were using either metric or customary units on the same ensemble, many measurement issues occurred. We found the use of different units to be one of the most teachable moments of the activity. Some students assumed that all diagrams used inches for the scale because they heard other students talking about and using inches on a yardstick. One said, “Oh, wait. We have centimeters, they have inches. But, the diagrams look the same.” Several students were interested in the different units that others were using. One said, “That doesn’t seem like 15 centimeters apart. It needs to be bigger.” The other responded, “It isn’t centimeters, it is inches.” Students wondered how two different units of measure—metric and customary—could be used and still get an accurate placement. The resulting answer was that it did not matter which units were used as long as the values of the measurements were equivalent.

Because the ceiling in the school was not as high as that in The Barnes Foundation, a few adjustments had to be made. Paintings placed above the center painting could not be moved to a point higher on the wall. One painting that was supposed to be higher than a doorway had to be moved to the height of the largest painting. Students used 163 centimeters to align this painting to the height of the largest painting from the floor while calculating multiple measures to find the distance from the largest painting to the location. Students added the distances between and across paintings before putting the final artwork in place.

When class ended, a few paintings remained to be installed and students needed to double-check the placement, so the next period of seventh-grade students visited both walls with their diagrams to confirm the measurements using the same measuring tools. Working in pairs, this new group of students began to check the paintings against the diagrams. A few minor mistakes were discovered, and paintings were repositioned. When measurement discrepancies occurred,

Fig. 4 The activity sheet listed the steps necessary for the installation.

ENSEMBLE INSTALLATION

1. a. What letter is your assigned painting?
   b. Where does your painting belong on the wall? Use your technical diagram.

2. a. Using your technical diagram from The Barnes Foundation, what measurements do you need?
   b. Record your measurements here.

3. Some students are using inches, and some are using centimeters. What did you predict would happen when different groups installed the paintings using two different units?

4. What happened when some classmates used inches and others used centimeters to install the paintings? Why?

5. What is the area of the wall, excluding the area of the pictures? Show all work.

6. Explain one challenge your group members encountered as they installed paintings on the wall.

7. Were any paintings placed in the wrong location? What mistakes did your group or the class make?

8. What advice would you give to students completing this same project next year? What helpful hints could you give?

Fig. 5 A student explored the area of the wall, excluding the area of the paintings.

E: 55.2×46.4= 2561.28 + 5.7 (frame) = 2566.98cm²
F: 89.5×116.8 = 10453.6 + 14.3 (frame) = 10467.9cm²
G: 21.4×33.3 = 712.62 + 2.9 (frame) = 715.52cm²
H: 54.6×45.7 = 2495.22 + 8.6 (frame) = 2503.82cm²
J: 55.9 ×46.4 = 2593.76 + 8.6 = 2602. Answer 36 cm²
I: 30.2×35.2 = 1063.04 + 5.7 = 1068.74cm²
A: 22.3×223 = 606.06 + 5.7 = 611.76cm² B: 46×556 = 2351.6×5.7 = 2563.3cm²
C: 22.2×27.3 = 606.06 + 2.9 = 608.96cm² D: 46.4×33.3 = 1545.12 + 5.7 = 1550.826
2566.98 + 10467.9 + 715.52 + 2503.82 + 2602.36 + 1068.74 +
1068.74 + 611.76 + 2563.3 + 608.96 + 1550.82 = 26328.9cm
105.6×38.9 = 4107.84 cm
+ 4107.84 cm
8215.68 cm²

26328.90
+ 8215.68
34544.58 cm²
48.6 + 137.2 + 151.4 + 40 = 377.2cm² (width)
111.4 + 5.7 + 17.1 + 111.4 = 245.6cm² (length)
245.6 + 377.2 = 92640.32 cm² Entire Wall
− 345.44.58 cm² Total of Pictures
58.095.74 cm²

the students were reminded to use the large center paintings as anchors. One student, Cooper, wrote detailed notes after checking the position of his assigned painting (see **fig. 3**).

After the reinstallation of the two gallery walls, the seventh-grade teacher asked the students to complete an activity sheet (see **fig. 4**). We found their responses to questions 4 and 5 particularly interesting. Although students discovered during the installation that using inches and centimeters "worked," many did not transfer this information when completing question 4. Instead, common incorrect answers included such responses as these:

- "The distances were off."
- "The paintings were too close because centimeters are smaller than inches."
- "It didn't match because millimeters and inches are completely different things."

Conversely, other students recognized that it did "work" but stated that their classmates made mistakes because they "used the wrong side of the yardstick" or "they used the wrong measuring tool." This student error sheds light on the importance of developing in students the standard of "using appropriate tools strategically" (CCSSI 2010). We found question 5 interesting simply because we were able to see the different approaches that students used to find the area of the entire wall, and from that, to subtract the area of each individual picture. See **figure 5** for a sample of student work from question 5.

ACTIVITY 2: PROPORTIONAL REASONING AND SCALING

The second activity, involving proportional reasoning and two photocopies of the largest paintings, occurred in math class and is described below.

Two separate classes of seventh-grade students were presented with an opportunity to resize a small replica of a painting from The Barnes Foundation to a larger version of the artwork. To begin, a small photocopy of the largest painting from each wall was first dilated to 8 in. × 10 in. This scaled-down version of the painting was cut into twenty 2 in. × 2 in. squares, and a number from 1 to 20 was written on the back of each square, in order, from top to bottom, left to right. Next, blank white paper was used to cut twenty 4 in. × 4 in. squares, which were also numbered from 1 to 20 lightly on the back.

Each student was given one of the 2 in. × 2 in. squares and a corresponding blank 4 in. × 4 in. square with no knowledge of the full painting image. They were asked to re-create an enlarged drawing of the 2 in. × 2 in. section of the painting on the blank square that was 4 in. × 4 in. by proportionally thinking where each color and design would appear so that it would match the smaller image.

To provide an example for the students, the teacher used a 2 in. × 2 in. sample of the painting on the document camera and showed how a red triangular shape started at about one-fourth the way down the left side and ended at the halfway point. She then drew the red triangle on the 4 in. × 4 in. blank square by finding 1/4 and 1/2 and placing the scaled-up red triangular shape in the same position proportionally. By not knowing the overall image of the painting they were creating, students focused on the location of the lines and shapes on their individual piece without being distracted by the full image.

Students used crayons to sketch and color and proportional reasoning to scale up the square. Students worked diligently to make their picture match the original. One student asked her peer, "Are you going to put purple in that? I think ours goes together." Several students started over after deciding that their picture was either too large or too small. After all students completed their squares, they glued their 4 in. × 4 in. squares on a common piece of chart paper at the place in the grid that matched their number. One student instantly made the connection and exclaimed, "We saw this in art! The paintings are famous!"

Once the students finished creating the larger version of the painting, they were given an activity sheet to complete (see **fig. 6**). Students applied their understanding of area and proportional relationships to compare

Fig. 6 The proportional reasoning and scaling activity sheet listed information that students needed to consider.

ENLARGING A PAINTING

You have been given a 2 in. × 2 in. square piece of a painting from The Barnes Foundation. You must enlarge it to a 4 in. × 4 in. square piece of a bigger version of the same painting.

1. a. How many times larger do you think the new painting will be?
   b. Why do you think that?

2. a. Compare the area of the original square with the area of the new square you created. How many times larger is the area of the bigger square?
   b. How much larger is the area of the entire painting created by the class compared with the area of the original square unit?

3. If you still used the original 2 in. × 2 in. square but instead received a blank square that tripled the dimensions to a square that is 6 in. × 6 in., compare the area of the original square with the area of the new square. How many times larger is the area of the bigger square?

4. What is the general relationship between changing the length of a side of the original square to the area of the painting?

5. Write an algebraic equation representing the general pattern from question 4.

6. Using the coordinate plane below, graph the relationship between the area of the original square and the area of the larger square.

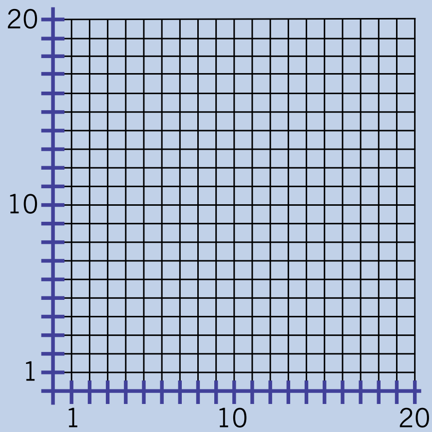


Fig. 7 Students assembled their 4 in. × 4 in. squares (a) and compared them with the reconstructed masterpiece from its 2 in. × 2 in. squares (b).

(a)

(b)

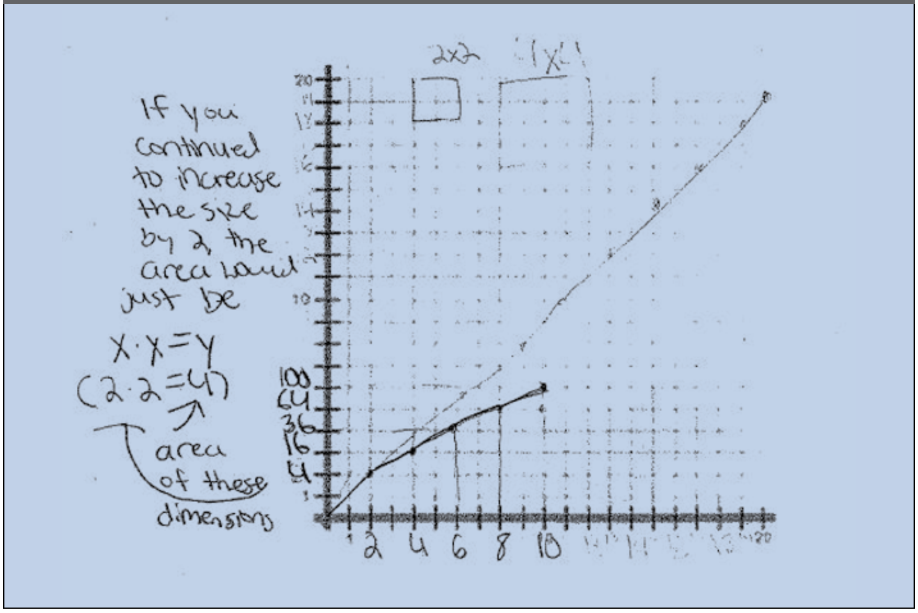
the original area (2 in. × 2 in.) with the new area (4 in. × 4 in.). Although many students incorrectly thought the new painting was going to be two times as large, other students correctly stated that the new painting was going to be four times larger. At first, students commented, "Doubling the dimensions makes the picture two times bigger" and "The painting has doubled because from 2 to 4 is 2, so it doubled." But some tested the actual pieces, suggesting that they were "Four times bigger because you can fit four little 2 × 2 squares in the 4 × 4 square," and "Four times bigger because one 2 × 2 square equals 1/4 of the 4 × 4."

The principal discovery expected from this activity was that if you double the length and width, the area quadruples. It was critical that we discussed this point during the debriefing of the activity sheet because we found that only 37 percent of students answered question 1 correctly. Many students did not conceptually understand that when you double the dimensions of a rectangle, you quadruple the area. Later, however, they saw how all their 4 in. × 4 in. squares combined to form a painting that was four times as large as the original painting (see **fig. 7**). Students also struggled to graph the relationship between the area of the original square and the area of the 4 in. × 4 in. squares (see question 6 on the activity sheet in **fig. 6**). **Figure 8** shows one student's basic understanding that the area of the dimension was used to calculate how many times larger the new area would be. Although this student did not use evenly spaced intervals on the *y*-axis, his intervals illustrated his understanding that a square number pattern would result.

MEANINGFUL MEASUREMENT

This activity provided an engaging and relevant context that helped

Fig. 8 One student's basic understanding of the relationship between the dimensions and area were both graphed and described.



students simultaneously learn about scaling drawings, proportional reasoning, measurement, and art history. Students who participated in this activity were excited to work with "famous" paintings and wanted to install the ensemble on the wall correctly, taking pride in their scale drawings. All students involved in the reinstallation process were given an opportunity to reflect on it in writing. When asked about advice for the next group of participants, students primarily commented that it was easier to measure from the floor than from other paintings. In addition, students were surprised to find that mixing centimeters and inches did not impede the process as originally predicted.

The process to move the actual art collection from its original location in Merion, Pennsylvania, took many months and included careful measurements of the ensembles of art. Schematics such as the ones used by students in this project ensured that the ensemble arrangements and scale would be preserved. As with moving the real collection, students in this project were also measuring and arranging their versions of the artwork. Students were using the same mathematics that Barnes used when he created his original arrangements of artworks.

We found this project to be a huge success, and nearly half the students in the school were involved in some way. As a result of these two activities, students engaged in meaningful mathematics involving measurement, proportional reasoning, and scaling.

REFERENCES

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%20Standards.pdf.

Lobato, Joanne, and Amy Ellis. 2010. *Developing Essential Understanding of Ratios, Proportions, and Proportional Reasoning for Teaching Mathematics in Grades 6–8.* Reston, VA: National Council of Teachers of Mathematics.





Sarah B. Bush, sbush@bellarmine.edu, is an assistant professor of mathematics education at Bellarmine University in Louisville, Kentucky. She is a former middle-grades mathematics teacher who is interested in relevant and engaging middle-grades math activities. **Karen S. Karp**, karen@louisville.edu, is a professor of mathematics education at the University of Louisville in Kentucky. She is a former member of the NCTM Board of Directors and a former president of the Association of Mathematics Teacher Educators (AMTE). She continues to work in classrooms to support teachers of students with disabilities in their mathematics instruction. **Victoria Miller Bennett**, vamiller8911@yahoo.com, a National Board Certified Teacher, is currently a doctoral candidate at the University of Louisville. **Liz Popelka**, liz.popelka@insightbb.com, a National Board Certified Teacher and doctoral candidate at the University of Louisville, teaches middle school mathematics in Kentucky. **Jennifer Nadler**, jnadler@barnesfoundation.org, is the Outreach Project Manager at The Barnes Foundation in Philadelphia, Pennsylvania.