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A Quilting Lesson for Early Childhood Preservice and Regular Classroom Teachers: What Constitutes Mathematical Activity?

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In this narrative of teacher educator action research, the idea for and the context of the lesson emerged as a result of conversations between Shelly, a mathematics teacher educator, and Lisa, a quilter, about real-life mathematical problems related to Lisa's work as she created the templates for a reproduction quilt. The lesson was used with early childhood preservice teachers in a mathematics methods course and with K-2 teachers who participated in a professional development workshop that focused on geometry and measurement content. The goal of the lesson was threefold: (a) to help the participants consider a nonstandard real-world contextual problem as mathematical activity, (b) to create an opportunity for participants to mathematize (Freudenthal, 1968), and (c) to unpack mathematical big ideas related to measurement and similarity. Participants' strategies were analyzed, prompting conversations about these big ideas, as well as an unanticipated one.

What would happen if the activities we, mathematics teacher educators, use to model best practices and standards-based teaching in mathematics methods courses and professional development workshops honored mathematical activity that is nonstandard in the sense that it is sometimes not even considered mathematics? Mary Harris (1997) describes how she uses "nonstandard problems that are easily solved by any woman brought up to make her family's clothes" (p. 215) in mathematics courses for both preservice and classroom teachers. To make a shirt, "all you need (apart from the technology and tools) is an understanding of right angles, parallel lines, the idea of area, some symmetry, some optimization and the ability to work from two-dimensional plans to three-dimensional forms" (p. 215). Although none of these considerations are trivial, making a shirt is not typically considered mathematical activity. Harris raises questions about why this is true. Is it because the seamstress is a woman or because only school mathematics is valued by our society? And, more broadly, what constitutes mathematical activity?

We contend that mathematical activity is both physical and mental. It requires the use of tools, such as physical materials and oral and written languages that are used to *think* about mathematics (Heibert et al., 1997). In the process of doing mathematics, one thinks or reasons in logical, creative, and practical ways. According to Sternberg (1999), American schools have a closed system that consistently rewards students who are skilled in memory and analytical reasoning, whether in mathematics or other domains. This system, however, fails to reward, in the sense of grades, students' creativity, practical skills, and thinking. In problem-solving situations, students should be encouraged to use both physical and mental activity to do mathematics in order to (a) identify the nature of the problem; (b) formulate a strategy; (c) mentally represent the problem; (d) allocate resources such as time, energy, outside help, and tools; and (e) monitor and evaluate the solution (Sternberg, 1999). Researchers who studied the consumer and vendor sides of mathematical reasoning found skills revealed by a practical test were not revealed on an abstract-analytical, or school-type, test (Lave, 1998; Nunes, 1994).

Too often, mathematics is viewed as the mastery of bits and pieces of knowledge rather than as sense making or as sensible answers to sensible questions (Schoenfeld, 1994). Sensible questions arise from many nonstandard contexts. If we design problems that are based on those questions, model best practices, and elicit mathematical big ideas, our students might begin to see mathematics as a human endeavor. They may use logical, creative, and practical thinking to solve those problems.

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As sometimes happens, an idea for a nonstandard real-world lesson took root in an unexpected place. During lunchroom conversations, Lisa, a member of the American Quilt Study Group (AQSG), described her work on a reproduction quilt with Shelly, a mathematics teacher educator. AQSG members participate in efforts to preserve quilt heritage through various publications, an extensive research library, and a yearly seminar. At this seminar, the AQSG invites members to make smaller versions, or reproductions, of antique quilts from a specified time period so that many of these can be displayed in one area.

Lisa and Shelly discussed the mathematical problems Lisa encountered as she designed the reproduction quilt. The square quilt she was reproducing, one her neighbor owned, had a side length of about 88 inches; however, the display quilt could not be more than 200 inches in perimeter. She wanted to trace the templates for the design from her neighbor's quilt (see Figure 1) and then use a copy machine to reduce these traced sketches (see Figure 2). She needed to decide which reduction factor to use and how much of each color fabric–white and blue–to purchase. She wanted to buy the least possible amount of fabric. These reproduction quilt problems became the context for the lesson that Shelly created and used with both early childhood education preservice teachers enrolled in a mathematics methods course and with K-2 classroom teachers in a professional development workshop.

Figure 1: Reproduction (left) and original quilt (right)

Figure 2: Templates

Literature Review of Lessons Related to Mathematics and Quilting

Because of a desire to know more about the connections between mathematics and quilting, we began by searching for literature related to lessons for teachers. We found some rich resources that included a wide range of mathematical topics embedded in these lessons.

Transformational geometry was the foundation for several lessons. Whitman (1991) provided activities for high school students related to Hawaiian quilting patterns with a focus on line symmetry and rotational symmetry. Ernie (1995) showed examples of how middle school students used modular arithmetic and transformational geometry to create quilt designs. Most recently, Anthony and Hackenberg (2005) described an activity for high school students that made "Southern" quilts by integrating an understanding of planar symmetries with wallpaper patterns.

The patterns and sequences found in quilt designs provided a basis for mathematical topics in other lessons. Rubenstein (2001) wrote about several methods that high school students used to solve a mathematical problem related to quilting: finite differences, the formula for the sum of consecutive natural numbers, and a statistical-modeling approach using a graphing calculator. Westegaard (1998) described several quilting activities for students in grades 7-12 that reinforced coordinate geometry skills and concepts such as identifying coordinates, determining slope as positive or negative, finding intercepts, and writing equations for horizontal and vertical lines. Mann and Hartweg (2004) showcased third graders' responses to an activity in which they covered two different quilt templates with pattern blocks and then determined which template had the greatest area.

Reynolds, Cassell, and Lillard (2006) shared activities based on a book by Betsy Franco, *Grandpa's Quilt*, which they incorporated into lessons for their second-graders. In these activities, students made connections to patterns, measurement, geometry, and a "lead-in" to multiplication. In a lesson for third graders, Smith (1995) described how she linked the mathematics of quilting–problem solving, finding patterns, and making conjectures–with social studies through the use of a children's book, *Jumping the Broom.* Also with a connection to integration with social studies, Neumann (2005) focused on the significance of freedom quilts, the Underground Railroad, the book *Sweet Clara and the Freedom Quilt* (Hopkinson, 1993), and mathematics–the properties of squares, rectangles, and right triangles–in her lesson for upper elementary school children.

In their book *Mathematical Quilts: No Sewing Required!*, Venters and Ellison (1999) included 51 activities for giving "pre- and post-geometry students practice in spatial reasoning" (p. x). These activities are situated within four chapters: The Golden Ratio Quilts, The Spiral Quilts, The Right Triangle Quilts, and The Tiling Quilts. The authors noted that the quilts that inspired their book were created when they were teaching mathematics and taking quilting classes in the mid-1980s:

> Because we had no patterns for our [mathematical] quilts, we had to draft the design and solve the many problems that arise in this process involving measurement, color, and the sewing skills needed for construction ... Taking on a project and working it through to completion provide invaluable experiences in problem solving. (p. ix)

These were the same challenges that Lisa faced when she created her reproduction quilt.

What was missing from this extensive list of resources was any reference to using mathematics and quilting in lessons for preservice teachers or professional development workshops for teachers. We felt that Lisa's real-world task would provide the opportunity for the preservice and classroom teachers to mathematize,[1] recognize big mathematical ideas, and consider what constitutes mathematical activity. We thought the big ideas that would emerge from this task included:

- Measurement is a way to estimate and compare attributes.
- A scale factor can be used to describe how two figures are similar.

Within this article, we briefly describe the preservice and classroom teachers who we worked with, the quilting lesson that we created–based upon the actual mathematical questions that Lisa faced as she created her reproduction quilt–and the mathematics that the preservice and classroom teachers used as they mathematized. We then summarize our follow-up conversations about participants' general reactions to the reading, *An Example of Traditional Women's Work as a Mathematics Resource* (Harris, 1997), and our question: What constitutes mathematical activity? Finally, we describe the emergence an unanticipated mathematical big idea, based on the ways that the preservice and classroom teachers approached the problem.

We piloted this lesson during the first semester of the 2004-2005 school year with a class of preservice teachers at a large public university in the Midwestern United States. We then obtained IRB approval to collect data in the form of work on chart paper that groups in a second class did the following semester. We used the lesson again during the summer of 2005 with a group of 20 classroom teachers, grades K-2, in a professional development workshop.

The K-2 Preservice Teachers and Classroom Teachers

Teaching Math: Early Childhood (TE300) was a 2-credit methods course that preservice teachers enrolled in prior to student teaching. The course included a two-week field experience in which the preservice teachers wrote one standards-based, "best practices" lesson plan, and then taught the lesson. During each class session throughout the semester, we focused on a chapter from *Young Mathematicians at Work* (Fosnot & Dolk, 2001) and one of the content or process standards from *Principles and Standards for School Mathematics* (*PSSM*) (National Council of Teachers of Mathematics [NCTM], 2000). The reading from *PSSM* for the week of the quilting activity focused on measurement.

All but one of the sixty TE300 preservice teachers were female. In mathematical autobiographies written during the first week of the course, about two-thirds of these preservice teachers said they either disliked or had mixed feelings about their previous school mathematical experiences, K-12 and post-secondary. Some who reported dislike for mathematics described feeling physically sick before math class, helplessness, and lack of self-confidence. Those with mixed feelings wrote about grades of A's and B's as "good times" and grades of D's and F's as "bad times." Many described board races and timed math tests over basic facts as dreaded experiences. Generally speaking, they hoped to help their own students experience the success that they did not enjoy in math classes. These mathematical experiences posed a special challenge for us because we felt that their beliefs about teaching and learning mathematics had to be addressed. Due to time constraints, we attempted to address them at the same time that we talked about best practices and standards-based methods.

The K-2 classroom teachers participated in a professional development workshop offered the summer after we implemented the lesson with the preservice teachers. Most opted for free tuition to earn graduate credit; each of them also received a $300 stipend to spend on math books, manipulatives, or other items. All but one of the 20 teachers were female. The majority of the classroom teachers described their own mathematical experiences as less than pleasant and their fear of mathematics was evident from the beginning. Similar to the preservice teachers, they were very bold about their dislike of mathematics. They openly discussed their views of mathematics as a set rules and procedures to be memorized. Although the focus of the workshop was on improving the teachers' content knowledge in geometry and measurement, we felt that we also needed to address their beliefs about teaching and learning mathematics within that context.

As a springboard for the semester and the workshop, we discussed the meaning of mathematics and mathematizing. To initiate discussion, we posed the following question: "Is mathematics a noun or a verb?" Some thought it was a noun because mathematics is a discipline or subject you study in school. Others argued that it was a verb because you "do" it. About half argued that it could be considered both.

When both the preservice and classroom teachers read *Young Mathematicians at Work* (Fosnot & Dolk, 2001), we again negotiated the meaning of mathematics and mathematizing (Freudenthal, 1968), reaching a consensus consistent with Fosnot and Dolk's interpretation: "When mathematics is understood as mathematizing one's world—interpreting, organizing, inquiring about, and constructing meaning with a mathematical lens, it becomes creative and alive" (p. 12-13). These are all processes that "beg a verb form" (p. 13) because mathematizing centers around an investigation of a contextual problem.

The Lesson

According to Fosnot and Dolk (2001), situations that are likely to be mathematized by learners have at least three components:

- The potential to model the situation must be built in.
- The situation needs to allow learners to realize what they are doing. The Dutch used the term *zich realizern*, meaning to picture or imagine something concretely (van den Heuvel-Panhizen, 1996).
- The situation prompts learners to ask questions, notice patterns, and wonder why or what if.

Guided by these components, we planned the lesson within Lisa's quilting context.

Throughout the semester and the workshop, Shelly read part of a picture book, *Sweet Clara and the Freedom Quilt* by Deborah Hopkinson (1993), in order to provide a context for the quilting problem. In this book, Sweet Clara is a slave on a large plantation. Her Aunt Rachel teaches her how to sew so that Clara can work in the Big House. There, she overhears other slaves' talk of swamps, the Ohio River, the Underground Railroad, and Canada. Listening intently to these conversations, Clara visualizes the path to freedom and creates a quilt that is a secret map from the plantation to Canada.

To launch the problem, Lisa told the groups about her work in the AQSG and explained why she wanted to produce a replica of a two-color quilt from the period 1800–1940. As it happened, her neighbor found a quilt in her basement and showed it to Lisa, who could hardly believe her luck! Not only did Lisa like the design, but she liked the two colors, blue and white, as well. She decided to use her neighbor's quilt as the original for her reproduction.

We then shared the parameters for the reproduction quilt, as given by the AQSG:

- Display: Each participant is limited to one quilt. Each quilt must be accompanied by a color image of the original and the story of why it was chosen.
- Size: The maximum perimeter of the replica is 200 inches. This may require reducing the size of the original quilt. Size is limited to facilitate the display of many quilts.
- Color: "Two-color" indicates a quilt with an overall strong impression of only two colors. A single color can include prints that contain other colors but read as a single color.

We also explained how the square-shaped original quilt had side lengths of 88 inches and showed them a photo of both the original and reproduction quilts (see Figure 1).

In order to help both the preservice and classroom teachers immerse themselves in mathematizing and consider what constitutes mathematical activity related to measurement and similarity, we posed the following three questions that were actual questions that Lisa faced as she prepared to create the study quilt:

1. By what percent did she need to reduce the original quilt to fit the 200 inches measured around all four sides (the perimeter)? The original was 88 inches on one side. (Lisa wanted to use the copy machine and a scale factor to reduce the pattern pieces she traced from the original quilt to create the pattern pieces for the reproduction.)
2. How much white fabric did she need to buy for the front and back of the quilt? (Please note: Fabric from bolts measures 44-45 inches wide.)
3. How much blue fabric did she need to buy for the appliqués, borders, and binding around the edges? (Use the templates from the original quilt to determine your answer.)

Before they began to work, we also showed them an actual bolt of fabric and explained how fabric is sold from the bolt because we were not sure they would know what this meant (and many did not!). We gave each group original-sized copies of the templates used for the appliqué blue pieces on the original quilt (see figure 2) to use to answer the third question.

We asked them to keep a record on chart paper of both the mathematics and mathematical thinking or processes they used to answer the questions so that they could share the results in a whole group discussion. Calculators, rulers, meter-yard sticks, tape measures, string, scissors, and tape were also available.

We walked around, listened, and watched the groups work. Some had questions we had not expected: Is there white underneath the blue? Does the back have to be all one piece of fabric? Can we round our numbers? Should we allow for extra fabric? The students' questions made us realize that, even though the three questions we posed might seem trivial for some quilters and mathematicians, they served as a springboard for the rich mathematical discussion that followed the small group work.

The Mathematics

We assessed the groups' strategies while they worked to answer the three questions by listening to their discussions and analyzing the chart paper record of their strategies. We noticed that most groups, both in the class for preservice teachers and the workshop for classroom teachers, took the directions quite literally (i.e. that the reproduction perimeter must be exactly 200 inches) and used similar strategies.

After the groups posted their chart paper on the walls, we began a whole-group discussion by posing the question: Are the two quilts, the reproduction and the original, mathematically similar? All agreed that they were but when asked why, their responses focused on the notion that they just looked similar. They knew the quilts were not congruent because they were different sizes. We told them that we would return to this question later so that we could negotiate a mathematical definition of similarity.

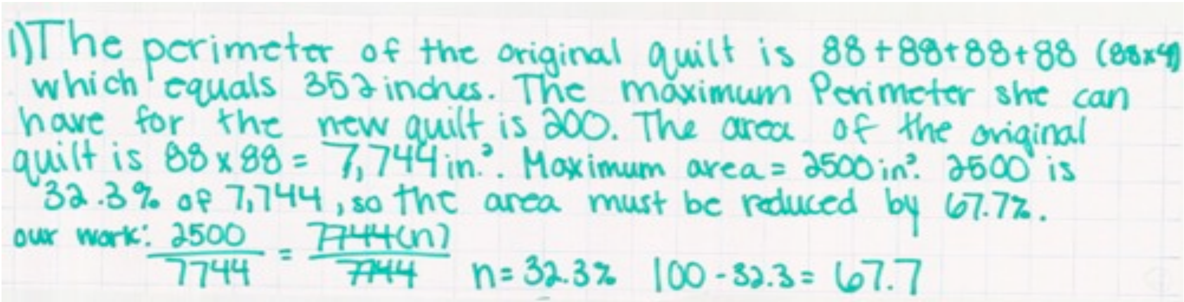

Figure 3: A solution to Question 1

Question 1

All but two groups thought of the perimeter parameter as exact and created scale factors to reduce the quilt so it would have a perimeter as near to 200 inches as possible. These groups said that the pattern should be reduced on the copy machine by either 57% or 43%; this led to an interesting conversation about how these were related and which one made more sense. Would we enter 57% or 43% into the copy machine? Which number makes the most sense based on what we know about copying machines and how they reduce images?

The two groups that did not use the method adopted by the majority used the same scale factor as Lisa, approximately 67.7%. We asked these groups to share their thinking (see Figure 3) because it seemed like their mathematical calculations and reasoning were also valid. How could there be different answers? Instead of focusing on perimeter, these groups created a ratio of the total area of the reproduction quilt to the total area of the original quilt, 2500/7744 (assuming the quilt would measure 50 inches by 50 inches); the ratio was 32.3%. So, the area needed to be reduced by 67.7%. At first, we wondered why the percents differed when groups compared areas instead of perimeters for the same geometric figure. This led to the opportunity to discuss an unexpected big idea, something we had to think deeply about ourselves before we realized why the results for the groups were different: When the perimeter of a rectangle is reduced by a scale factor, the area is *not* reduced by the same scale factor. In fact, the ratio of the areas is the square of the ratio of the perimeters. In addition, this is true for any size of rectangular quilt or similar figures.

We had to encourage the preservice and classroom teachers to think about why the two percents were different. When pressed, they realized that, because area is a square measure, taking the ratio of two areas resulted in a different value than taking the ratio of two perimeters or side lengths. In fact, 32.3% was approximately the square of the ratio for the perimeter comparison, $(50/88)^2$.

This led us to rethink our questions about the copy machine. Does the word "reduction" lead to mathematical misconceptions? How does the reduction scale factor change the perimeter and the area? For instance, is the original image reduced by the selected percentage or does the machine create an image that is that percentage of the original? Experimentation with the copy machine reduction function helped us answer this question (we leave it to the reader to explore).

Interestingly, even though most groups considered the perimeter parameter as strict, Lisa knew that the reproduction quilt could be *no larger* than 200 inches so she decided to use a 50% reduction—this made her study quilt 44 inches per side with a perimeter of 176 inches, which was "close enough." Like Lisa, two groups decided that 50% was a reasonable and "friendly" number to use, making other calculations for the quilt less cumbersome. This led to a conversation about when close enough is sufficient for measurement and other uses of mathematics. We felt this was especially important because many of the preservice and classroom teachers experienced mathematics as problems with one exact answer. The idea that measurement can be precise but not exact was something they needed to think about.

Questions 2 and 3

For the second and third questions, the chart paper revealed that the groups had a wide range of answers and some mathematical misconceptions. Most had answers close to 3 yards of white fabric and 1.5 yards of blue fabric. Some groups drew sketches of the fabric (see Figure 4). Groups that drew sketches or representations had the best estimates for conserving fabric. Even though one might think that determining

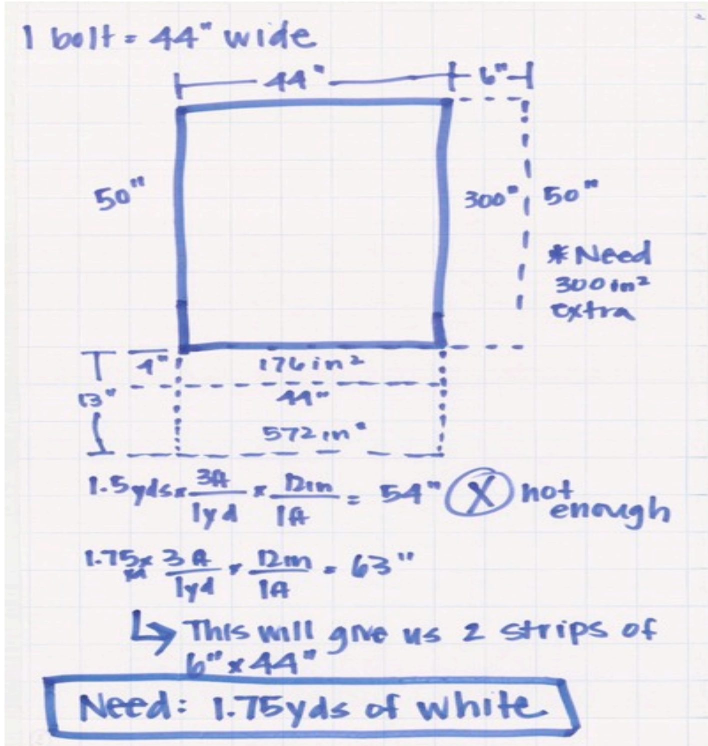

Figure 4: A solution for Question 2

the amount of white material would result in trivial mathematical conversations, we noticed that most groups tried various ways to overcome the fact that the width of the material (44-45") posed a real contextual dilemma, as it was shorter than the width of the quilt. In other words, they had to consider both area and length in their attempt to minimize the amount of fabric needed.

For the second question, one group decided that Lisa needed to buy 47 yards of white fabric. This group felt the sides of the quilt should measure 41 inches because the fabric was 44-45 inches wide (see Figure 5). This was similar to Lisa's thinking and within the 200-inch parameter for total perimeter.

However, we were shocked by their answer of 47 yards! They did not take into account the notion that you must divide by 144 to convert square inches to square feet and by 9 to convert square feet to square yards. This mistake is one that could have been predicted with out-of-context problems, but Lisa had shown her reproduction quilt before they began working in their groups. What was most disturbing about this answer was the fact that 47 square yards made no sense given the size of one square yard.

Similarity

Returning to the definition of similarity, we again posed the question: Why are the two quilts mathematically similar? The preservice and classroom teachers negotiated a definition that made sense to them. They talked about "not the same size but the same shape" in terms of scale factors and created a

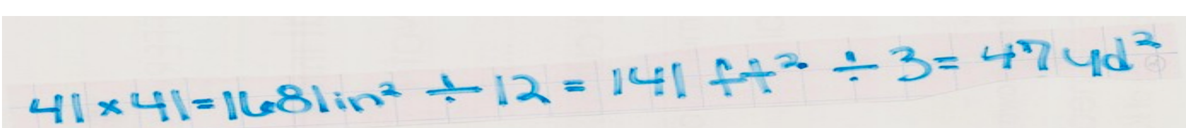

Figure 5: A solution for Question 2

working definition: The scale factors or ratios of the corresponding sides of the two quilts are equal (or proportional) and the ratio of the areas is the square of the ratio of the side lengths.

Generally speaking, we felt as though this task provided opportunities to talk about many mathematical notions related to measurement and similarity including exactness versus precision, estimation, ratio, proportion, percent, scale factor, perimeter, and area. We briefly discussed the kinds of symmetry—reflection (flip), rotation (turn), and translation (slide)—in the quilt but this was not a focus. The preservice and classroom teachers also noted that they used all five NCTM process standards (problem solving, communication, reasoning and proof, connections, and representation) as they worked in their groups and during our class discussion.

What Constitutes Mathematical Activity?

As a way to help the preservice and classroom teachers consider what constitutes mathematical activity, we gave them copies of *An Example of Traditional Women's Work as a Mathematics Resource* (Harris, 1997) to read before our next class or professional development session. According to Harris, in mathematical activity, women are disadvantaged in two ways: (a) until very recently, female mathematicians were barely mentioned; and (b), in a world where women's intellectual work is not taken very seriously, the potential for receiving credit for thought in their practical work is severely limited. In her book, Harris showed her students a Turkish flat woven rug, called a kilim, and her students explored the mathematics involved in its construction. She also displayed a right cylindrical pipe created by an engineer and a sock knitted by a grandmother. She then posed the following questions: Why is it that the geometry in the kilim is not usually considered serious mathematics? Is it because the weaver has had no schooling, is illiterate, and is a girl? How do we know that the weaver is not thinking mathematically? Why is designing the pipe considered mathematical activity but knitting the heel of the sock is not?

This reading helped create an opportunity for the K-2 preservice and classroom teachers, groups that are mostly female, to talk about their own beliefs regarding what constitutes mathematical activity in the context of women's work. Many of them had considered school mathematics as the only kind of mathematics. After doing the quilting activity and discussing their reading of Harris (1997), however, they began to talk about doing mathematics within traditional women's work such as measuring and hanging wallpaper, cooking, creating flower garden blueprints, playing musical instruments, and determining the number of gallons of paint needed to paint a room. We did not discuss the nature of mathematical activity as both physical and mental activity but, after thinking more deeply about it ourselves, we now realize that this was a missed opportunity. It seems that our conversation should also focus on the logical, creative, and practical ways in which we think and reason while doing mathematics.

Concluding Remarks

Through our collaborative effort to create a lesson with real-world applications and a reading related to what constitutes mathematical activity, the preservice and classroom teachers saw mathematics as something you do *outside* of school. They were mathematizing, organizing, and interpreting the world through a mathematical lens as they made conjectures about the same questions that Lisa faced when she created her reproduction study quilt.

Analysis of the student strategies revealed opportunities to discuss big ideas related to measurement and similarity and what constitutes mathematical activity. It also prompted Lisa to take another picture of the two quilts, to illustrate the big idea that emerged from the groups' sense-making: reducing the perimeter by 50% created a reproduction quilt with one-fourth the area of the original quilt (see Figure 6).

Within this lesson, we modeled the kind of teaching we hope these preservice and classroom teachers will think about and use in their classrooms: helping students mathematize, make connections to big ideas and real-world mathematics, and question what constitutes mathematical activity. As Harris (1997) noted, the role of mathematics teachers should not be to teach some theory and then look for applications, but to analyze and elucidate the mathematics that grows out of the students' experience and activity. Using nonstandard contextual problems creates opportunities to honor school mathematics and mathematical activity that exists within the real world of everyday activity. By doing so, we also honor and respect our students' logical, creative, and practical thinking. We give voice to their mathematics.

Figure 6: The reproduction quilt on top of the original quilt

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[1] The term mathematize was coined by Freudenthal (1968) to describe the human activity of modeling reality with the use of mathematical tools.