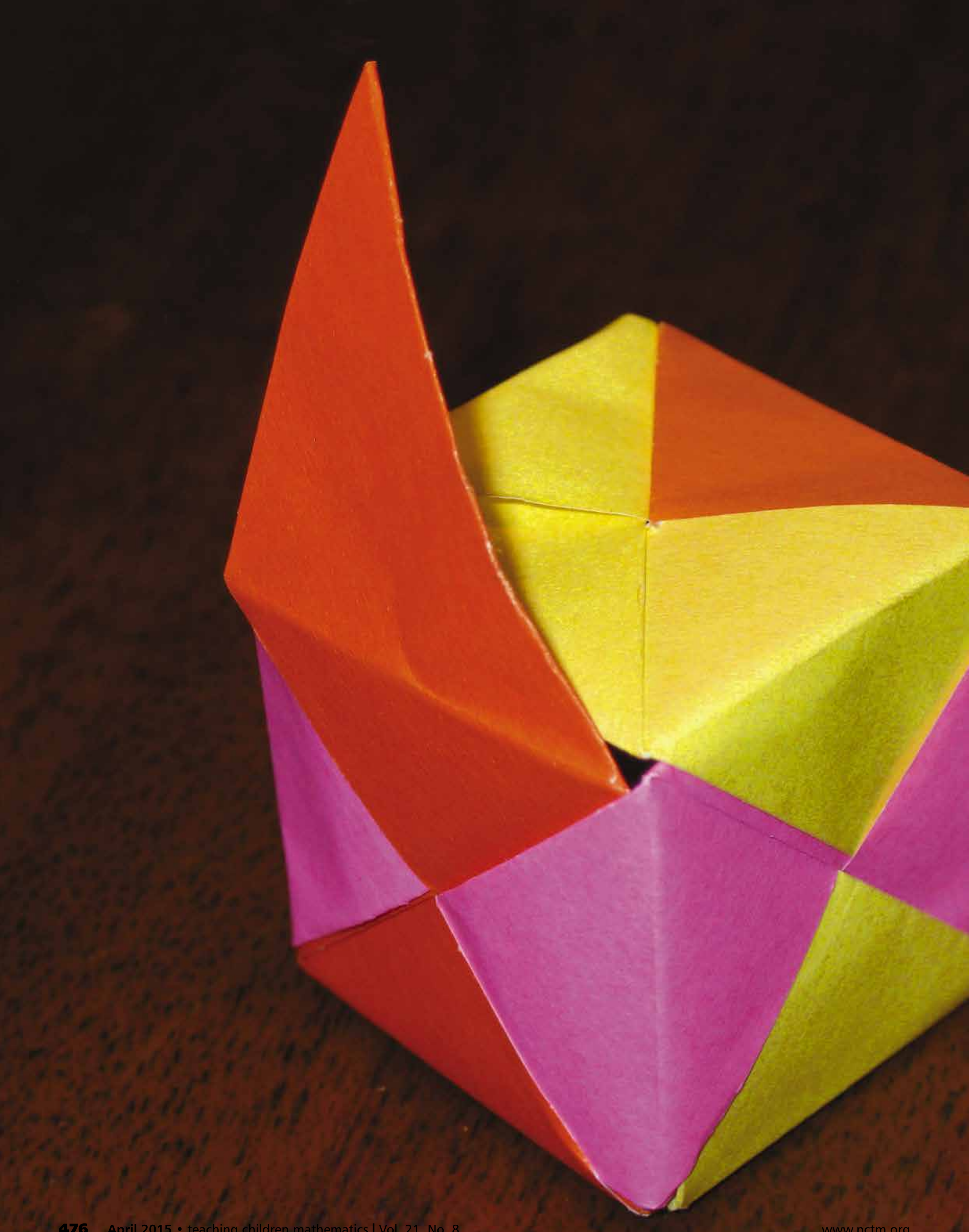

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UN-FOLD-ING A PROBLEM

Learn how origami is more than arts and crafts; it can take problem solving in new directions.

Sarah Cox Currier

When I mentioned to another district math specialist that I had done an origami project with my students, she was surprised, asking where I had found time for a craft project. We were all feeling pressured to keep to a tight schedule as we worked to meet the standards. I was puzzled. I had not thought I was *adding* anything at all! It was just the opposite: I was using origami in a deliberate manner to teach content. I will share how I have used paper folding to teach mathematical concepts, to reinforce vocabulary, and as a problem-solving model. I will also offer ideas for using origami in your classroom.

The author stumbled on an effective approach to teaching origami: focusing on the process rather than the outcome.

SARAH COX CURRIER (2)

From craft project to rich learning experience

I never set out to be an origami master. In fact, I first discovered paper folding because a friend wanted to make a project in a book and could not understand the directions. I shared the project with my students, and that was the beginning of an ongoing love.

In my early origami lessons, I would hand out paper and stand in front of the class demonstrating a fold as children folded along with me. They would interrupt, "Is this right?" "Like this?" or "Wait! I don't get it!" I was pulled in many directions. Some children would be confused, others would be impatient, and we would all be a little frustrated. Even though the children clamored for more origami, I found myself wondering if it was worth the trouble. Yet I was sure it had the potential for real learning.

One day, without fully planning it, I gathered students around me and demonstrated an entire project, step-by-step. I wanted them to watch a tricky fold carefully before they tried it. I then took out a second paper and asked my students to tell me what they remembered. Many remembered quite fully and called out the steps as I made a second model. We returned to our desks, and as we folded, many children remembered what to do and helped others sitting nearby. I had stumbled onto something.

I began to use a different approach to teach origami. I looked for ways to use it to reinforce or teach particular topics. I used precise mathematical vocabulary. Origami had moved from being a craft project where the *outcome* was the goal to being one where the *process* was the focus. I wanted to take it even further.

Origami can be used to teach concepts, vocabulary, and problem solving.

Identifying the problem

In his book *How to Solve It*, George Pólya identifies four basic steps or principles for problem solving. His first principle of problem solving is to *understand the problem*. Too often, my students barely read a problem before they start in, combining or subtracting numbers without thinking. When I remove the numbers and have them read the problem and tell me about it *before* starting to work, they are much more likely to form a logical plan. Multistep problems are especially challenging. When several steps are involved, students become confused and lose sight of the meaning. By focusing on the origami project before actually folding, my students had focused on the "big picture."

In my work toward my master's degree, I learned about backward design. By identifying and understanding our objectives first, and working backward, we can create a "map" for reaching our goal. As teachers, when we start by considering the standard we want children to master, we can work backward to form our daily lesson plans. Would such an approach work with origami? Could students concentrate on the process of problem solving in a hands-on activity and transfer this strategy to other areas? I decided to try it with my students.

A cube project

I brought in a completed cube made from six Sonobe modules of three different colors of paper (see **fig. 1**). A Sonobe module is a folded piece or "unit" that can be combined with others to form increasingly complicated creations. It is a type of origami called *modular origami*. I held it up and asked my students to think about how it might be constructed. I asked how many pieces of paper it might require. They called out their ideas:

"Four!"

"Six!"

"Three!"

"Twelve!"

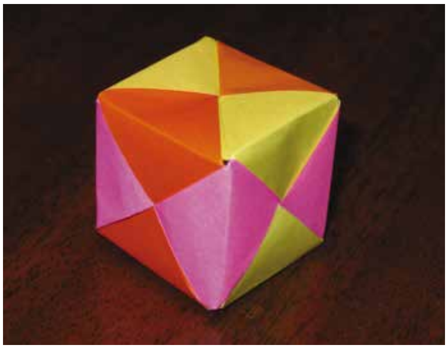
"Squares have four sides," one student said. "So I think it has four pieces of paper."

"But there are three colors," another replied. "That doesn't make sense for four sheets of paper. It would have to be three pieces."

"Yes, but if the paper is square, it doesn't seem like the pieces could be big enough to go all the way around. There must be two of each color," responded another student.

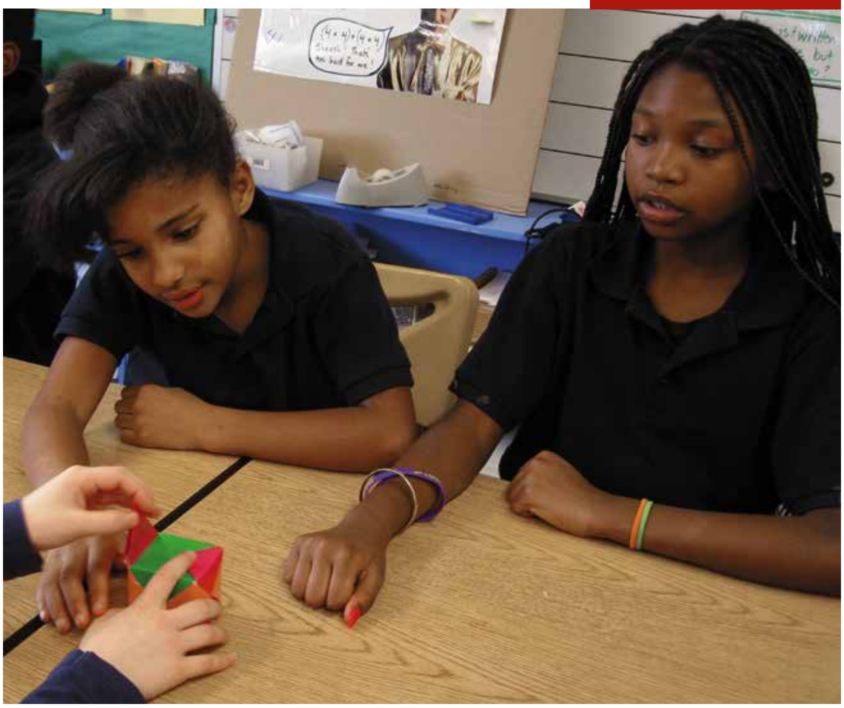
FIGURE 1

Sonobe modules can be combined to form complicated *modular origami*. Below is a cube of six Sonobe modules in three colors.



Our list grew as we shared ideas.

Pólya's second principle of problem solving is to *devise a plan*. Some of the strategies he identifies include working backward, eliminating possibilities, and using direct reasoning. As our discussion continued, I asked the children to give reasoning for their suggestions. I listed predictions on chart paper and asked them what information they would need to feel sure of their prediction. Some said they would need to take the whole cube apart. Others said they



Using a "work-backward" strategy, students identified the steps required to build a Sonobe cube.

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FIGURE 2

The teacher began to deconstruct the cube.

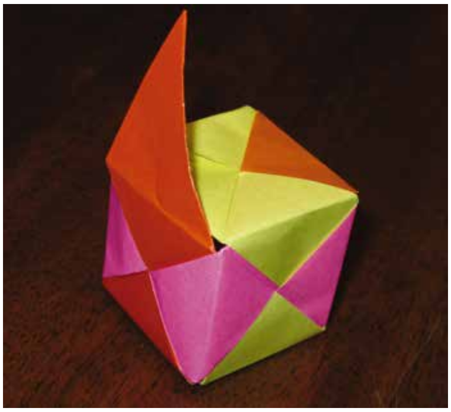

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FIGURE 3

Many students saw that they could rule out some of the class predictions about how many pieces of paper were used.

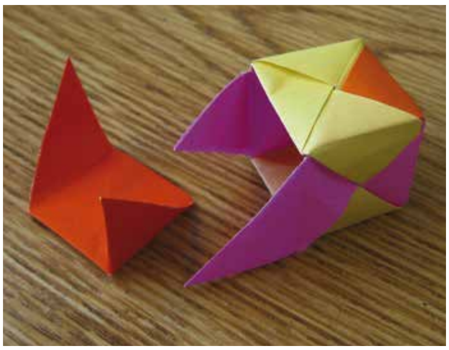


FIGURE 4

Others, however, would need to see the entire deconstruction before they fully understood the cube's construction.

might need to see only part of it. I began to deconstruct the cube and carefully pulled out a part of one of the six pieces (see **fig. 2**). Many students said, "Oh! I see it now!" As I removed the first piece of the cube (see **fig. 3**), I asked if they would like to change or refine their guess. We looked at our predictions and realized we had ruled out many. Most students now said that it would take six pieces. Some still needed to see the entire cube disassembled.

I continued to deconstruct the cube and lay out the six pieces. Many students had not thought about what the smaller parts would be. They held a discussion about whether the pieces were rhombuses or just parallelograms. We considered rotational symmetry and congruence as we stacked the pieces on top of one another (see **fig. 4**). I drew out mathematical vocabulary, helping children focus on *faces*, *edges*, *vertices*, *intersections*, and so on.

The project continued in this manner as we deconstructed an individual piece. Two students recorded on paper the math vocabulary we used (see the **sidebar** on **p. 482**).

Reconstruction, step-by-step

Now that the cube was disassembled, I challenged my students to think about putting it back together. Pólya's third principle is to *carry out a plan*. As we thought about the last thing unfolded, we worked our way back to what must be the first step. We looked at the units as we formed our plan. This time, the students told me what to do; I tacked up a piece that had been folded up to that stage, creating a step-by-step series of instructions (see **fig. 5**). The class was ready to fold. Everybody remembered the first two steps and got started. Because the project required six pieces and students folded at different rates, individuals were ready for the next step at staggered intervals.

Pólya's fourth principle is to *look back and reflect*. If students asked, "What do I do next?" I challenged them to reflect. Instead of helping them right away, I directed them to our board to look at what others were doing or to think back to our discussion. I asked which step was confusing. I encouraged students to orient their paper like the model to determine where to go next. In most cases, that was enough direction. I could concentrate on supporting students who really struggled.

As students completed the six pieces needed to make the cube, I gathered small groups together and followed a similar process for assembling the cube. As often happens, somebody inadvertently made a mirror image of a piece or two. When the pieces did not fit together, we had an opportunity to discuss reflective symmetry and congruence. Leaders emerged as children helped one another. Instead of one teacher, now we had many. I began to look for more ways to build on this phenomenon. In the past, I had taught children to cut snowflakes as an art project, so I knew we could deepen our experience.

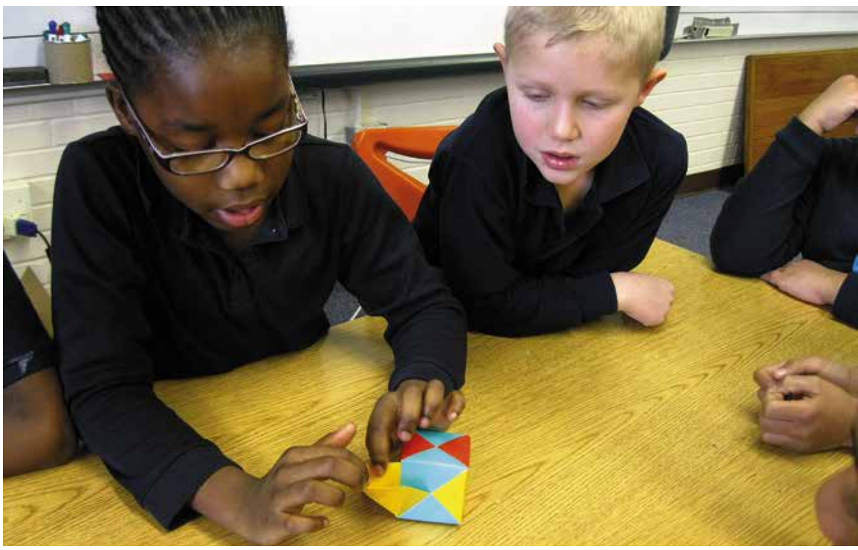
Snowflakes, pizzas, and angles

In Minnesota, the first snowfall was always a big event. Now it is also an opportunity for a math lesson. I set aside my plans for the day, and we learn to cut six-point snowflakes. As with the cube, I start by focusing on the goal. I ask students to describe a real snowflake. We list characteristics: six points, hexagon, angles, symmetry, and so on. I hold up a round sheet of paper and ask for ideas about how to fold it. Invariably, students will tell me to fold it in half, then in half again. I follow these suggestions, and then I unfold the paper to show fourths. Students will tell me to fold it again, producing eighths. With symbols and words, I will record what happened: "When we folded in half and then in half again, we got fourths: 1/2 = 2/4; and when we folded again, we got eighths: 2/4 = 4/8."

Someone may recognize the pattern and suggest 3/6. I will ask, "If we want to end up with *six* parts, how should we fold?" After discussing with partners, we will share ideas. If necessary, I will lead them to realize that each half must be divided into three parts if we want sixths. I will highlight 1/2 = 3/6 on our chart. We will discuss sharing pizzas; I will have a volunteer point where to draw imaginary lines to create equal pieces. I will demonstrate finding

FIGURE 5

Together, the class created step-by-step instructions, which the teacher posted along with the paper from that stage of deconstruction.



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Whenever students were confused about what to do next, the teacher's suggestion to reorient their paper to match the model was often all the help that they needed to start progressing again.

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Students posted steps, which classmates tested when creating their constructions.

the center, then sliding over one part of the circle until the two angles appear equal, then folding one section to the back. Nearly everybody can tell without measuring whether the pieces are fair. At this point, I will hold up the folded "pie piece" and ask what angle we created. For younger students, "acute" may be all the answer I expect. I challenge fifth graders, who have learned about the degrees in a circle, to tell me the degree measure of a circle and the individual sections. If we have folded carefully, a quick check with a protractor will show fairly accurate 60 degree angles. Now that we have divided the paper into sixths, we look carefully at each point. We note that each point is symmetrical. We fold the paper one more time, creating a pie piece with a 30 degree measure.

In no time at all, our room is littered with snips of paper, and we have transformed the classroom into a winter wonderland. Ironing the snowflakes before hanging them from the ceiling creates models of reference for discussions of symmetry, angles, and fractions in the weeks to come.

Reflections on practice: Origami in the classroom

The beauty of origami in the classroom is that it can be used in so many ways. An origami center (a repurposed cardboard display box from curriculum materials), which holds books, copies of directions, and supplies of paper, becomes a resource for cooperative and independent work.

Writing about origami pushes children to reflect on their understanding and to share with their peers. Exit slips might focus on using particular vocabulary words, outlining the steps of a problem, or reflecting on the broader ideas of perseverance, cooperation, and problem solving.

Simply folding has value because it is fun and because children love it. But with a little more thought, it can become a rich experience and a metaphor for learning. Today, when my students struggle with a word problem, I coach them, "Think back to when we made the cube. When you were stuck, what helped you?" Or when they raise their hand to ask for my help, I can prompt them, "What other resources in the room can help you?" and gesture toward fellow classmates and materials in the room.

If you try using origami in the classroom, I am sure you will discover for yourself how it can enrich and deepen your own experiences.

Vocabulary for cube deconstruction

Below is a sample of the mathematical vocabulary list that two students created as the class deconstructed a cube.

Face	Bisect	Vertex	Parallelogram	Cube
Base	Square	Parallel	Symmetry	Angle
Edge	Acute	Triangle	Intersection	Obtuse
		Center	Congruent	Rhombus

Common Core Connections

4.G.A.3 5.NF.B.7
5.G.B.4 5.NF.B.7a
4.NF.A.2

Sarah Cox Currier, **sarah.currier@mpls.k12.mn.us**, also known as Angle Woman, Pi Lady, and The Mathemagician, is a math specialist at Elizabeth Hall International School in Minneapolis, Minnesota. She loves math of all kinds but especially when it involves using hands-on materials. She believes strongly that all children are mathematicians and that learning by doing is the path to understanding.