Understanding Geometry and Measurement through Service-Learning

Susan C. Gillmor and Samantha A. Rabinowicz

Calculating volume and surface area of three-dimensional figures can become a routine process of "plug and chug" for many middle-grades students. We offer the following activity that is anything but routine. In this service-learning lesson, students apply their knowledge of volume and surface area while giving back to their communities. Service-learning is "a teaching and learning methodology that utilizes experiential learning and combines academic study, community service, reflection, student voice, civic participation, community partners' involvement, and assessment" (McCarthy 2008).

During our first year as seventh-grade math teachers at Colegio Menor in Quito, Ecuador, and Cameron Middle School in Framingham, Massachusetts, we integrated components of service-learning into a lesson in geometry, combining the concepts of volume and surface area. Although each school is geographically and demographically distinct, their missions reveal important similarities in terms of community engagement: The official vision of Colegio Menor is to be the top educational institution in the region, in part because of a strong commitment to community participation. Similarly, Cameron Middle School emphasizes preparing students to be citizens of a global community by prioritizing civic awareness.

In this service-learning lesson, we challenge our students to apply their knowledge of volume and surface area as described in NCTM's grade 6–8 Geometry and Measurement Standards and the Common Core State Standards for Mathematics (CCSSM) (6.G.4, 7.G.1, 7.G.4, and 7.G.6) while serving the community and learning about hunger (NCTM 2012; CCSSI 2010). The lesson requires students to construct the most efficient rectangular prism for the packaging of food that will be donated to local families and community centers. This application provides a direct link between CCSSM seventh-grade math content standards and practice standards. We

Edited by **Barbara Zorin**, drbzorin@gmail.com, MATHBonesPro, and **Carrie Fink**, cfink@methow.org, Liberty Bell Junior-Senior High School, Winthrop, Washington. Readers are encouraged to submit manuscripts through **http://mtms.msubmit.net**.

found that this mathematical exploration engages students of all learning types and gives new, real-world meaning to their academics.

THE HOOK

In the weeks leading up to the lesson, students participate in a food drive, which benefits local food pantries as well as low-income families within the community. We begin the food drive with a kickoff assembly to educate students on the issue of hunger and motivate them to collect food.

We introduce the objective of this particular lesson at the beginning of the instructional unit for the practical reason of collecting cans (see **fig. 1**). However, we found that two important results ensued: First, the students became highly motivated to understand the *why* and the *how* of the unit content. Students took the tasks more seriously because they knew they were going to have to apply the knowledge in a meaningful, real-world situation. Second, the classroom culture took on a teamlike atmosphere. By the end of the unit, many of our classes had developed telephone chains and used social networking websites to coordinate collection strategies. Groups of students also went door to door in their neighborhoods, asking for canned food donations. With this personal investment, our food drives proved to be remarkably successful, raising over 1000 pounds of food between the two schools.

Fig. 1 Objectives were shared with students before they began the first task.

Objectives

- Students will make sense of problems and persevere in solving them, construct viable arguments and critique the reasoning of others, model with mathematics, use appropriate tools strategically, and attend to precision.
- Students will solve real-life and mathematical problems involving angle measure, area, surface area, and volume.

THE LESSON TASKS

Two main goals for this lesson are for students to demonstrate their understanding of the unit concepts and to take ownership of their final product. For the lesson to be completely student led, we spend time outlining task-by-task expectations, discussing the final product, and explaining the grading rubric. Next, the students are placed into groups and self-appoint members to the given roles of a measurer, a calculator, and a recorder. The group shares the responsibility of ensuring mathematical accuracy throughout the lesson.

Measure Cans

For task 1 (see **activity sheet 1**), a number of canned food items of various sizes are distributed to groups of students at their station. Their assignment is to classify each can, measure its radius and height, calculate the area of its base, compute its volume, and record the information in a table using appropriate units. For struggling students, you can modify this task by—

1. supplying cans of similar size and shape; and
2. providing a number of cans that can be easily factored into dimensions resembling a cube.

Determine Packaging

The goal of task 2 (see **activity sheet 2**) is to determine the dimensions of the box that students are going to build so that their cans can be packaged in the most efficient way possible. Through a variety of previous in-class activities, students have defined efficiency as minimizing surface area while maintaining the necessary volume. They discovered that the most cube-like formation would satisfy these conditions. Students manipulate and stack the cans in different rectangular formations and record the length, width, and height in centimeters of the different possibilities.

Because of the thickness of the cardboard, we recommend suggesting to students that they account for a little extra "breathing room" when recording the dimensions. We tell students that hypothetically each square centimeter of packaging material costs $0.05. They then calculate the packaging material cost for each of their potential boxes by multiplying the surface area by $0.05. All measurements and calculations including volume, surface area, and cost of packaging are recorded in the table.

If students are having trouble during this exploratory stage of the process, teachers can facilitate productive and creative experiences by asking such questions as these:

- What is your group's strategy for finding the dimensions of your box?
- What would the most expensive box look like?
- What would happen to the cost of the box if you stacked all the cans on top of one another in a single tower?
- What would the opposite of this formation look like?

After analyzing the results of their recorded calculations, the groups select which boxes to build and write short explanations about why and how they chose their box. One group of South American students writes, "We chose it by seeing the box with the least surface area and right volume. The one that has all these qualities is the box that is the most cubic."

Draw with Proportion and Perspective

For task 3 (see **activity sheet 3**), students sketch a proportional,

scaled-down version of the net of their chosen box to act as their box blueprint. Because of the many possible ways to design a net for a rectangular prism, the students should label the dimensions of the top, bottom, front, and back; left and right faces; and all edge measurements.

Build Packaging

For task 4, students construct their nets (see **activity sheet 3**). After the teacher approves the groups' sketched nets, students draw their full-size nets on large pieces of cardboard (for those on a budget, supermarkets have plenty of free, extra-large cardboard), then the teacher cuts out these nets with a box cutter. This step then allows students to work on folding along the edges and constructing their box with packaging tape. When all but the top of the box is taped together, the students place their cans inside. At this point, students are assessed on their accuracy. Ideally, students are able to fit all the cans inside the box with minimal extra space.

For task 5 (see **activity sheet 3**), the students wrap and decorate their boxes. After persevering through tasks 1–4, we find that the students take pride in their work and decorate their boxes with care. Students can write cards and messages to the donation center or beneficiaries instead of decorating the box itself.

POSTLESSON STUDENT REFLECTION

Research has shown that reflection is essential for students to connect their service activities to learning (Hatcher and Bringle 1997). Our students then complete a short survey, adapted from S. Mark Pancer's Youth Social Responsibility Scale (see **fig. 2**). It gives the students an opportunity to reflect and then engage in a meaningful class discussion (Pancer et al. 2007). They are asked to respond to this prompt:

> Are you glad that we used class time to package cans to be donated to people who need them? How does that make you feel?

The data show that 84 percent of the students agree that helping others gives them a tremendous feeling of accomplishment; the remaining 16 percent were neutral. Of the students, 86 percent agree that young people have an important role to play in making the world a better place. The short answer question reveals that 69 out of the 70 South American students are glad that they took the time out of their school day to donate

Fig. 2 A survey was given to students after completion of the project.

REFLECTION SURVEY

1. Helping others gives me a tremendous feeling of accomplishment.
   Disagree Neutral Agree
2. Young people have an important role to play in making the world a better place.
   Disagree Neutral Agree
3. Everybody should volunteer some time for the good of their community.
   Disagree Neutral Agree
4. It is important for young people to know what is going on in the world.
   Disagree Neutral Agree
5. Schools should spend time trying to teach students about moral or social issues.
   Disagree Neutral Agree
6. People should help one another without expecting to get paid or rewarded for it.
   Disagree Neutral Agree
7. Open response: Are you glad that we used class time to package cans to be donated to people who need them? How does that make you feel? Please explain.

to people in need. One Framingham student reflects on the experience by writing,

> Not only was it fun, but we also used our [math] knowledge to make our boxes. Also, we did it for an important reason. We are giving food to those in need. . . . Doing this makes me feel grateful for what I have. Also, it makes me feel happy and good that I'm helping someone.

THE VALUE OF SERVICE-LEARNING

As teachers, we are held accountable for student success on state and national standardized assessments. McCarthy asserts that high-quality service-learning can improve students' scores on mandated assessments (McCarthy 2008). Moreover, other researchers have found that community service-learning experiences can lead to growth in student character and civic responsibility (Billig 2011).

Service-learning scholar Shelley Billig defines the components of a high-quality service-learning experience to be the following: strong link to curriculum, sufficient duration and intensity, meaningful service, community partnerships, diversity, progress monitoring, opportunities for reflection, and youth voice (Billig 2011). Although we address each of these components in the design of our lesson, the strong link to the curriculum makes this service-learning experience applicable to all classrooms.

Students are able to engage with the content in a meaningful way. Working together to plan, scale, and build rectangular prisms for a given set of donated canned food deepens students' understanding of the content. Because this lesson is so closely tied to the curriculum, it more than suffices as the primary form of summative assessment for the volume and surface area instructional unit.

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Susan C. Gillmor, scgillmor@ku.edu, is a former seventh-grade math teacher who is currently pursuing graduate study in Research, Evaluation, Measurement and Statistics at the University of Kansas. **Samantha A. Rabinowicz**, srabinowicz@gmail.com, is a current seventh-grade math teacher in Massachusetts and also serves as the professional development coordinator for the Center for Character and Social Responsibility at Boston University.

activity sheet 1

Name _____

TASK 1: CYLINDER DIMENSIONS

You are responsible for packaging canned foods. Use what you know about volume and surface area for both cylinders and rectangular prisms. After packaging, sealing, and decorating your products, you are going to donate them.

Step 1: Decide the responsibility of each team member and have the recorder write the names below:

Measurer: _____ Calculator: _____ Recorder: _____

Step 2: Record information about each can in the table below. You will use this information to design your packaging, so it is important that all information is accurate. You might need to measure and calculate more than once.

Cylinder (Can) Volume Chart

Can Number or Type of Food	Radius (cm)	Height (cm)	Area of Base ($\pi = 3.14$)	Volume (cm^3)
Total:				

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activity sheet 2

Name _____

TASK 2: DIMENSIONS OF PACKAGING

Today, you will find the most appropriate dimensions for the rectangular prism you will create to package your cans.

1. Using the information you calculated on **activity sheet 1**, record different possible combinations for the box dimensions below.

Height (cm)	Length (cm)	Width (cm)	Volume (cm^3)	Surface Area (cm^2)	Cost of Packaging ($0.05 per cm^2)

2. Use a highlighter and mark the dimensions of the box that you are going to use. Your box should use space and materials in the most effective manner possible.

3. Explain below why and how you chose which box dimensions are best.

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activity sheet 3

Name _____

TASK 3: SKETCH A NET

1. Sketch a net for your box in the space below using the highlighted dimensions from **activity sheet 2**. Identify and include an appropriate scale factor. This will act as the blueprint for your actual box.

2. Label the top, bottom, front, and back; left and right faces; and all edge measurements.

TASK 4: CONSTRUCTION

You will now build your box. After your blueprint has been approved, you will be given cardboard.

- Carefully draw the actual net of your box on the cardboard.
- Once everything from your blueprint is labeled on your box, the teacher will cut out your design with a box cutter.
- Fold the box and tape it together using masking tape.
- Place your cans in your box and seal it.

TASK 5: DECORATE THE PACKAGE

Cover and decorate your box to be donated. Extra points will be given to the team with the most creative decorations.

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