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# Using STEM to reinforce measurement skills

**When measurement is** taught without a context, students may struggle to make sense of the numbers and units involved:

***Teacher:*** How do we measure rain?

***Student 1:*** Inches! Feet!

***Student 2:*** By how long it's been raining?

***Student 3:*** If it's just a light rain, you won't need feet.

***Student 4:*** Yes. Feet only if it's been raining for a long time.

To master measurement, elementary school students need opportunities to discuss how they measured and applied their developing skills and reasoning in context. Measurement is an essential life skill, required to do everything from painting and decorating a room to determining how long it takes to drive to work. NCTM's *Principles to Actions: Ensuring Mathematical Success for All* (2014) calls for "a curriculum that develops important mathematics along coherent learning progressions and develops connections . . . between mathematics and the real world" to ensure mathematical success for all (p. 5). Science, technology, engineering, and mathematics (STEM) units can integrate multiple topics and ideas with context, allowing students to deepen their understanding of mathematical concepts like measurement.

Modeling applications inherent in STEM lessons allow students to develop a better understanding of mathematics and science principles (Carpenter and Romberg 2004). Modeling also encourages solving problems that require higher-order-thinking skills (Lesh, Lester, and Hjalmarson 2003). The STEM unit presented in this article teaches measurement concepts through real-world applications and highlights how these lessons can be useful in addressing some of the challenges students face when using measurement in a context. A fourth-grade class from the Midwest participated in the unit with their teacher and a researcher/observer.

This was a large unit that took several weeks to complete. Students explored the field of Biomimicry—an innovative approach to problem-solving that uses nature as inspiration (see **fig. 1**). Students first learned how nature addresses the problems of gathering and storing water. The remainder of the unit focused on using plant and animal adaptations as inspiration to design a water catching and storage system. Using ideas from Biomimicry as well as knowledge of plant and animal adaptations, students brainstormed ideas for a catchment and storage system (see **fig. 2**) that will help the people of Popa Island. In this article, issues of measuring the volume of rain were challenging for our students; we present the student dilemmas that arose and how these challenges were



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addressed within the context of this design unit using biomimcry.

## How do we measure rain?

To design their rectangular prism water storage tank for the unit, students grappled with the complex issue of measuring rainfall. This part of the unit was designed to engage students meaningfully in connecting their previous knowledge of linear measurement with two-dimensional (for surface area) and three-dimensional (for volume) skills necessary for the completion of the engineering design challenge. When asked, students voiced no difficulties describing the ways in which liquids are measured; teaspoons, ounces, gallons, and buckets were among the answers given. One student had an empty juice container and read the label, "Sixteen fluid ounces. One pint. 473 milliliters." However, when asked how to measure rainfall, their conversations indicated confusion:

*Student 1:* Do we measure the rain falling all over or just in one place?

*Student 2:* You can't measure rain. It soaks into the ground. It doesn't pile up.

*Student 3:* We could measure the puddles.

*Student 4:* We could hang towels out in the rain and catch it, then wring it out into cups. Then we can measure it.

The teacher later stated that this confusion was unexpected, as students initially seemed to understand how to measure a liquid. After the contextual element was introduced, students expressed confusion about using measurement units to actually measure rainfall. One theme that kept recurring throughout the classroom was a need for piling or stacking up the rain. For example, our town received several inches of snow. Students pointed toward the windows and were in agreement that if rain piled up the same way snow did, they would have no problem measuring it.

## How can we "stack" the rain?

Initially, the teacher was puzzled by students' reactions. Two options could address their confusion:

**FIGURE 1**

The overall task of the unit is for students to create a rainwater storage and collection device.

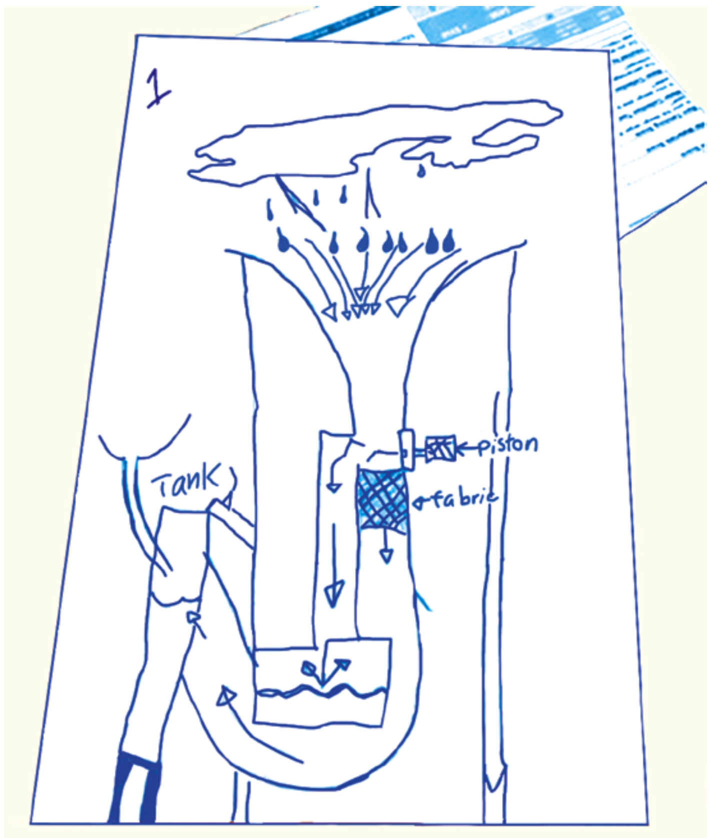
**The task**

To create a rainwater storage and collection device that—

- is large enough to provide water for one family during the dry season (volume application);
- is not so large that it has too high of a cost or takes up too much space (cost determined using surface area);
- contains a top design that is larger than the base (to catch the rainfall); and
- is inspired by animal or plant adaptations.

**FIGURE 2**

Using biomimicry and inspiration from a bromeliad and a blue whale, one group of students collaboratively designed this catchment system.

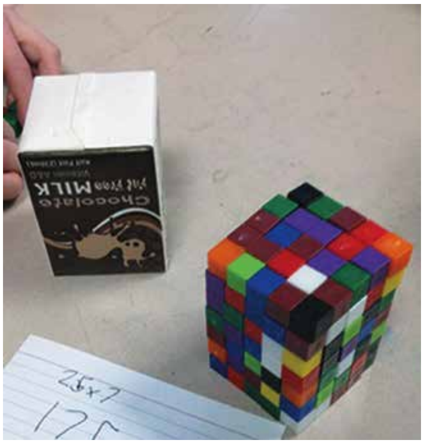



1. Tell them how to do it and go on.
2. Devise a way to demonstrate how rain stacks up.

We felt very strongly that students learn best through discovery learning. To continue the

FIGURE 3

Student 3 shared his understanding of volume.

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lesson centered around discovery, groups of students were given cubic centimeter blocks and an actual rain gauge to capture and measure the rain. This was an attempt to enable students to contextualize stacking, or piling up, the rain through the meaning of volume. However, in trying to fill the rain gauge with the blocks, students could not get an accurate measurement. They were frustrated by the solid quality of the blocks, complaining that the blocks were too loose and did not fit. Students passed the rain gauge around, seeking help from classmates to make the cubes fit, but they were unsuccessful. By actively engaging in this process, students' explorations became personal. Rather than hearing a teacher inform them, "Water takes the shape of its container," we heard from students, demonstrating their developing knowledge:

- "Rain spreads out. These blocks don't."
- "There are spaces between the blocks. Rain doesn't leave spaces."

Finally, a student said, "Let's put a bucket out in the rain with a ruler attached to the side. Then we can measure it as it fills it up!"

With this newfound understanding of how to measure rainfall, students began the predesign phase of the unit. In this part of the project, students analyzed average rainfall data from Panama to determine which months provide adequate water through rainfall. Using these data helped students establish the size of their storage container. Students knew that the standard water usage needs for a family of five was determined to be 200 liters, so they had to design a container with the necessary volume. After a quick question-and-answer session with the class, we realized that although students could state the formula for volume, none understood the connection between milliliters and cubic centimeters when measuring liquids. Remembering our success with the cubic centimeters and rain gauges from before, we decided to use them again, using boxes that could contain the centimeter cubes with little leftover space.

In small groups of three students, and using a half-pint milk box from the cafeteria, the class modeled liquid with cubic centimeters. We asked students to tell how many cubic units were in the container and to support their answer with a description. The teacher expected them to do more than just present a standard algorithm as a response. They were to provide a contextualized explanation of volume, using the language of the units and referent as they understood them:

***Student 1:*** We looked at ours, and we had five times five for each floor and then seven floors; so five times five, then that times seven [*drawing the three-dimensional figure*].

***Student 2:*** We just did seven rows, and there were twenty-five in a row.

***Student 3:*** There's seven layers; and the width is five, and the length is five. So five times five equals twenty-five, then times seven. [*See* **fig. 3**.]

***Student 4:*** We did seven times five equals thirty-five times five equals one hundred seventy-five.

We were excited to see students make the leap to repeated area as they began to notice that each layer contained the same number of cubes. By stacking cubes in the milk boxes, they created the formula for volume with understanding, rather than repeating an algorithm without context.

At this point, we asked students if their answer was the same or different from others. A contextual occurrence of the associative law of multiplication was explored. Nearly everyone found the volume: 5 × 5 × 7. However, one group used 5 × 7 × 5. Students were asked to explain how the two solutions are similar and

different. By encouraging students to analyze their multiplicative structure, we gave them the chance to explain that the dimensions of the faces of the rectangular prism could be multiplied in any order and still yield the same volume.

Students began to see and understand the third dimension of volume. They were able to compare and contrast different measurements, developing their own construct of understanding among the three dimensions. For example, most students called the units *cubes*, but one group of students called them *cubic centimeters*, sparking a wonderful conversation in which they defended their language regarding the differences between a square centimeter and a cubic centimeter.

## Personalizing the concepts

The design and modeling aspects of integrated STEM lessons presented the interactive environment necessary for our students to learn the curriculum through personalization of concepts. As well, students engaged in an active learning environment specifically designed to support the acquisition of mathematics and science principles. Although some of our students had previous knowledge of how liquids are measured and knew the formula for volume, they did not have applicable understanding for use in context. Through participation in this STEM unit, students had multiple opportunities to practice reasoning skills necessary to contemplate the concepts of linear measure, square area, and cubic volume as they worked toward applying these ideas in the engineering design challenge. Because of the constraints of the design challenge, students required knowledge of measurement concepts—to measure rainfall, to design a catchment system of a specific volume, and to consider building costs based on surface area. The personal connection of building a system to help the people of Popa Island created opportunities for students to actively—as opposed to passively—construct knowledge, retaining information that could otherwise be easily forgotten.

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