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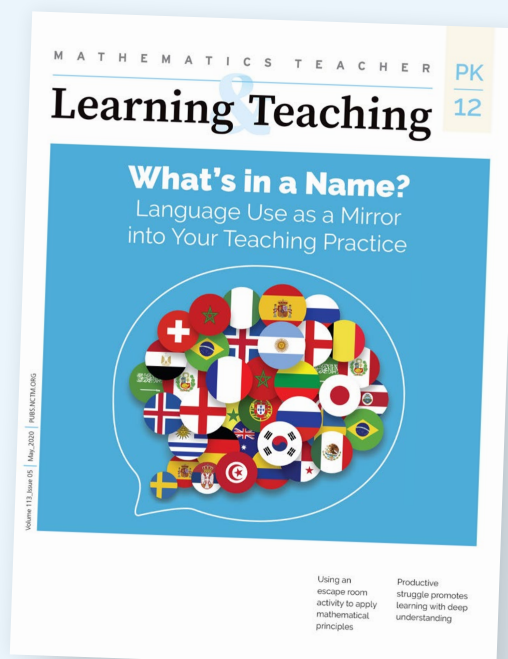

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Give Plants an Inch; They'll Take a Yard

A real-world integrated activity allows middle school students to design a scale drawing for a garden at their school.

Katherine N. Vela, Michelle Parslow, Rita Hagevik, and Kathy Cabe Trundle

"Why is this important?"

"When will I ever use this?"

These questions ring out in almost every mathematics classroom, every day. Incorporating real-world activities that integrate across various disciplines gives students opportunities to see the application of content in a meaningful and coherent way and answer these age-old questions. More specifically, when students see mathematics as an integrated field of study, they make connections, gain a deeper understanding of mathematical concepts, and see mathematics as a whole rather than disconnected, unrelated ideas (NCTM 2019). Measurement concepts are the perfect *seed to plant* to show how different mathematical strands integrate within other subject areas.

An integrated activity may seem daunting at first, but once we stop to think about real-world scenarios where we have used mathematical concepts, we can help students begin to see the connections to different mathematical strands and other subjects. Many students have conceptual difficulties involving measurement and area concepts (Doabler et al. 2021; National Assessment for Educational Progress [NAEP] 2019). Therefore, a need exists for instructional activities that focus on foundational concepts of measurement that encourage students to apply skills needed for science, technology, engineering, and mathematics (STEM)-related fields (Clements et al. 2020). The activity we share here allowed our students to engage with measurement concepts and see the application of perimeter and area in a real-world scenario. Additionally, this activity allowed students to engage in spatial reasoning by measuring a physical space and rendering a scaled drawing to plan a school garden. Integrating these types of activities helps students relate physical spaces to mental models, thereby improving their spatial reasoning. We integrated the arts and *cultivated* conceptual understanding of measurement and STEAM (science, technology, engineering, art, and mathematics) subjects by asking our students to create a scale drawing or map of a garden.

3-H LEARNING MODEL

To engage our students emotionally, physically, and cognitively, we use a 3-H learning model (Saçkes, Trundle, and Shaheen 2020; Trundle and Smith 2017), a three-phase cycle (Hearts-On, Hands-On, Heads-On) that helps our students effectively learn targeted content. We connect the targeted concepts to students' personal experiences or prior knowledge (**Hearts-On**, affective connections), and we allow students to explore the concepts in a real-world scenario and collaborate with their peers (**Hands-On**, inquiry exploration). Students come back together as a whole class to discuss the concepts they explored. This process allows students to make connections among their observations, identify patterns, and label their newly constructed knowledge (**Heads-On**, cognitive sense making). Students return to Hearts-On learning by applying what they learned to familiar or novel contexts.

Hearts-On (Connections and Launch)

To open this lesson, we asked students to think about a time they used a map and to identify some key components that helped them understand how to use that map (see supplemental files online: teacher handouts, discussion questions). One student provided this description: "The key helped me to see what signs meant and how far a mile was on the map." As the discussion continued, students began to make emotional connections to their own personal experiences and to those of their peers:

> A time I used a map was when we were going on a trail in Snow Basin. What helped me understand it was the key in the bottom corner—the key that had different colors of trails on it, and then there were different trails in colors on the mountain. My experience was scary, we were on the side of a mountain a lot. I thought we were going to roll down and die. It was so steep.

Another student shared this summary of previously using maps: "I have used a map when hiking and hunting. The things that helped me understand the maps are the compass, keys, and nearby bodies of water."

Scale drawings were introduced to students by referencing maps and analyzing the scale provided. See teacher handouts, scale drawing examples (supplemental files online) for examples of scale drawings and maps with various scales that we used to guide

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discussions. We encourage other teachers to find maps of parks, neighborhoods, or schools that are in their local communities or familiar to their students.

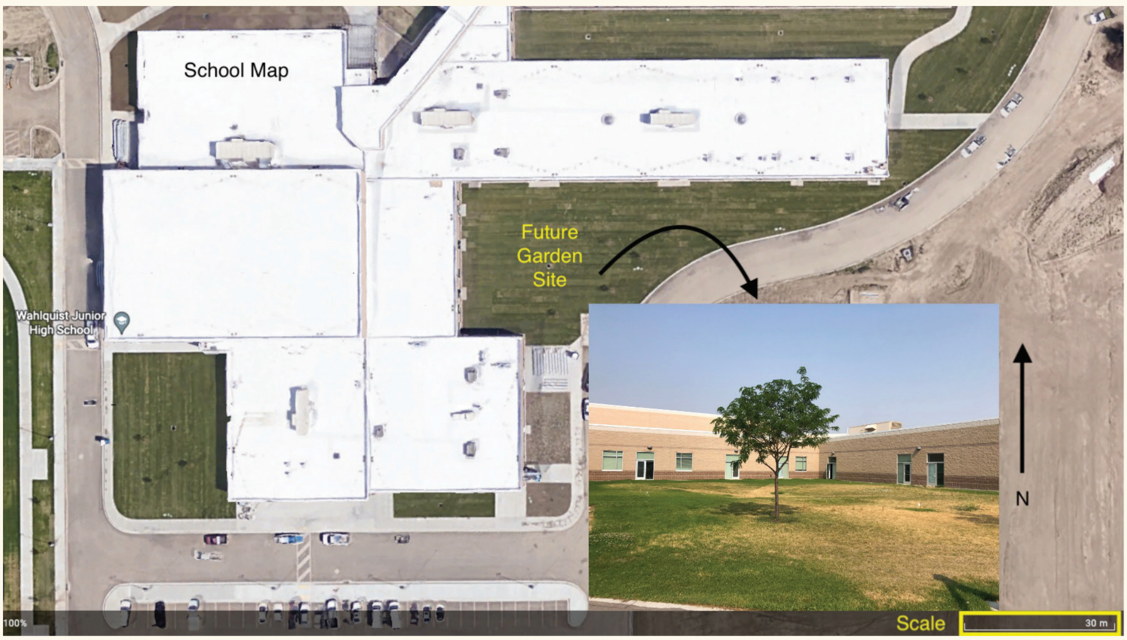
We asked students to look at the two maps we provided (Highland Park and Lake Claire Neighborhood) and share what the maps had in common. One student shared, “The two maps have a key, and they show which way North is. They both have a title and a scale.” As students continued to explore the two maps, we asked about the scale on each map and what it meant. One student responded, “The scale is the distance on a map. They mean how much distance on the paper is the distance of feet in real life.”

We asked students to interpret the maps, using the scale provided, to determine actual lengths. For example, they calculated the approximate area of Basin 2 in Highland Park. Most students agreed that “the area was 500,000 feet.” This response showed the need for more discussion about the meanings of different units (e.g., feet, meters, and when to use square units). Students soon realized their responses for the area question should have included square feet. When asked to calculate the approximate length of Almeta Street in the Lake Claire neighborhood, a student shared that the length was about “500 meters.” We followed up by asking if the appropriate unit to use in this case was meters, feet, square meters, or square feet. Students agreed it was not square meters or square feet because they were finding the length and not the area. But a debate began over whether the length should be expressed in feet or meters. We asked the student to clarify which scale was used to calculate the length. In an aha moment, the student who originally shared 500 meters realized they had actually used the feet scale and changed their answer to about 500 feet. Another student stated that an alternative correct answer could be about 150 meters. At this point, we felt comfortable that the students understood how to interpret the scales appropriately, and we continued with the lesson.

Hands-On (Explore)

We introduced the main activity by telling students the school received $15,000 in grant funding to install a school garden. The principal identified an open space near the building for the garden installation (see figure 1). A school contest was announced in which groups of students would design a garden that met certain requirements and stayed within budget. Groups were to provide the principal and garden team with a map of their garden, drawn to scale, and include their budget. All entries that met the requirements and remained under budget were considered.

Fig. 1



This is the future site of the school garden.

First we gave each group a school map (see figure 2) and went on a walking tour of the school grounds and site of the school garden to practice reading the map, navigating the actual space, and measuring the space for the garden area. This experience created a mental spatial model for the students as they worked together to plan their garden (Taylor and Tversky 1992).

Next students created the perimeter of the garden space on their graph paper. To create the perimeter, groups determined the scale they intended to use for their map. Given the size restraints of the garden area and the size of their graph paper, students chose a workable scale. Using an online graph paper generator (link online), groups could choose to create their own graph paper and adjust the number and size of the squares.

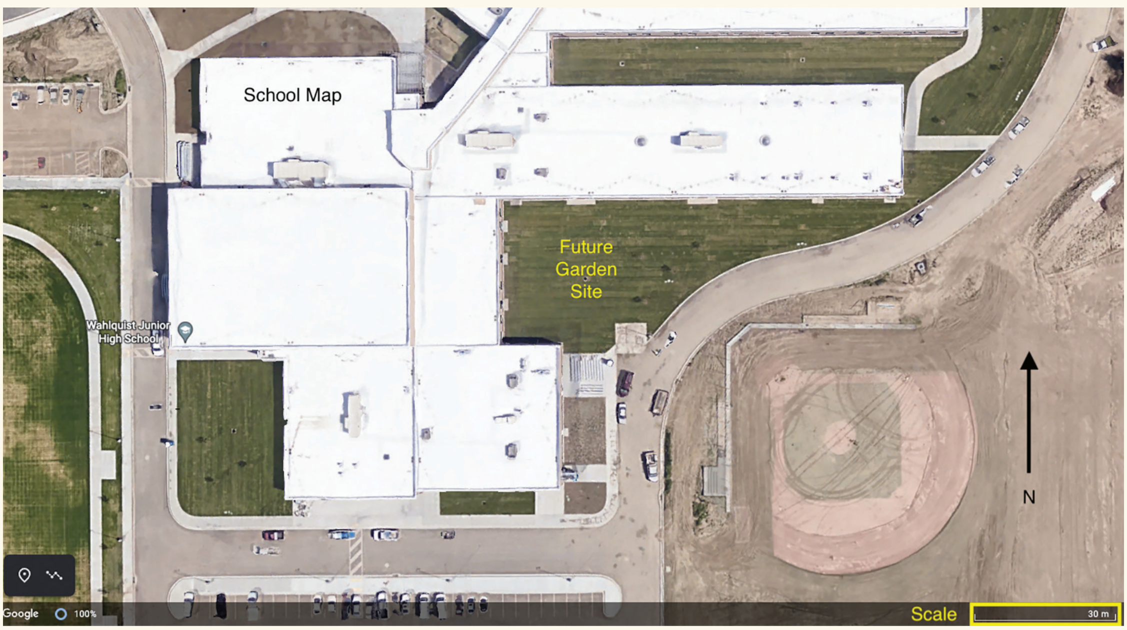
Groups collaborated to determine their scale and discussed its reasonableness. For example, the graph paper we provided had approximately 40 squares across and 50 squares down, and the actual space allocated for the garden was about 100 feet wide by 150 feet long. A possible scale would be the connection of the 50 squares to the 150 feet so that 1 cm equals 3 feet.

Once groups had the perimeter of the space on their map, with a scale clearly labeled, they began incorporating the required items (see supplemental files online: teacher handouts, required items for garden project). Students were also encouraged to brainstorm other items they would like to include in their plans as long as they met the requirements and stayed within budget. We reminded students to use a ruler to draw their map with precision (Standard for Mathematical Practice 6: Attend to precision). As students made their plan, we asked them to consider the aesthetic aspect of their design, thinking about the type of balance and composition of the space they wished to create (Art Connection; e.g., symmetry, asymmetry, creativity, rule of thirds). Figure 3 shows student examples of scale drawings created for our school site.

As students created their maps, they tracked their budget on the budget tracker (see supplemental files online: teacher handouts, budget tracker). Groups determined the total cost of their garden using the required items list and identified the type of base they planned to use for the shed and greenhouse. On the basis of their budget, some groups chose to add other items to the garden (see figure 4).

For an extension, we used an activity that connected technology and nature in school yards using Google Earth® (Horton et al. 2013). After students finalized their scale drawings and calculated their budgets, we asked them to use Google

Fig. 2



The location of the future garden site can be seen on the school map.

Earth to create a virtual rendering of their garden (Technology Connection). We asked students to locate their school on Google Earth and take a screen shot of the school garden area, ensuring the scale was visible. Students annotated the image to create a digital image of their scaled drawing.

Fig. 3

These are examples of student-created scale drawings of the garden site.

Figure 5 provides examples of students' images using Google Earth.

Heads-On (Discussion)

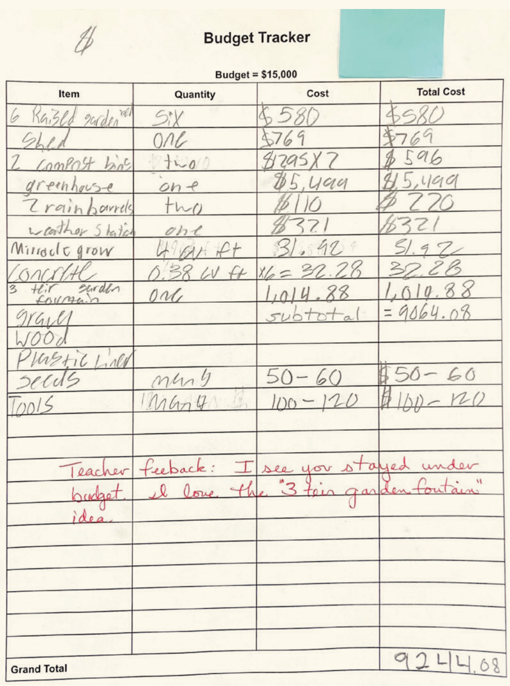
After each group finalized their garden plan, we brought the class back together to discuss the importance of drawing to scale, creating precise maps, and sticking to a budget. Groups pitched their plans to the class and let classmates vote to select the best scaled design for the school garden. This investigation provided a chance for students to discuss what is most important to them in their gardens and to adjust their drawings and budgets accordingly. Additionally, this investigation allowed students to apply measurement, perimeter, and area concepts in a real-world setting to help address student misconceptions.

Hearts-On (Going Further and Installing the Garden)

We used several options to make connections to STEAM disciplines and extend this project. For example, we turned the students' hypothetical plans into reality by seeking funds for students to install an actual school garden. We received grant funding and considered the students' designs as we planned and installed our school garden. We founded an after-school garden club for students who wanted to be more involved in our garden. Student members assisted with the selection, installation, and maintenance of our plants. In planning the bed placements and developing a planting design, our students tracked the sun to determine the light conditions (i.e., partial shade, full sun) of the garden space. The students used their sun plots to identify the intensity and amount of light exposure based on the time of day and season for our geographic location (Science Connection; see figure 6 for an example). They used the sun plot data and information about the light needs of different plants to determine the best growing locations for each plant type. See Trundle and Hilson (2012) for an example of tracking the sun and shadow plots.

As students built the garden beds and other structures (e.g., shed, greenhouse), we asked them to consider points of stress on the structures (e.g., corners, the middle of the lengths, wind on taller structures) and to plan how they could strengthen the

Fig. 4



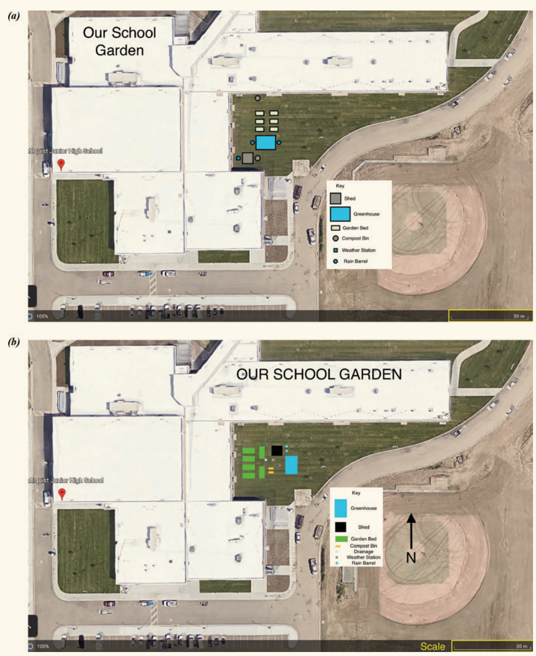
Budget Tracker

Budget = $15,000

Item	Quantity	Cost	Total Cost
6 Raised garden bed	Six	$580	$580
Shed	one	$769	$769
2 compost bins	two	$295X2	$596
greenhouse	one	$5,499	$5,499
2 rain barrels	two	$110	$220
weather Station	one	$321	$321
Mirracle grow	4 cu ft	31.92	51.92
Concrete	0.38 cu ft	x6 = 32.28	32.28
3 teir garden fountain	one	1,014.88	1,019.88
gravel		subtotal	= 9064.08
wood			
Plastic Liner			
seeds	many	50–60	$50–60
Tools	many	100–120	$100–120
Teacher feeback: I see you stayed under budget. I love the "3 teir garden fountain" idea.			
Grand Total			9244.08

Students tracked their budgets to ensure they stayed under budget.

Fig. 5



Students used Google Earth to create digital images of their scaled drawings.

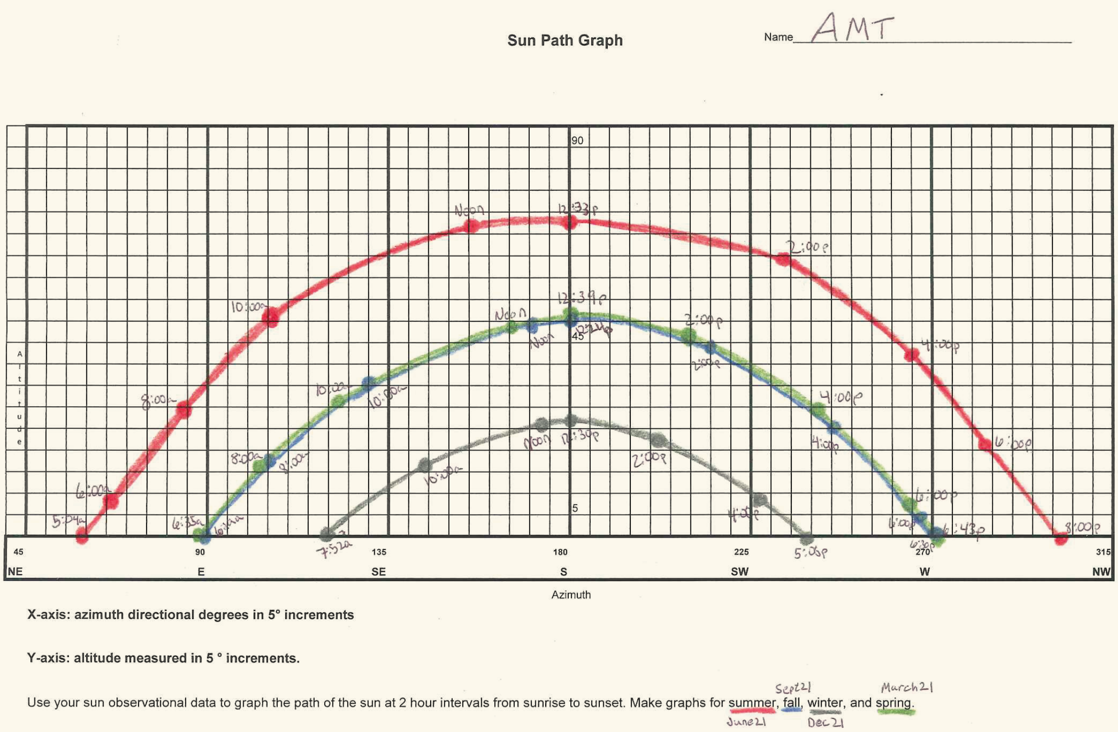
structures on the basis of these stresses (Engineering Connection; e.g., corner brackets, stakes to hold the sides of lengths in the garden beds from moving when filled with dirt, hold-downs for greenhouse). See figure 7 for brackets the students decided to use to strengthen the bed corners. As students installed the brackets, they were instructed how use the Pythagorean triple 3, 4, 5 to ensure that they created a right angle.

Students in our garden club also researched and selected native, pollinator-friendly plants that thrive in our growing zone. The students selected plants on the basis of their research of appropriate plants for our climate, basic needs of plants, and their personal interests. They also worked together to determine the best placement for these plants in the garden beds. Figure 8 shows how a student member from the Garden Club measured the length to determine spacing for plants in the area of the garden bed. Students considered areas of sunlight and shade and plant heights and maximum widths at maturity when selecting and planning placement of plants in the garden.

Fig. 7

Students strengthened their garden beds by using corner brackets.

Fig. 6



Students tracked the sun to identify the intensity and amount of light exposure.

CONCLUSION

When students and teachers dream of having a garden at their school, the first step involves developing a plan for where, what, how much, and the size and layout of the garden items. The best way to create a plan involves a scale drawing so that the actual size of the garden components can be determined from the scale. This task fits appropriately in the geometry Common Core State Standards for seventh-grade mathematics: solve problems involving scale drawings of geometric figures, including computing actual lengths and areas from a scale drawing and reproducing a scale drawing at a different scale (NGA Center and CCSSO 2010).

Integrated learning projects, like the one described here, ground students' mathematical learning in real-world applications. Important life skills include interpreting and creating scales. Students can apply these skills when reading maps, diagrams, and plans. Additionally, students love participating in activities that make them feel like architects, engineers, designers, and money managers.

Fig. 8

Students used yardsticks to plan the placement of plants in their garden beds.

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