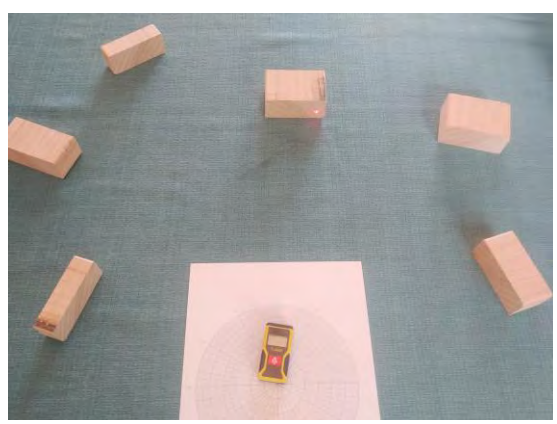
Helping all students, especially girls, to be interested in engineering as a possible future career can be challenging. Research suggests that role models are important for helping students to see themselves in jobs where they have been underrepresented. In addition, having challenging and fun engineering experiences help students to want to become engineers.

Many engineering projects though are focused on competitions, but that isn't the essence of engineering. The cycle of determining a problem, identifying what's needed to solve the problem, trying and testing possible solutions, and optimizing and iterating to find an adequate solution is what makes an engineering project.



In this lesson plan, students will watch a video where Samantha Dominguez explains how she became a successful engineer. After figuring out what she says are some key factors to being a great engineer, they will embark on an engineering project where they will try to determine the key factors to using radar to find the position of objects. Finally, they will look back at their work habits to determine how closely they matched skills that the engineer suggested were important.

NGSS Standards
ETS1.A: Defining and Delimiting Engineering Problems
ETS1.B: Developing Possible Solutions
ETS1.C: Optimizing the Design Solution

Part I: Watching the Samantha Dominguez Video

Before the students watch the video, the teacher should explain that in this video an engineer will explain what makes her a successful engineer. The teacher should ask students to record what personality traits, desires, and behaviors are important to becoming an engineer.

For younger students, you may need to use sentence starters like

Samantha Dominguez said that she had to overcome the obstacles of _________
Samantha Dominguez said that she want to _______

The video has on-screen icons that will help students when she is saying key components of her success. For some students, pausing the video at those moments will help them better record what is going on.

In small groups have the students summarize what they saw and then make sure that the entire class has all of the points. While they may have more than these, they should at least note:

- Samantha Dominguez has made engineering her career.
- Samantha Dominguez is an engineer because it gives her a chance to be creative.
- Samantha Dominguez persevered to overcome obstacles.
- Samantha Dominguez works with others as a team.

Making a Great Engineer Checklist

Students now should now make a checklist of things for themselves to do if they want to be a good engineer. Then when they do something on the checklist, they should mark it off. For example,

Activity	
I helped someone	卌 I
I didn’t give up when something didn’t go the way I planned	卌 III

Students will use this checklist several times in the following projects. Don’t assign points or give too much praise, otherwise students will just game the system. We just want them noting when they are doing something a good engineer does, helping them to internalize that they can be an engineer. Alternatively, you can make it the task of one of the members of the group to note when their groupmates are being good engineers.

Part II: Engineering Cycle

Samantha Dominguez helps to engineer radar systems. The main purpose of radar is to detect the position of an object. While building a radar for the classroom might be daunting, laser tape measures have some similar features to radar. In this activity students will first use an inexpensive laser tape measure to find the distance to an object and determine the accuracy of the measurement. Then the students will develop a system for scanning and plotting an area to determine where the objects are located in two dimensions. Finally, students can use a laser tape measure to determine what and where some hidden objects are.

Looking around with a laser tape measure

Materials

- Laser tape measure (These come in many different price ranges; ones with higher ranges, more accuracy, or faster to take measurements are more expensive. For this activity inexpensive 30 foot, ⅛ inch accuracy, and 2 second response time measuring instruments are fine.)
- Standard measuring tape at least 30 feet long
- 6 wooden blocks
- Graph paper
- Stopwatch
- Protractor photocopy (included at the end)
- Polar graph paper (included at the end)
- Cardboard about 1 foot by 1 ½ feet (the top of a bankers box works well)
- 4 risers to lift the cardboard off the table.
- Assortment of materials that can fit under the cardboard

Although the lasers used in laser tape measures are lower power Class II lasers, they should still be handled with caution. Students shouldn't point them towards their eyes or allow them to reflect off of shiny surface s towards their eyes.

Characterizing the laser tape measure

Stretch out the standard tape measure so that it is extended 1 foot. We will use SAE measurements here since most measuring tapes in the United States are SAE, but all these activities will work fine if you have metric tape measures as well. Most laser tape measures can have their output switched between SAE and metric.

Place the laser tape measure (LTM) at one end of the tape. Place the wooden block at the one foot mark. Aim the LTM and record the distance. Compare its readout to the actual length.

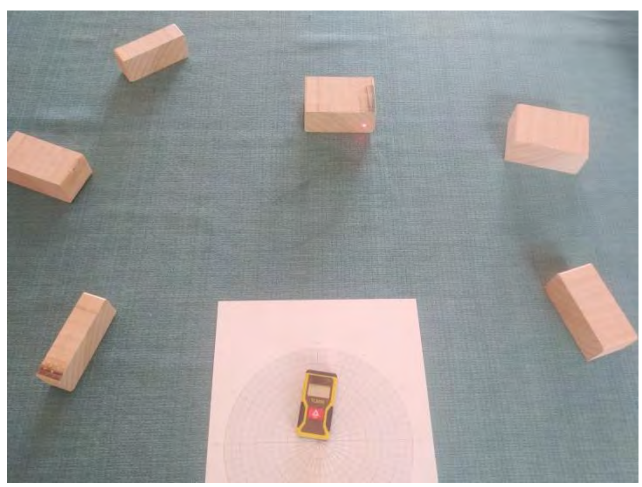
Working carefully but quickly try to determine how much time it takes to make 10 measurements and record them. Note how much variation each measurement has.

Using the tape, move the block in three foot increments away from the LTM. Take 10 measurements again, recording the accuracy of the LTM and the time necessary to take those measurements.

Summarize the data from all the students on the board. Ask the students to determine how many measurements they need to have to get accurate data on the distance to the objects.

Determining the distances to an array of objects

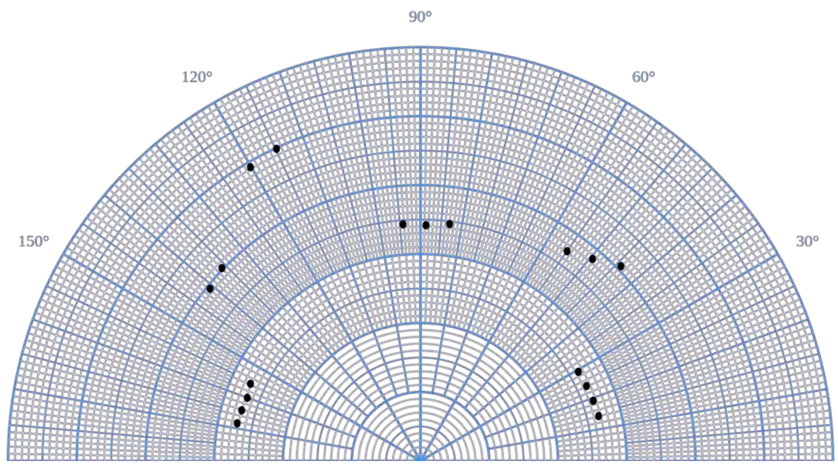
Place the photocopy of the protractor at the center, and place six objects in a circle at varying distances between 1 ft and 3 ft from the center point. Most LTMs can't measure closer than about seven inches.



Have students rotate the LTM in a semi-circle taking a measurement every 5 degrees. Have them plot the data on a piece of polar graph paper. Students may need to be introduced to polar graph paper. Some sample data is recorded below.

θ	ft	in		θ	ft	in		θ	ft	in		θ	ft	in
0				45	1	5.5		90	1	3		135	1	3.5
5				50	1	4.75		95				140		
10				55	1	4.25		100				145		
15		11.5		60				105				150		10
20		11.5		65				110	1	9		155		9.75
25		11.5		70				115	1	8.5		160		9.75
30		11.5		75				120				165		9.75
35				80	1	3.25		125				170		
40				85	1	3		130	1	4		175		
												180		

Using the polar graph paper, have the students show the positions of the objects.



Although the plot has a lot of information in it, it isn't complete. Ask students to explain what is missing. They typically note that they don't know

- The depth (size) of the objects.
- If the objects are moving.
- Much about the shape of the objects.
- The exact widths.
- If anything small is in between the objects.

The last three come about because the data collection only occurred every 5°. For example, we know that there was an object at 30° but the object could extend all the way to 34.5°, perhaps, and they wouldn't know it. Similarly, if there were an object that extended from 62° to 64°, it wouldn't show up at all.

For some situations these limitations are fine, but in other situations they would be problems. In the case of airport radar, it might be okay not to be able to resolve insects or small birds, but many or large birds and private planes must be able to be detected. Of course, the speed of planes is particularly important as well.

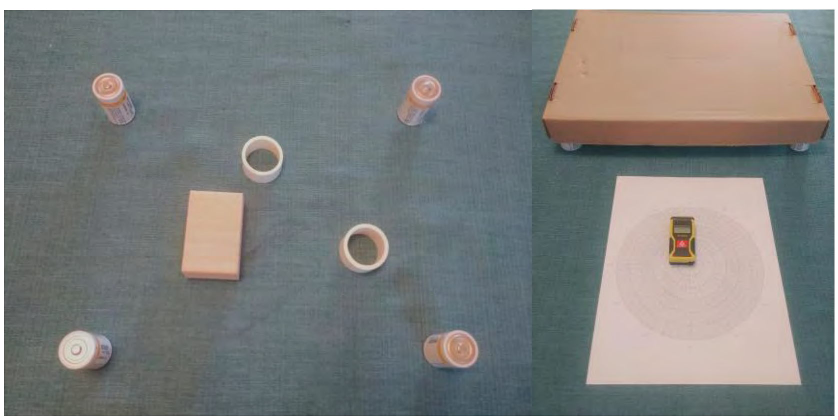
Have students try to imagine using their LTM to navigate around the room. What strategy would they need? For younger students, you may need to give prompts like

- Would you need to aim the LTM all around you or just in front?
- How many degrees would you need between measurements?
- How fast could you move?

If your class can try their ideas safely, the results can be very instructive.

Figuring out how to measure or find a hidden object

Have each group take three items from the assortment in the front. Encourage them to take items of different sizes. Place them under the cardboard using the risers so that the LTM can still measure distance but the objects aren't visible. After everything is in place have them change stations with another group so the members of the group won't know what is under the cardboard.



The task for the students is to use the LTM to find out what is under the cardboard without looking. Don't give much other instruction as we want the students to try different things. Ask them to keep track of what they do. When they think that they have figured out what is under the cardboard, have them articulate what is there. Before they check, bring the class together to investigate what they tried. Students will often try a large variety of methods. Some will

- Keep the LTM in one place and change the angle like we did in the previous activity.
- Move the LTM but keep it perpendicular to the sides.
- Measure on all four sides.
- Measure on two sides.
- Measure on only one side.
- Make many measurements, say every ½ inch or 2 degrees.

- Make as few measurements as possible.

Students will want to know what strategy they should have used, but of course it depends on what the goal is. If the goal were to find everything under the cardboard, then moving the LTM along the sides might be the best strategy, but if the goal were to just recognize what the objects are, rotating the LTM might tell enough information without having to move it. Self-driving cars and airports both use radar but they have different needs and so the radar systems are differently implemented. Both need to minimize scans to increase speed. A utility company uses ground penetrating radar to find things buried but has less of an imperative to have fewer scans.

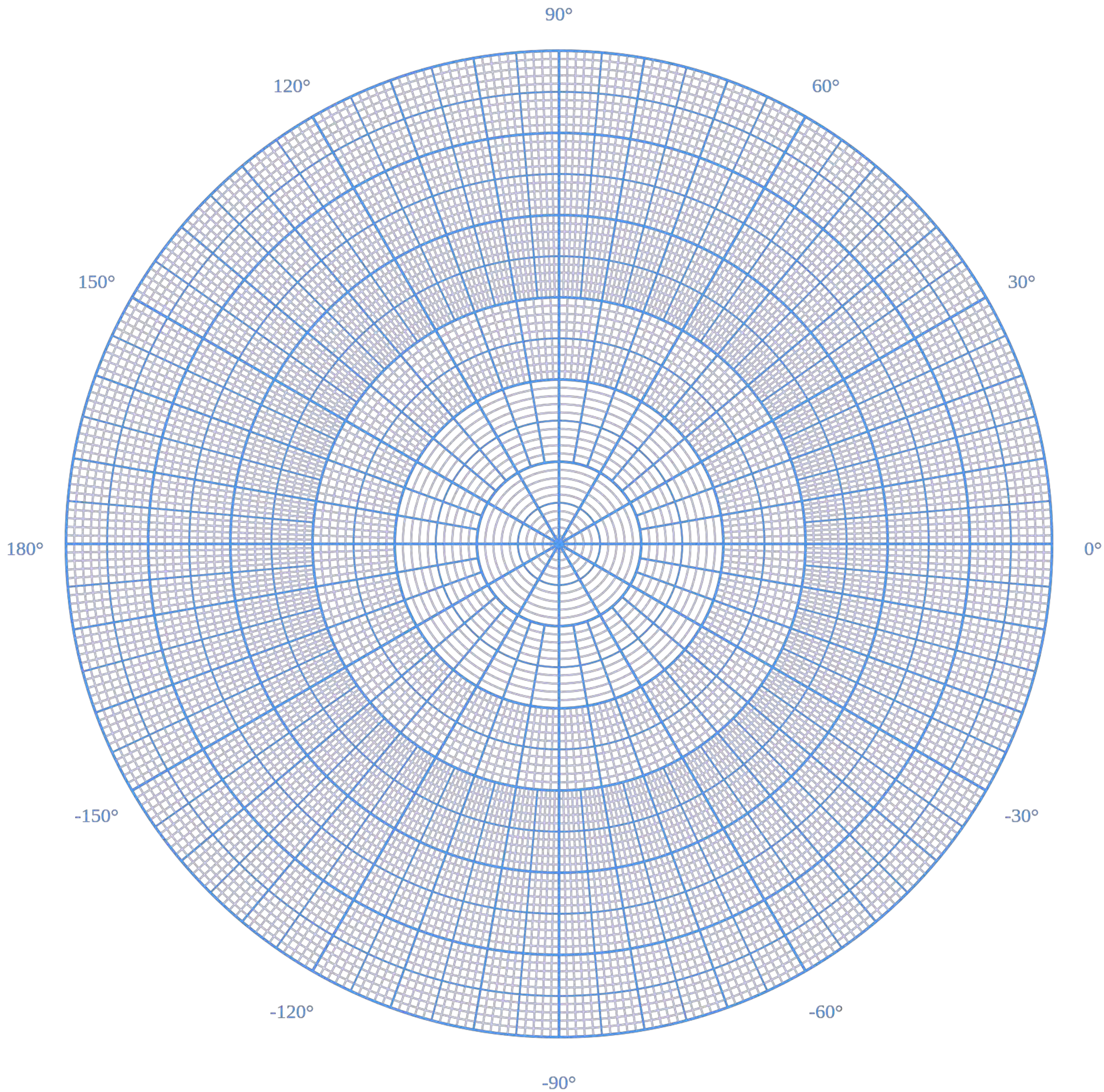
Have each group decide on a situation and then determine a successful method to find what is under the cardboard. After they think that they've got something, have another group make a new arrangement for them to test their method. Groups should repeat to find a successful approach.

Part III: Evaluation

While many kinds of assessment work, the students and the teacher should assess how well their method of finding the hidden objects matched their goals. If their situation required speed, was their approach speedy? If their scenario required precision, were they precise? What did they learn were the key findings to successfully find what is under the cardboard.

In addition, each group should determine how well they worked together. Having the students briefly present their work to their classmates tends to give the best opportunity to figure out what happened in their group. They should explain

- What their problem/goal was
- What they tried
- Whether or not it was successful
- How they could tell if it was working
- What they did if they didn't all agree on what to do
- How often did they get to put a mark on their checklists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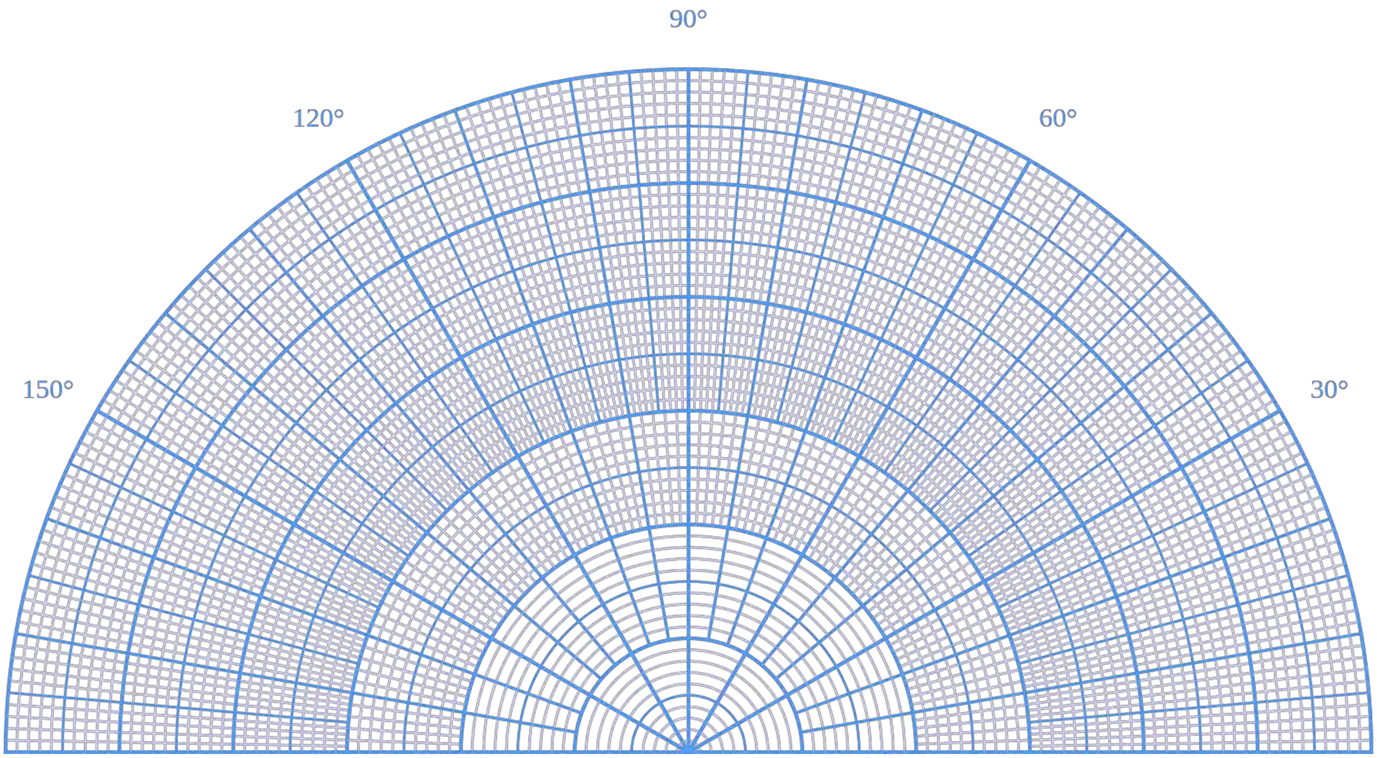
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