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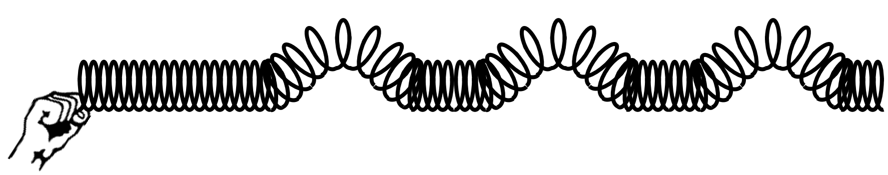
VICTORIA SCHEIN

Learning to Send Analog and Digital Signals to Become a Great Engineer

STEM Lesson Plan for Grades 6-8

Helping all students, especially girls, to be interested in engineering as a possible future can be challenging. Research suggests that role models are important for helping students to see themselves in a 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 acceptable solution is what makes an engineering project.

In this lesson plan, students will watch a video where Victoria Schein 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 how sending analog and digital (like Bluetooth) signals are different using long springs. Then they will devise a scheme for sending a piece of information using digital information. 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
PE MS-PS4-3. Integrate qualitative scientific and technical information to support the claim that digitized signals are a more reliable way to encode and transmit information than analog signals.
PE HS-PS4-2. Evaluate questions about the advantages of using digital transmission and storage of information.

Part I: Watching the Victoria Schein 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

Victoria Schein said that she had to overcome the obstacles of _________

Victoria Schein said that she wants 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:

- Victoria Schein has made engineering her career.
- Victoria Schein is an engineer because it gives her a chance to be creative.
- Victoria Schein persevered to overcome obstacles.
- Victoria Schein 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	𝍸 I
I didn’t give up when something	𝍸 III

didn’t go the way I planned	

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

Bluetooth is a wireless protocol for sending information. While understanding the entire protocol is beyond the scope of a middle or high school science class, understanding how it is a digital rather than analog method of communication can help students to understand a key part of the Next Generation Science Standards.

Sending and Decoding Analog and Digital Information

Materials

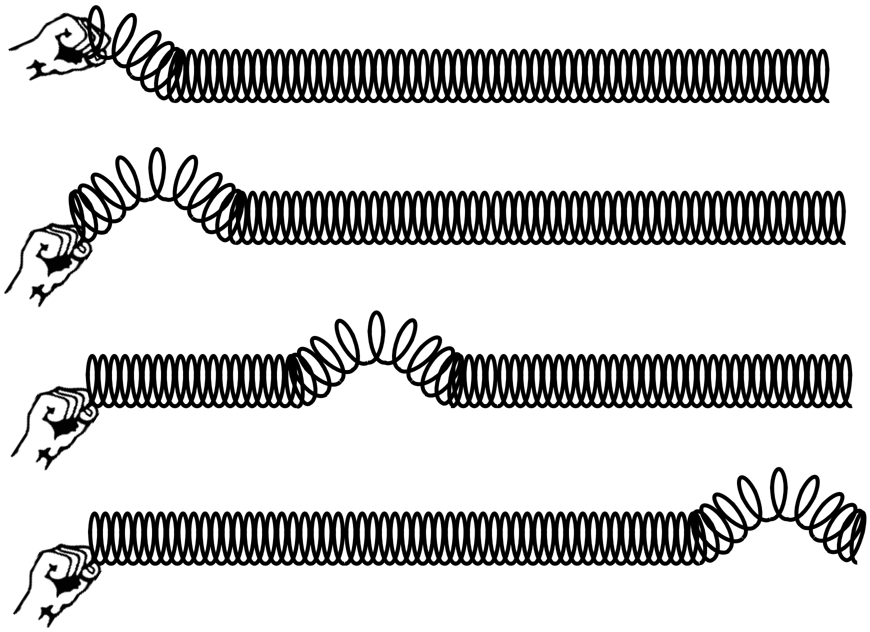
- Long spring (double length Slinky style)
- 2 meter sticks
- Masking tape

Becoming familiar with the spring

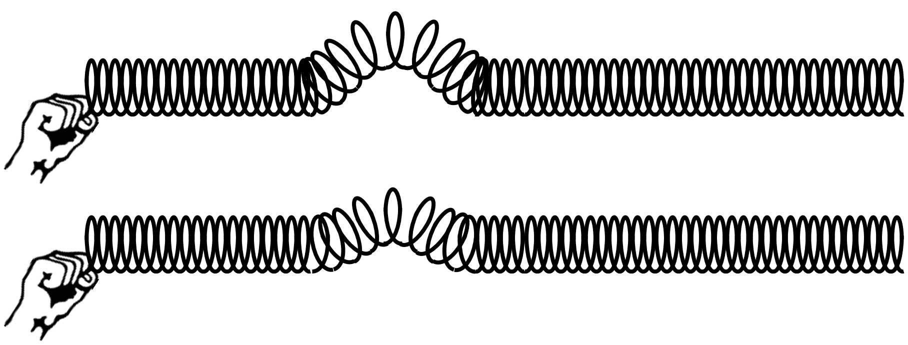
Have two students stretch the spring on the floor, sitting approximately 3 to 4 meters apart depending on the length of the spring. The spring should be stretched but not so much that the loops become permanently deformed.

The waves you want the students to send down the spring are transverse waves, or waves where the medium (the spring) moves perpendicular to the wave’s motion. In addition, **the wave should move parallel to the floor and the spring should remain touching the floor at all times.** This makes the wave much easier to see and much less likely for the spring to get tangled.

Explain to the students that they can send information from one student to another along the spring. **A quick flick of the wrist parallel to and touching the floor** will send a hump (a wave) down the spring toward the other student. You probably want to allow the students to get a chance to play with this for a while.



Most students will notice that they can send waves where the hump is a different height (amplitude). Use a meter stick to measure the heights.



Ask students to try to send waves of a particular amplitude to their partners. Students will often describe how difficult this is as the wave doesn't stay the same height as it moves done the spring. The sender might have to send a wave with an amplitude of 50 cm so that it is 40 cm by the time it gets to the receiver due to the attenuation that is caused by spring's friction with the floor and other factors.

Sending a movie rating along a spring

At this point, we're going to ask the students to send a piece of information down the spring. There are a lot of choices, but we'd like the students to develop a variety of different ways to send the information. Asking students to send a rating for a movie (say 7.5 or 6 1/4 out of 10) works pretty well because it can have a variety of different values in a relatively small range. Allow each group to figure out a method to send the information on the spring alone, offering the meter sticks and tape as aids to deciphering the signal on the spring. Students will sometimes want to video record the spring to help them better see what height the wave is. Groups will usually divide into a sending team that specializes in making the waves and a receiving team that analyzes the signal.

Once the teams are feeling like they are ready, have the groups test their methods in front of the whole class. Secretly tell a movie rating to the sending team and have them send the signal to the receiving team. Have the receiving team explain their answer and compare it to the movie rating you gave the sending team.

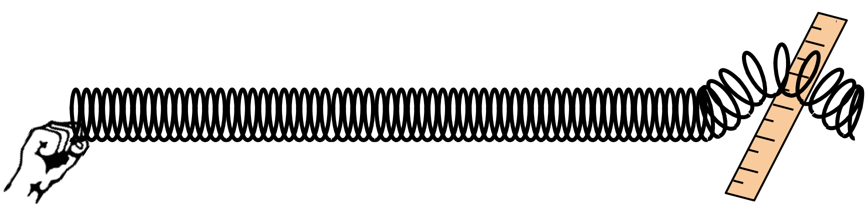
After all the groups have gone, have the class consider the benefits and weaknesses of the methods.

You are likely to find methods that fall two major categories:

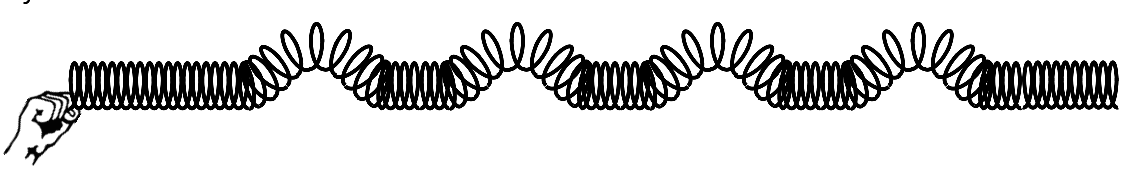
- Analog
- Digital

Analog information is a signal that is continuous. In principle, it can have any value within certain boundaries. Digital information is discrete and can only have certain values. Techniques that send information based on the amplitude (height or width) of the wave are typically analog, while techniques that use the number of waves to determine the information are digital.

For instance, a group might try to have every 5 cm of amplitude of the wave (on the receiving end) equal one point of the movie rating. An amplitude of 45 cm might indicate a 9 rating. A score of 42.5 cm might be an 8.5. This system is an example of an analog method. Any possible value can, in principle, be send. If the group wanted to send a rating of 8 ⅓, they could send a wave that is 41 ⅔ cm tall.



Another group perhaps will use a method of sending one pulse for each whole number. To send an 8, they'd send eight pulses. This system is an example of a digital method, since only a limited set of values (only whole numbers in this case) can be sent. Of course, students can set up systems that allow them to send to some additional precision if they set up that in the system.



Try, try again

To help students to understand the advantages and disadvantages of analog and digital systems, ask them to imagine taking the value from the receiving team and give it back to their sending team. Ask what would happen over 10 iterations.

Many students notice that the receiving teams of groups using analog methods don't always get the answers exactly right. For instance, if the sending team sent a movie rating of 6 ¼, the receiving team might think that it is 6 ½. Ask the students what they think might happen if the receiving team gave that value to another analog team. Most of the teams will realize that each analog pass can change the signal.

The digital systems on the other hand, often don't have enough precision built into them. For example, if you asked the group who could only send whole numbers to send a movie rating of 6 ¼, they wouldn't be able to send that value. They'd have to truncate or round, losing some information. On the other hand, once they had made the adjustment, they could send the signal over and over without loss of information. Of course, the group could change the method of their encoding at the beginning to include a whole number and two one decimal. That system could handle 6.2 but not the extra 0.05. It would be a little off, but maybe that bit off isn't a big deal. Alternatively, they could use a system that sent a whole number and two decimals, handling 6 ¼ but not 6 ⅓. Digital systems often have to approximate.

Asking to send the school's telephone number

Ask the groups to come up with a system to send an accurate telephone number, an ISBN from a book, a barcode, or a serial number down the spring so that the receiving team can decode it without non-spring information (like texts, significant looks, or whispers, etc.) from the sending team.
Groups should examine the problem, try out options, determine what works, and iterate and optimize until that get a system that works.

While students using analog systems can easily see that the approximations inherent in analog systems can add up to trouble, even digital systems can struggle. For example, you may need to ask the groups how will they know that they are done with one number and are moving on the next? Some students may choose to use binary numbers, but that isn't a defining feature of digital system.

Part III: Evaluation

While many kinds of assessment work, having students present how well they succeeded at sending their long number is probably the best way to see what the groups have learned.

In addition, each group should report out on how well they worked together. Even for classes that didn't have time for the groups to work on their own project, 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