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Optimizing Cell Phone Cameras 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 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 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.

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

In this lesson plan, students will watch a video where Katie Schwertz 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 turning their cellphone into a low-power microscope. Finally, they will look back at their work habits to determine how closely they matched skills that the engineer suggested were important.

Part I: Watching the Katie Schwertz 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

Katie Schwertz said that she had to overcome the obstacles of _____
Katie Schwertz 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:

- Katie Schwertz has made engineering her career.
- Katie Schwertz is an engineer because it gives her a chance to be creative.
- Katie Schwertz persevered to overcome obstacles.
- Katie Schwertz 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 didn't go the way I planned	𝍸 II

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

You may wish to save this activity for a time when you have a need for a microscope/dissecting scope camera in your classroom.

As you bring the camera in a cell phone closer to an object, the image of the object becomes bigger. Closer than some distance, however, the camera can't focus the image anymore, and it becomes blurry instead of larger. Stacking another convex lens on the camera lens will let the camera get closer and still have a focused image.

Getting Close Up with a Cellphone Camera

Materials

- Collimating (focusing) lens for laser pointers (either purchased separately or scavenged from a laser pointer)
- Poster tack putty
- Cellphone
- Old US penny with the Lincoln Memorial on the reverse or tails side (1958 to 2008) plus 20 additional pennies (new or old)
- 2 rulers
- Additional materials: bobby pin, paper clip, straw, cardboard, LED flashlight, clear plastic, clear tape, and so on

Characterizing the Cellphone Camera

Place the ruler on the table. Starting next to the ruler, start moving the phone away until the image is sharp. Measure this distance with the other ruler and take a picture.

Open the picture on the phone and enlarge the image as much as possible. Measure the distance between two millimeter marks. You can determine the magnification of the camera by dividing the distance measured on the screen by the actual size of the thing being measured. For example, if the distance on the screen between to millimeter lines is 13 mm, then the phone can enlarge something close by 13 times.

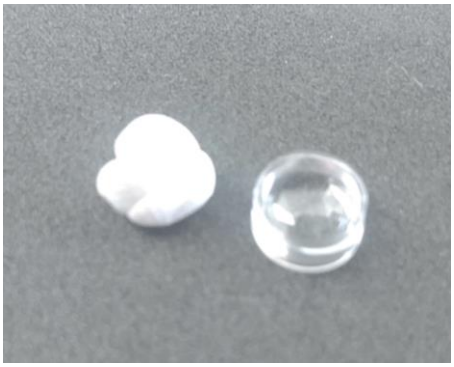
$$Magnification = \frac{measured\ size}{actual\ size}$$

$$Magnification = \frac{13\ mm}{1\ mm} = 13$$

The real magnification is actually much less than this value, though, as expanding the image causes pixilation to occur which prevents additional resolution. Still, this is a good place to start.

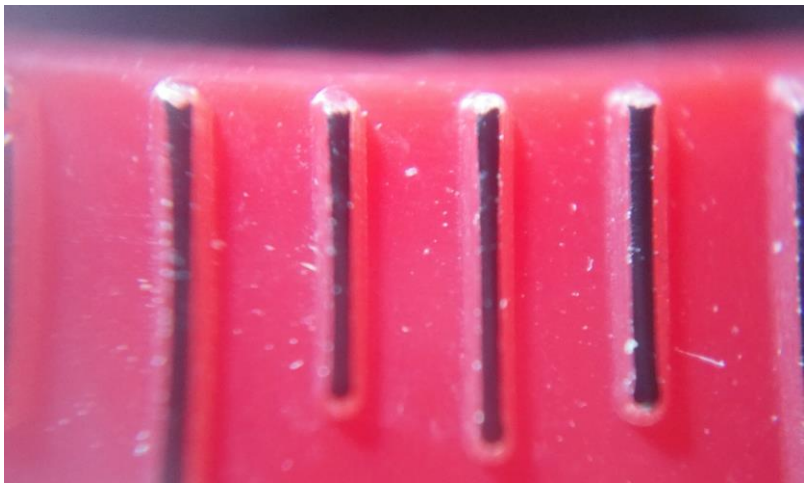
Characterizing the Cell Phone Camera

Take a small amount of poster tack and roll it into a snake. Place that around the edge of the laser pointer collimating lens. Remove any excess.



With the camera on, place the collimating lens against the camera lens. If the collimating lens has a flat side, place it against the camera lens. With the lens down, move the camera close to the Lincoln Memorial side of a penny until it comes into focus. The phone will have to be very close the penny and you may have to move the collimating lens around over the phone lens. It can be hard to get the two lenses to line up.

Repeat the characterizing you did the first time. It may be hard to measure the distance from the lens to the ruler. You can use a stack of pennies to help measure this distance from the paper. Each penny is 1.5 mm thick.



A good first try of the cell phone microscope is taking a picture of the Lincoln Memorial on the reverse side of the penny. With a steady hand it is usually possible to get a clear picture of the seated Abraham Lincoln inside the Lincoln Memorial.

Making the Camera Easier to Use

Although the add-on lens helps the cell phone camera take closer and, thereby, larger pictures, it is awkward to use. Have students point out some difficulties. Typically, they notice that

- It is hard to hold the camera the right distance away from the object.
- The image is shaky.
- The image is sometimes too dark.
- Installing the lens was difficult.
- Handling small items to be imaged can be difficult.

Task the students with improving the camera. For older students, you should have them keep track of what a better camera is. Perhaps

- The images are sharper.
- More of them clear.
- More the image is clear.
- The objects in the image are larger.

The groups can work on all or part of the difficulties that the class determined were flaws in the current design. Allow the students access to various material that you have available. For younger students, you may need to show them what you have. You might need to show them for example that a lens can be held by a bobby pin or that a hair to be imaged can be supported in a piece of packing tape.

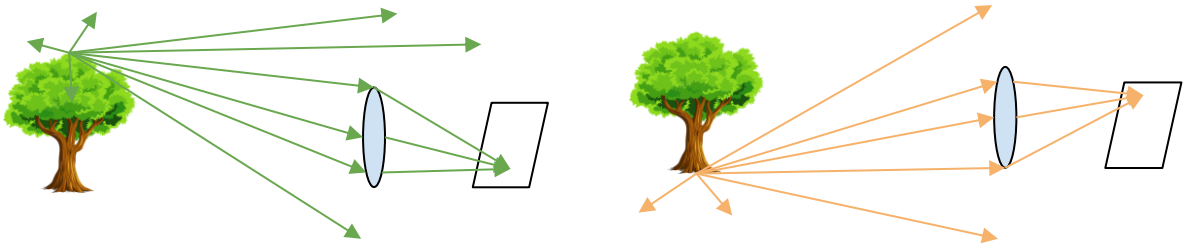
As the students finish their work, tell them that they are going to present their improvements to their classmates. They should explain how they have changed the camera and how they know that it has improved the images. Summarize the results on the board.

Have the students consider which improvement they would want to implement for their group's camera. You may notice that not all the students want the design that gives the best image. Often, that design requires a very complicated set up that other students will perceive as not worth the investment of time or resources.

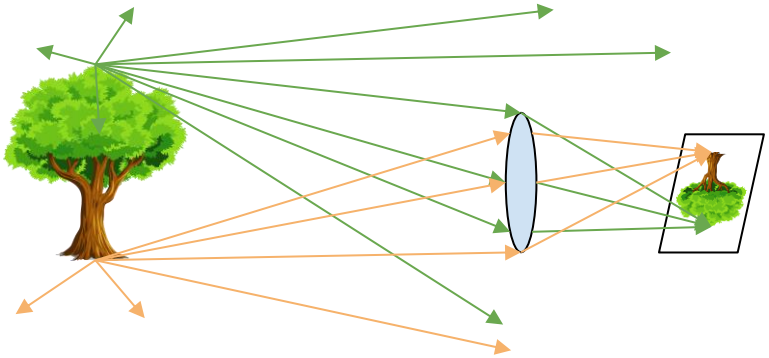
The best design is not always the one with best result. All benefits have to be weighed against the costs. Further, engineers don't have all the time in the world to make their designs. In the end, they have to get to an acceptable design that is good enough in the time available.

A Little Bit About the Physics

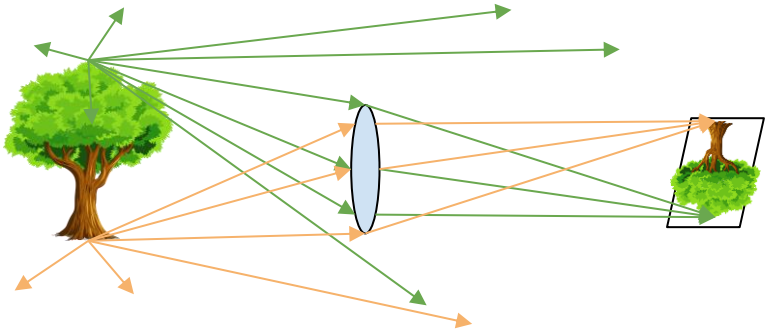
A simple convex lens makes an image by bringing the rays of light from one spot on the object together to another spot behind the lens. For example, in the image below the green light from the top of the tree is brought together in one location and the brown light from the trunk is brought together into another location. It is the special curved shape of the lens that bends the light.



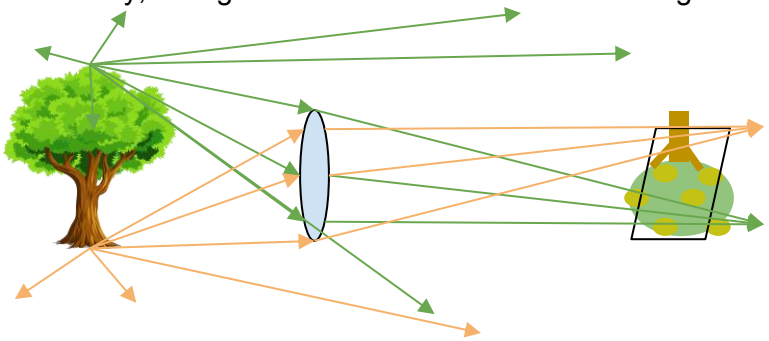
Since that happens for every spot on the tree, a whole image of the tree is made.



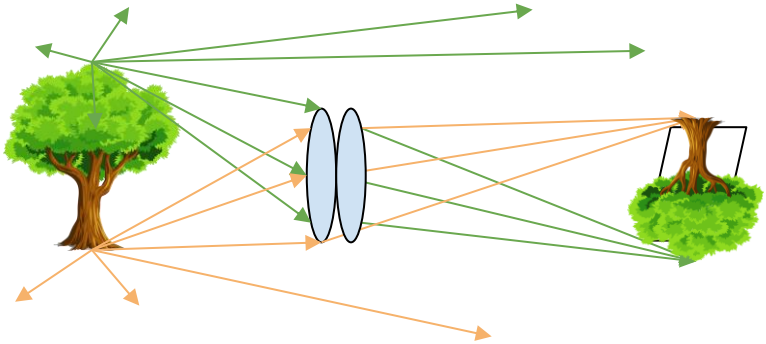
As the distance between the lens and the tree gets smaller, the image gets bigger but also farther away from the lens. To keep the image sharp the camera moves the light sensor farther away.



Eventually, the light sensor can’t be moved far enough backwards, and the image will be blurry.

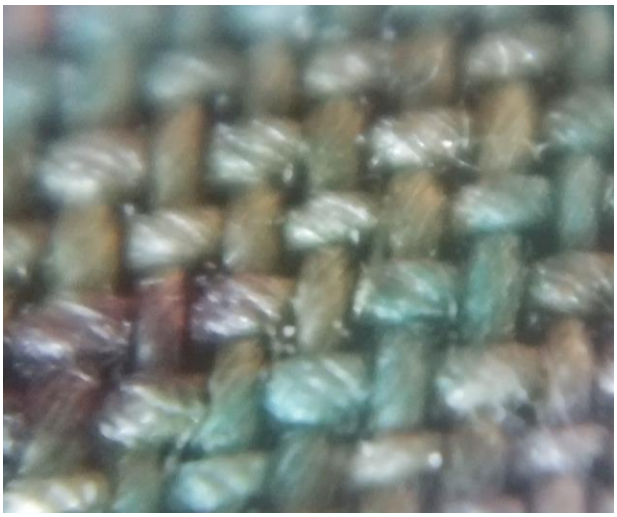


Our second lens is a workaround. Both lenses can bend the light, and the two lenses bend the light more than one lens, meaning that the rays can still come together on the light sensor, making for a bigger but in focus image.



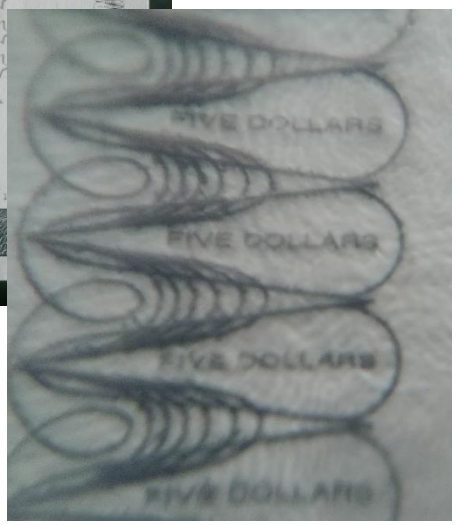
Other possible images

Fabric can be interesting.



US bills have microprinting that can only be seen with large magnification.

Double Stacking



You can actually put two lenses on top of each other, increasing the magnification still further.

Part III: Evaluation

While many kinds of assessment work, the students and the teacher should assess how well they improved their camera while considering how much other students wanted to use their idea or design. What did they learn about how to make a camera work and what did they learn about how to make a camera workable.

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