Clips and clamps

by Richard H. Moyer and Susan A. Everett

If you opened a desk or junk drawer, how many different kinds of clips or clamps would you find? You are likely to find paper clips and binder clips of several different sizes each, and perhaps a chip clip, clothespin, or hair clip or two. Around your house you may also find a clipboard, alligator clips on a wire, or jumper cables and spring clamps in your garage. If you look at this collection of clips and clamps, you will notice that they all function by means of a spring. Springs are not always coils of wire, but can be any device that has the tendency to return to its original position when it is displaced. Other than the paper clip, most of the clips or clamps you have around school or your home will probably fall into two different types of designs. One uses a coiled spring (see Figure 1) that holds the jaws together, and the other uses either a triangular or C-shaped piece of sheet metal or plastic as a spring (see Figure 2).

In this 5E learning-cycle lesson, students will investigate the design of simple, everyday binder clips and how they function. In the process, students will apply concepts related to levers and forces as noted in the middle-level National Science Education Standards (NRC 1996, p. 154). The lesson also addresses the following International Technology Education Association standard for middle-level students: "A product, system, or environment developed for one setting may be applied to another setting" (ITEA 2002, p. 49). To this end, students will examine a number of clips in order to determine how they function and will experiment with altering one of the parameters, namely, the length of the handle.

Historical information

People have been holding papers together since at least the 13th century. Early methods included sewing papers together with string and ribbon. When straight pins were invented, they were employed to hold paper together. Then, in the mid- to late 1800s, various types of paper clips became available. One advantage of paper clips was that they could hold papers together without making holes.

The binder clip was introduced around 1911 by a teenager named Louis E. Baltzley (Hales 2006). He was motivated to invent the binder clip because his father was a writer and had many papers that needed to be held together. The binder clip's basic design is still in use today, 100 years later.

Paper fasteners are so common that it is difficult to completely pin down their development over the years. As noted by Henry Petroski, an engineering professor at Duke University:

"When all is said and done, any attempt to sort out the origins and patent history of the paper clip may be an exercise in futility. For there appear to have been

FIGURE 1 Collection of spring-type clamps

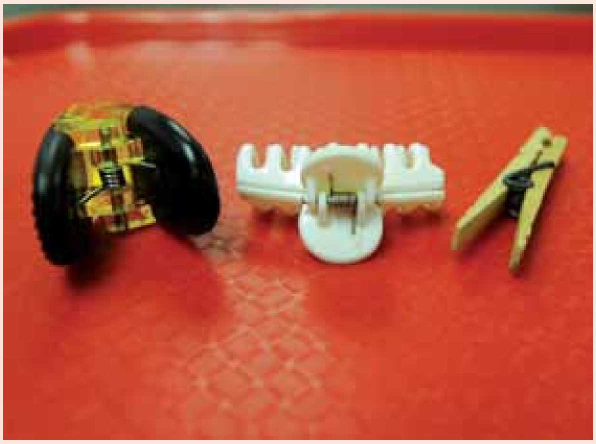
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FIGURE 2 Examples of binder clamps

countless variations on the device, a great multiplicity of forms, and some of the earliest and most interesting versions seem not to have been patented at all" (Petroski 1994, p. 62).

It is often compelling to be able to share exact dates and inventors with students, but technology does not always develop singularly, but rather on many fronts. In this case, there was a need for holding papers together, and when the machinery was developed to bend wire economically, an explosion of ideas ensued. You may wish to share early paper clip images from the Early Office Museum website with your students (*www.officemuseum.com/paper_clips.htm*).

Investigating clips and clamps (teacher background information)

Materials

You must provide students with safety goggles for this entire investigation in the unlikely event that a clip breaks loose and becomes a projectile. For this activity, you will need an assortment of binder clips as well as various other types of clips, such as hair clips, food bag clips, clothespins, spring clamps for carpentry, a clipboard, etc. Containers of assorted metal binder clips can either be found in your school's office supply area or purchased for approximately $6 for a box of 60. You will also need three to four clips of the same size for each group. We recommend using the 1.9 cm (¾ in.) size, which are available for about $4.50 for a box of 36. The clips can be reused from one class to the next.

For the Engage phase, each group of three to four students will need two identical binder clips, one of which has the handles removed. For the Explore phase, each group will need three additional 1.9 cm clips, which have had their handles changed. It is recommended that the teacher prepare these clips prior to class. Use the assorted clips to obtain handles of different sizes and transfer them to the 1.9 cm clips. We used one smaller handle, one normal handle, and two larger handles (see Figure 3). The exact lengths are not important and will likely vary from one manufacturer to another. Students will also need two unsharpened pencils, duct tape, scissors, and a ruler. For the demonstration in the Explain phase, the teacher will need two clips from the Explore phase—the standard size and the largest size—duct tape, and three or four identical textbooks. Each group will need several different types of clips in the Extend phase. Finally, for the Evaluate phase, students can either be given an array of different-sized binder clips (with standard handles attached), be shown a photo, or observe the image of clips projected from an overhead.

Engage

To activate prior knowledge, initiate a brainstorming session with students regarding their experiences

FIGURE 3 Four 1.9 cm clips with different-sized handles

FIGURE 4 Clip with extra-long handles

with clips and clamps. Focus attention on the binder type of clip and encourage students to determine how it works by opening and closing. Give students a clip with the handles removed and let them feel how difficult it is to open without the handles—in fact, it may not be possible to open. At all times during the investigation, students should not try to force clips apart with tools of any kind. If enough are available, each student should have a clip to examine. Have students share their ideas and lead the discussion to the explorable question "How does the size of the handle affect the opening and closing of a binder clip?"

Explore

In this investigation, the size of the binder clip is held constant—1.9 cm—while the length of the handle is the independent variable. The dependent variable, how difficult it is to open each clip, is qualitatively measured by squeezing the clip with the fingers. Students will likely rank the clips or state that some are "easy" and some are "more difficult." Students should conclude that the longer the handle on a clip, the less force is required to open it. While the same applies to closing the clip if it is done slowly—with continuous pressure applied—students will likely simply let the clips snap closed and thus report (correctly) that the length of the handles is not a factor in closing. When students design a clip that requires less force to open, they will likely construct one with much longer handles—perhaps by attaching pencils to the existing handles (see Figure 4).

Explain

If students are familiar with levers, this may be a review and an application. Otherwise, you may need to guide them in understanding how a lever works and its main parts—the fulcrum and effort and resistance forces. In the case of the binder clip, note that there are actually two levers, one on the top and one on the bottom. In the following discussion, we focus on just one of the levers. When opening a clip, the fulcrum is located at the point where the handle touches the top edge of the V-shaped clip. This is the balance point about which the handle rotates as it is squeezed. Thus, the length of the handle—the length of the lever's effort arm—is the distance the handle extends out past the clip's top. The resistance force is applied by the spring to the end of the handle where it fits into the round grooves. Thus, the resistance arm is from these grooves to the fulcrum at the top end of the clip. The longer the effort arm relative to the resistance arm, the less force will be required to open the clip.

To further this concept, the teacher should conduct the following demonstration. Measure the length of the effort arm on a clip with the standard handle (ours measured 18 mm). Then measure the effort arm on a clip with the largest handle (ours measured 28 mm). Tape the first clip securely to the table and

FIGURE 5 Quantitative testing of handle lengths

FIGURE 6 Exploded view of C-shaped spring clips

add textbooks until it begins to open (see Figure 5). While the weight of the books will vary, we selected books so that it took three books to open the standard size. Repeat using the clip with the longer handle. If you used clips with handles like ours, you should find that it only takes two books to open this clip with the longer handle.

Students should be able to conclude that these quantitative data support what they discovered qualitatively in the Explore phase. Help students understand that because both clips have the same size spring, the resistance—the force to open the spring—is identical. However, the clip with longer handles requires only two books to exert enough force to open the clip, while it takes three books to apply the same force to open the clip with the standard handles. For this reason, we consider the mechanical advantage (MA) of the longer-handled lever to be 3/2, or 1.5. This is equal to the ratio of the effort arms—28 mm ÷ 18 mm = 1.56. The MA can be determined either way. You may wish to have students calculate the MA of the extended-handle binder clip they designed. The one in Figure 4 has an effort arm of 184 mm compared to the standard arm of 18 mm, giving an MA = 184 mm ÷ 18 mm = 10.2.

Extend

Depending on what is available, students will likely sort their clips into two or three groups—the "binder clip" group, a group using coiled springs, and possibly a third group such as food bag clips. Some food bag clips contain a plastic or metal C-shaped spring clip and function the same as the metal binder clips or the C-shaped metal binder clips (see Figure 6). Note that in some binder clips, the spring is plastic rather than sheet metal. If it is part of your curriculum, you may wish to have students identify the fulcrum, effort, and resistance arms of the different types of clips.

Evaluate

Provide students with different sizes of binder clips or show photos (see, for example, Figure 7). Ask why different-sized clips have handles of different lengths. Students' answers should indicate that they understand that longer handles require less effort force to open a given clip and that larger clips with stronger springs require a greater effort to open and thus need longer handles. To test their ideas, students should suggest an experiment similar to the teacher demonstration that measures the effort force needed to open the clips.

Some students may wonder why all clips simply do not have longer handles to make them easier to open. This question leads to some of the engineering variables that constrain the manufacture of the clips. Some of these factors may include the cost of the additional material, the cost of shipping and packaging larger clips, as well as the bulkiness of the final product.

ACTIVITY WORKSHEET: Clips and clamps design

You must wear safety goggles at all times during this investigation.

1. Brainstorm a list of different types of clips and clamps with which you are familiar and discuss with the class.
2. Carefully examine the binder clip your teacher has provided to determine how it works. How does it open? What keeps it closed? Record your ideas.
3. Now examine the clip without handles. Compare how easily it opens to the one with handles. Record your findings.
4. In the Explore phase that follows, you will test clips with handles of various sizes. How does the size of the handle affect the opening and closing of the clip?

Explore

1. Your teacher will provide your group with binder clips for your investigation.
2. Measure the length of each handle and then carefully try to open each binder clip using only your fingers. Construct a data table to record your results.
3. Qualitatively describe how much force was required to open each binder clip and record.
4. Using the materials provided by your teacher, construct a binder clip that requires much less force to open. Make a drawing of your idea. Share your plan with the teacher before you build it.
5. Test your idea and record your results.
6. Use your results to answer the following questions: How does the size of the handle affect the opening of the clip? Closing?

Explain

1. Share your results with your classmates.
2. Why do you think the length of the handle is important? How is the handle like a lever?
3. Your teacher is going to do a demonstration with two clips that have handles of different lengths to quantitatively determine how much force is needed to open each clip. Compare the length of each handle to the amount of force needed to open each clip. Determine the length of the handle that protrudes out beyond the clip. Record your results in the table below.

Force needed to open clips with different handles		
	Length of handle (protruding beyond the clip, cm)	Number of books needed to open the clip
Clip 1		
Clip 2		

4. How do the data you collected in the above table relate to what you discovered in the Explore phase?
5. Think about how many books are needed to open each clip. How much easier was it to open one of the clips?
6. The mechanical advantage (MA) of a lever is a measure of how much the effect of the applied force is increased. What is the MA of the binder clip with the longer handle?
7. What do you notice about the ratio of the length of the longer handle to the smaller one? Compare this to the MA you determined above.

Extend

1. Look at the different clips your teacher has provided to determine how they open and close.
2. Sort the clips based on their operating mechanism.
3. Which are similar to binder clips and which ones are different? Explain.

Evaluate

Different-sized clips have different-sized handles. Why? How would you set up an experiment to test your idea?

FIGURE 7 Different-sized binder clips

Conclusion

The modern binder clip is another example of everyday engineering where a design has withstood the test of time. Today's clips are essentially the same as they were 100 years ago. The usefulness of this type of spring has been applied to many different products, such as hair clips, food bag clips, and spring clamps of many types. The simple binder clip is an example of a lowly, yet elegant design that is used decade after decade. Binder clips are all based on the idea of a simple spring that is used to hold something closed. Perhaps you can think of some types of springs that hold things open. ■

Acknowledgment

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References

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Petroski, H. 1994. *The evolution of useful things: How everyday artifacts—from forks and pins to paper clips and zippers—came to be as they are.* New York: Vintage Books.

Mechanical advantage

Consider the force required to open the binder clip. It is nearly impossible to pull one apart with your fingers. The use of the handles provides what is called a *mechanical advantage,* allowing you to open the clip with considerably less force. How is this possible? First, one must appreciate that you "cannot get something for nothing." In order to open the binder with the handle, you had to move the handle much farther than the jaws of the clip actually opened.

This is because no machine can produce more work than is put into the machine. You may recall that scientists usually define *work* as the product of a force acting over some distance. The smaller force we apply with our fingers acting over a greater distance is equal to the larger force exerted by the jaws times the smaller distance that they move when they open.

The ideal mechanical advantage of a lever can be calculated by comparing the distances from the fulcrum to the effort force and to the resistance force. If the so-called effort arm is twice as long as the resistance arm, then the ideal mechanical advantage of that lever would be 2. In our exploration here, making the effort arm (the handle of the binder clip) longer by a ratio of 3 to 2 resulted in a mechanical advantage of 1.5 for the clip with the longer handles. Because of friction, the actual mechanical advantage will, of course, be less than the ideal mechanical advantage and can be determined empirically by calculating the ratio of the actual output force to the input force.

Resources

Early Office Museum: History of the paper clip—*www.officemuseum.com/paper_clips.htm*

Moyer, R.H., J.K. Hackett, and S.A. Everett. 2007. *Teaching science as investigations: Modeling inquiry through learning cycle lessons.* Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.

Richard Moyer (*rhmoyer@umich.edu*) is a professor of science education and ***Susan Everett*** is an associate professor of science education in the School of Education at the University of Michigan in Dearborn, Michigan.