Be an Engineer!

Estimated Time: 30 – 45 minutes

SUMMARY
Engineers often work to construct huge things like buildings and bridges, but these are just the most noticeable things for engineers to work on. The concepts of engineering can be applied to anything big and small, and they can work with any material! In this activity, students will build bridges out of paper and see that, with engineering, they can get them to hold some pretty impressive weights.

WHAT YOU'LL LEARN

- The engineering process of designing, testing, and redesigning.
- The vocabulary word "parameter" and learning to work with constraints.

Materials Used	
• Four sheets of 8.5"x11" printer paper per student (plus extra). • Masking tape • Tables, chairs, or thick books.	• Small, heavy objects such as metal washers, nails, coins, etc. • Small square (3" x 3") of cardboard or plastic (optional)

WHAT TO DO

1. Start by talking about what bridges are made out of. Encourage students to list out all the materials they can think of for bridges such as stone, wood, bricks, metal, etc. Have they ever seen a bridge made of paper? Probably not, and if they can imagine it they won't expect it to hold much weight.
2. Tell the students they will be building a bridge out of paper and seeing how much weight it can hold. They can't just design anything, though, they have certain parameters for their design:
   a. You are limited to four pieces of printer paper and some masking tape.
   b. You need to cover a gap of 8.5 inches.
   c. The most successful design will be the one that holds the most weight without collapsing.
   d. You can't tape the paper down.
3. **Build.** The gap for the bridges can be made by stacking up books (as shown in the picture to the right), pushing two tables together, or pushing chairs near each other. Making the gap 8.5 inches seems arbitrary but it is the first design challenge: the papers won't work with the narrow length of printer paper, you have to use the long dimension.

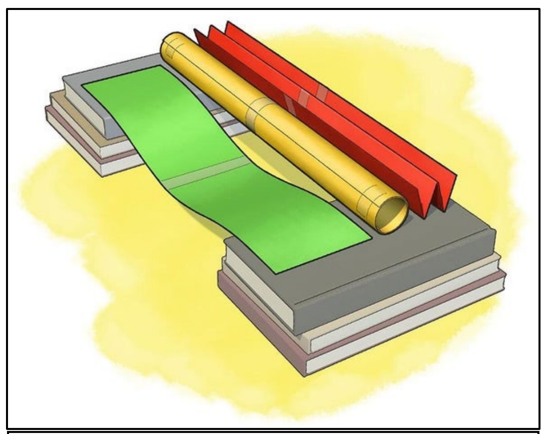

Image © Scientific American

4. **Test.** Most students will start by stretching their pieces of paper flat, but they will soon find that the paper buckles under the first weight added. Use this to talk about ways the bridges might be redesigned.
    a. Paper has very little strength against forces applied to the flat side of the paper, which you can tell by simply poking a piece of paper and watching it fold.
    b. Trying to pull a piece of paper apart, though, shows how strong it is against edge-on forces. How can we apply the weight to the paper's edge?
5. **Analyze.** Each time the bridge collapses is a chance for discussion and analysis. Cheer each design's advantages and pick out the weaknesses to improve on. During these analyses, you can ask the following questions.
    a. **What worked?** Where did the bridge hold up against the weight? What did you change from last time and how did it help? Is there a general rule you can make from your observations (e.g. "Triangles are strongest.")?
    b. **What didn't work?** How did the bridge perform worse than you'd planned? What changes did you make that had no effect? Is there a general rule you can make from your observations (e.g. "Just a sheet of paper isn't strong enough.")?
6. Repeat the Build, Test, and Analyze steps to continue redesigning the bridge. Redesigning bridges might take many times, but with each failure students will learn more. Eventually, they should try one of the other designs shown in the picture above: a rolled beam of paper and a folded accordion. Both of these changes will put weight onto the edge of the paper where it's stronger and the triangles of the accordion will also spread the weight out over the triangles' base making it the strongest option.
7. After each redesign, add weights until the bridge collapses. Keep track of the record and use each collapse as a lesson for what to change next time. You can use the data table below as an example of keeping track of changes. Take breaks frequently to discuss and swap ideas.

Student	Record	Notes
Dajae	21 nails	Used accordion design, multiple layers
Chris	15 nails	Reinforced folds with tape, strengthened center of bridge.

TIPS

- Having a square of cardboard or plastic to put your weights on is optional, but it can make it easier to balance the objects on the bridge. Make sure that all the squares are about equal in size and shape to make comparisons between bridges fair.
- Having multiple teams working on different bridges is the best way to generate ideas with this activity. Students will have different ideas and try different approaches, then they can share them during conversations between tests. However, it is recommended that this activity *not* be conducted as a competition. Engineers often share ideas and compare notes to improve their work and students will gain more learning to explain their discoveries than trying to work on their own without input.