MAKING STUFF SAFER

NOVA PBS WGBH

How do engineers use their knowledge of structures and materials to make our world safer?

THE STORY OF SAFER

The world is a dangerous place. Monumental forces of nature—such as earthquakes and hurricanes—can destroy our homes and cities in a heartbeat. Today's scientists and engineers are developing new tools and gaining knowledge to protect us from natural disasters and keep us safer than ever before.

TALKING "SAFER"

Start the conversation with the following questions:

- What does "safe" mean to you?
- Describe some things from your daily life that are designed to help keep you safe.
- What are some examples of natural disasters?
- What are some of the ways that we protect ourselves from these natural disasters?
- How can we make stuff safer?

REAL-LIFE EXAMPLES

- "Engineering Soft-Story Safety" clip from *MAKING STUFF Safer*
- Safer PPT Slides

PROJECT PREVIEW

In the following series of investigations, students explore how to build and test the strength of different shapes and then use those shapes to design and build strong structures. Students also experiment with materials to design miniature buildings that can withstand simulated earthquakes.

ACTIVITY: BUILD STRONG SHAPES FOR A SOUND STRUCTURE

Overview

Students build various shapes with gumdrops and toothpicks and then test their shapes for structural integrity.

Materials

Recommended for each student:

- 11 toothpicks
- 11 gumdrops

Brainstorm & Discuss

Begin the brainstorm. Ask students:

- Why do you think buildings come in different-shapes and sizes?
- Do certain kinds of buildings tend to come in similar shapes?
- How do you think different shapes provide different amounts of support or strength for buildings?

DESIGN & BUILD

Introduce the activity. Inform the students that they're about to build some different shapes and test which ones are the strongest.

1. Distribute the materials that students will have to work with.

2. Demonstrate how to use a toothpick to connect two gumdrops.

3. Ask students to use this method to build a square and a triangle.

Tips and Tricks for Inclusion

Students with physical or visual impairments may struggle with using gum drops to connect toothpicks together. The following approaches could be used to help make this activity more accessible:

- Instead of toothpicks and gumdrops, use k'nex, legos or erector set pieces so triangular and square structures can be built and tested (See Tools E8,K1,L1 in Tools Table in Appendix).
- Instead of toothpicks and gumdrops, which might be too small for some students to easily handle, use popsicle sticks/craft sticks and connect them together with double sided tape (See Tools A1,C5 in Tools Table in Appendix).

TEST & REBUILD

Students will now test the structural integrity of their individual shapes.

1. Once students have built a square and a triangle, ask:

- How would you determine which shape is strongest?

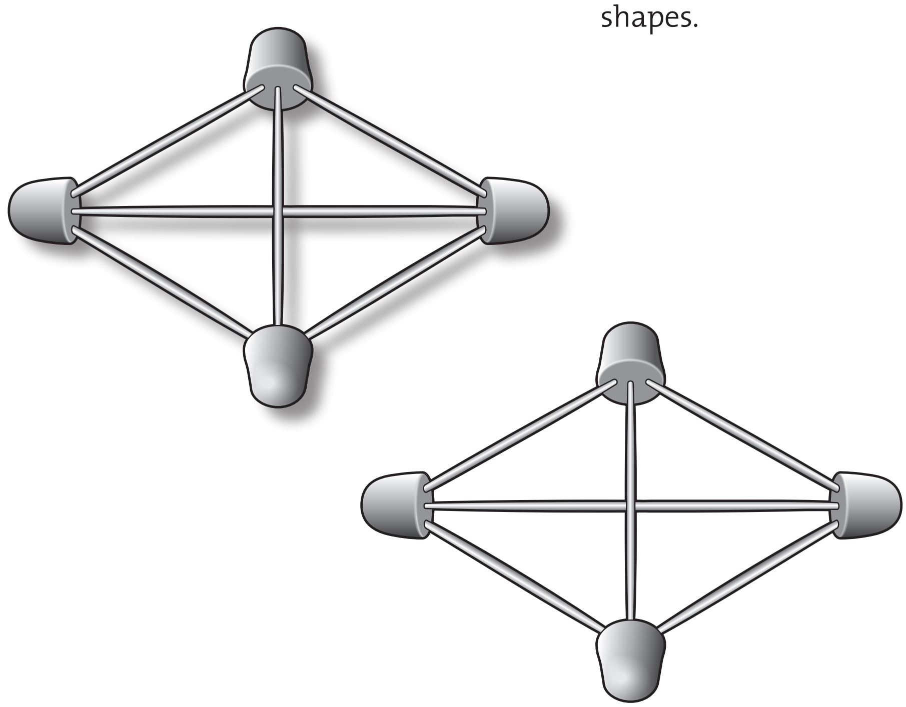
2. Facilitate the group in devising methods to test the different shapes for strength. One possible method for testing the strength of a shape is to stand it upright and apply pressure to the center of the top. Strength can be determined by how well the shapes support the amount of pressure applied before bending or collapsing.

3. Check for understanding by asking the following questions:

- What happened to your square when you tested it? What happened to your triangle?
- Which shape—the square or the triangle—is stronger?

4. Give students time to design and create a range of different shapes (including combinations of shapes).

5. Have them continue to test the shapes for strength in the same ways they did for the square and triangle. In addition, encourage students to create new ways to test their new shapes.



Quick Tip: *A square can be broken down into four equilateral triangles by making an X with two toothpicks and adding them as two cross beams from corner to corner. This will make the square structurally sound.*

WRAP UP

When a wide variety of shapes have been built and tested, gather the students together with their shapes and ask:

Ask them:

- Were there any differences in how the paper fans and the cardboard fans worked?
- Was this what you predicted would happen?

DESIGN CHALLENGE: USE SHAPES TO BUILD STRONG STRUCTURES

Overview

Students apply what they learned in the previous activity to design and construct a model building with the provided materials. Students then test their buildings for structural integrity and redesign them as appropriate.

Materials

Recommended for each student:

- Pencil and paper
- 20 gumdrops
- 30 toothpicks
- Small weights
- 4" x 4" piece of 1/8" plywood or 1 firm piece of cardboard measuring 4"x 4"

Brainstorm & Discuss

Watch the video clip ***"Engineering Soft-Story Safety"*** from *MAKING STUFF Safer.*

Begin the Brainstorm. Ask students:

- Why were the soft-story buildings featured in the video considered unsafe?
- What did the engineers do to make the buildings safer?
- What tools did the engineers use to test the effectiveness of their solutions?
- How might you simulate the effect of an earthquake on a smaller scale?

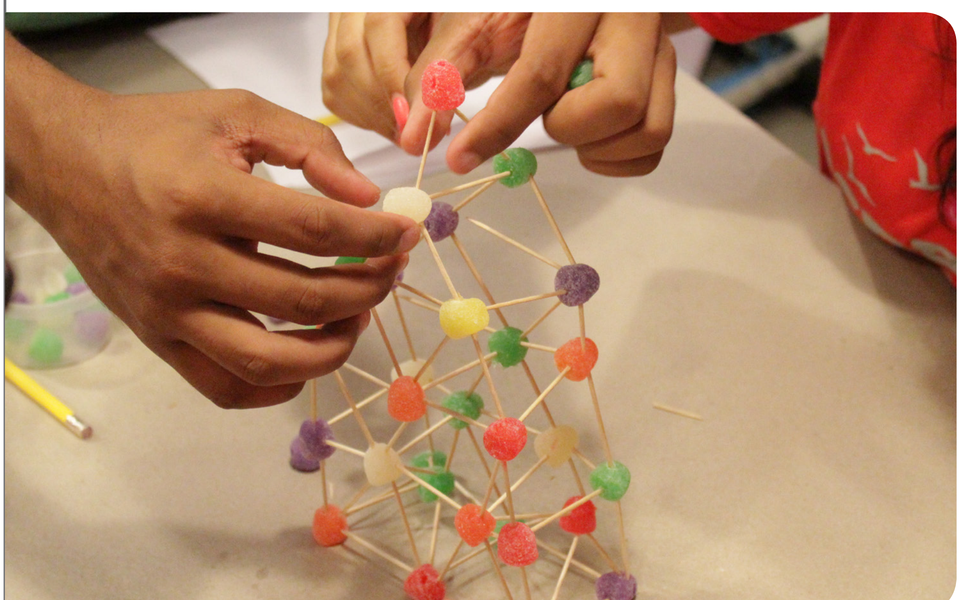
Inform students that they will be constructing model buildings and testing them for structural integrity. Explain that when architects and engineers design and build structures, they take many factors into consideration. Students should consider the following questions:

- Where will the structure be built?
- What is the area like? Is the structure likely to encounter earthquakes, flooding, or any other natural disasters?
- What are the best available materials to use that meet the budget?
- What is the desired shape and size of the structure?
- How can the structure be built to maximize its safety?

DESIGN & BUILD

Introduce the challenge: The students' goal is to build a strong and resilient structure by applying what they learned from the previous activity about the structural integrity of different shapes. Students will test their structures to see which ones are the strongest and the safest.

1. Introduce students to the building materials available. Encourage students to make creative choices that best suit their design ideas and allow the class to produce a range of outcomes.
2. Have students start by sketching potential designs for their structures. Each student/group should come up with at least two different designs before starting to build. They can use the same shapes from the previous activity or enhance their structures with new designs.
3. Once students have their designs and materials ready, they can begin building.



Tips and Tricks for Inclusion

Students with physical impairments and visual impairments may not be able to sketch design solutions or review others' solutions. To make this activity more inclusive, provide strings and/or clay for all students to use when designing their structures (See Tools C7,C8 in Tools Table in Appendix).

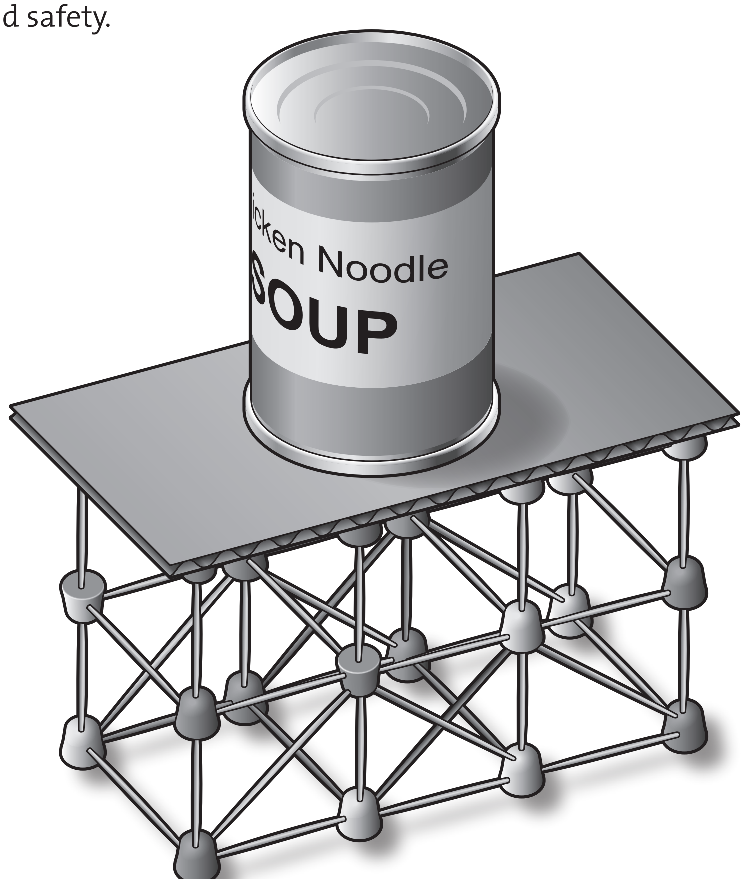
TEST & REBUILD

Once students are satisfied with their structures, they can test for strength and resiliency. Done together, this can add a fun, social component to the class or workshop.

1. To test strength of a structure, place a 4" x 4" piece of plywood (or a firm piece of cardboard) on top of it. Place weights on top of the plywood, adding one at a time. (Students may devise weights using whatever materials are readily available.) The structure that can hold the most weight without collapsing will be considered the strongest!

2. (Optional Safety Test) Students' can test their structures for safety under earthquake conditions by using a shake table. Students should place their structures on the shake table and simulate an earthquake of a particular magnitude and duration.

3. (Optional Strength & Safety Test) If a design passes the initial safety test, students can add weight onto the building in the same way that they did in the strength test, and then simulate another earthquake. By combining the force of the ground's movement delivered by the shake table, and the shifting load from the weight, the structure will be tested for both strength and safety.



Quick Tip: *Looking for an additional challenge? Establish a minimum height for the structures so that students will need to explore different shapes to meet both strength and height specifications.*

WRAP UP

At the conclusion of the exercise, students should reconvene as a class and discuss what they learned.

Depending on which tests were performed (strength, safety, or both) facilitate the discussion with the following questions as appropriate:

- Which structures survived the weight-bearing test?
- Which structures survived the simulated earthquake with the least amount of damage?
- Were there adaptations that made structures better able to bear weight or withstand a simulated quake?
- If you could use different materials to build your structures, which materials do you think would be the strongest and safest? Why?
- How do you think materials and shapes combine to make the safest structures?

OPTIONAL DESIGN PROJECT ADDITION: BUILD A SHAKE TABLE

Overview

Students will construct a "shake table," a moveable surface that can simulate the effects of a seismic event on model structures.

Quick Tip: *Looking for an additional challenge? Establish a minimum height for the structures so that students will need to explore different shapes to meet both strength and height specifications.*

Materials (for one large shake table)

- 24" x 28" piece of 3/8" plywood
- 18" x 24" piece of 1/8" Masonite
- 2 pieces of 3/4" x 3/4" plywood, 17 " long
- 2 pieces of 3/4" x " plywood, 23 " long
- 3/4" x 3/4" piece of plywood, 10" long
- 16 screws, 5/8" long
- 2 bolts, 2" long, with wing nuts
- 8 small rubber bands
- 9 bottle caps, (such as Gatorade caps)
- 9 bouncy rubber balls
- Hot glue gun

DESIGN & BUILD

1. Using glue, attach the nine plastic bottle caps to the 24” x 28” plywood in a 9-point grid, in three rows of three. The caps will provide a cradle for the rubber balls. Complete this step as follows:
   a. Measure the center mark of the board and glue one cap there.
   b. Glue two more caps in line with the other one, 8” away on either side, parallel to the 18” side.
   c. Repeat this process 10” above the middle line and 10” below the middle line to complete the grid.
2. Place a rubber ball in each lid.
3. Create a border along the edge of the Masonite sheet by attaching the 4 pieces of 3/4“ wood with hot glue.
4. Once the wood border is in place, use a ruler to divide each side into thirds and screw eight screws halfway into the 3/4” wood at each mark.
5. At one of the corners, measure along one of the pieces of wood and mark 2” and 4”. Drill two holes through the wood and the Masonite on the marks.
6. Take the 10” piece of wood and mark 1” and 3” from the bottom and drill two more holes. Slide the bolts into the holes from the bottom of the Masonite board up, then thread the 10” piece of wood over the bolts.
7. Screw the wing nuts on to tightly secure the 10” piece of wood.
8. Lay the Masonite piece on top of the rubber balls and mark the plywood to line up with the eight screws in the Masonite.
9. Next, screw the other eight screws horizontally into the plywood.
10. Stretch the rubber bands around each pair of screws, one from the Masonite board on top, and one on the plywood.
11. Now you’re ready to test your shake table. You’ll pull on the 10” piece of wood to simulate the earthquake. To make each earthquake similar in strength, pull the Masonite platform back and mark a point on the plywood to which operators can pull and release consistently. There can be several different marks to increase the intensity of the earthquakes.

DESIGN & BUILD (CONTINUED)

Quick Tip: *The class can build one large shake table, or each group can build its own. If each group builds its own shake table, different teams should use different designs so that the various teams can test their structures under different seismic effects. Students can also add landscape components to their shake tables such as streets, trees, houses, etc. This will lend a more real-world look, and can add a city planning element to the overall activity. It is recommended that the landscape added to the shake table be based on a real location (such as a local neighborhood, a distant geographical location, or an historic location) to add a storytelling aspect to the activity. This can enhance the students' overall engagement with the Challenge, and may also enhance students' investment in the final outcome.*

Tips and Tricks for Inclusion

Building a shake table may be difficult for children with visual or physical impairments. To make this activity more inclusive, try the following:

- Provide pre-cut or marked pieces.
- Split up the tasks based on ability, having children with physical impairments assembling components and keeping track of the task list, while others use the glue gun and fabricate other pieces.

Other shake table resources include:

- ***A shake table design from the Resource Area for Teaching (RAFT)***
- ***A video tutorial on how to build a shake table from the George E. Brown, Jr. Network for Earthquake Engineering Simulations (NEES)***
- ***Brief instructions on how to put together a shake table from ehow.com.***