Freestanding Structures: A Tech Museum Floor Activity

Please note: This activity was initially developed to be a floor activity for guests of The Tech Museum. It can be modified for classroom use and is a good example of an introductory level Design Challenge.

Description:
In this Design Challenge, families and friends work together to design the tallest structure that they can, using only the materials provided.

Grade Levels: 3-8

Educational Outcomes:
- Students will explore strategies for building tall and strong structures.
- Students will explore such concepts as elasticity, tension, torque, compression and force.
- Students will get a first-hand experience of the design process that scientists and engineers undergo.

Estimated Time: 15-20 minutes.

California Science Standards Connections:
Grade 8: Physical Science *Forces*
- *Students know* a force has both direction and magnitude.
- *Students know* when an object is subject to two or more forces at once, the result is the cumulative effect of all the forces.
- *Students know* when the forces on an object are balanced; the motion of the object does not change.
- *Students know* how to identify separately the two or more forces that are acting on a single static object, including gravity, elastic forces due to tension or compression in matter, and friction.
- *Students know* that when the forces on an object are unbalanced, the object will change its velocity (that is, it will speed up, slow down, or change direction).
- *Students know* the greater the mass of an object; the more force is needed to achieve the same rate of change in motion.

All grades - Investigation and Experimentation: Scientific progress is made by asking meaningful questions and conducting careful investigations. As a basis for understanding this concept and addressing the content in the other three strands, students should develop their own questions and perform investigations.

The Tech Museum Connections:
Innovation Gallery - Pushing the Limits (http://www.thetech.org/exhibits/subgallery.cfm?id=43)
Exploration Gallery – Living on a Restless Planet (http://www.thetech.org/exhibits/subgallery.cfm?id=47)

Materials and Set-up:
PER TEAM of 2-3:
- 20 3/8" Wooden dowels (typical size when purchased without cutting)
- Unlimited rubber bands.

SET-UP:
- Tape measure to measure building height

Design Challenge
Design the tallest structure possible that can stand on its own, using only rubber bands and 20 dowels.

Constraints:
- All 20 dowels must be used and attached with rubber bands.
- Individual dowels may not be used only to add height (e.g. used to create an antenna).

Notes for Teacher/Facilitator

There are four ways to measure a building's height:
1. Highest occupied floor
2. Traditional roofline
3. Decorative structures
4. Rooftop antennas

A building's official height is the highest overall measurement not including any rooftop antennas. By this standard, the Petronas Towers in Kuala Lumpur are the tallest buildings, each measuring in at 1,483 ft. However, the Sears Tower, in Chicago, has the tallest occupied floor at 1,431 ft, and the highest traditional roof, at 1,454 ft.

As an extension, add a load. Have the participants design a structure that can support a load (a book on top).

Although this activity was developed to be a building Design Challenge, the focus can be shifted to building a structure that can withstand an earthquake by testing the structures on a shake table.

Testing:
Stand your structure up and let it go. A structure that remains standing is a success. You can leave the tallest successful structure standing to give participants a mark to improve upon.

Teaching Points to guide Reflection Questions:
- Force: Any influence that tends to accelerate an object; a push or a pull; force = mass x acceleration (F=ma).
- Highlight the following features that affect building stability in various student designs:
  - Shear (sliding)
  - Tension (stretching)
  - Torque (twisting)
  - Compression (squeezing)
  - Support/Reinforcement
  - Use of Triangles or other geometric shapes (compare stability of shapes)
  - Wide to narrow (wide at base, narrow at top)

Reflection Questions:
Are there different ways to use the rubber bands?
What kinds of shapes do you most often see in buildings?
Are there other shapes that might work well?
How can you make it more stable?
What are some ways you can use the materials to provide support for your structures?
What do you think might happen to your structure in an earthquake?
How would your design change if you were given more dowels?
What changes would you make if your structure had to support a book on the top?

Discussion:
If you were to do this again, how many of you think you could build an even better structure? Discuss how scientists & engineers go through this Design Challenge process on a daily basis; learning from their mistakes, reflecting and improving upon what they have already designed.

Optional Post activity:
Repeat Design Challenge but introduce a load (e.g. a book) to include in the design.

Resources:
Building: the Fight against Gravity by Mario Salvadori. Margaret K. McElderry Books, Athenuum NY, 1979.
Building Big (PBS production of David Macaulay's book) website: http://www.pbs.org/wgbh/buildingbig/index.html
How Stuff Works website http://www.howstuffworks.com/skyscraper.htm
The New Way Things Work by David Macaulay. Houghton Mifflin, Co, New York, NY.1998.
The Tech's Earthquakes Tech Topics Unit: http://www.thetech.org/exhibits/online/topics/
The Tech's Exploration Gallery – Living on a Restless Planet (http://www.thetech.org/exhibits/subgallery.cfm?id=47)
The Tech's Innovation Gallery - Pushing the Limits (http://www.thetech.org/exhibits/subgallery.cfm?id=43)

Glossary:
- Buckling: When a material bends under compression.
- Compression: When a force pushes materials together.
- Elasticity: The property of a material to bend or deflect, and then return to its original shape.
- Force: Any influence that tends to accelerate an object; a push or a pull; force = mass x acceleration (F = ma: Newton's 2nd law).
- Load: The weight which a building or structure must carry. Dead load = the weight of the building itself plus all permanent fixtures, does not change. Live load = weight of objects which move in, out, or shift in the building (people, furniture, etc.), constantly changing.
- Plasticity: The property of a material in which it does not return to its original form after a bend or deflection.

- Shear: When a force slides materials against one another.
- Tension: When a force pulls materials apart.
- Torque: When a force twists materials.