Science Unit: ***Physics Ideas***

Lesson 3: ***Structures - Directing Force***

School year:	2006/2007
Developed for:	Tecumseh Elementary School, Vancouver School District
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Grade level:	Presented to grades 6-7; construction challenges appropriate for Grades 3-7, physics calculation component appropriate for Grades 6&7 each with appropriate modifications
Duration of lesson:	1 hour and 20 minutes
Notes:	These activities are likely to take longer than the estimated duration. Originally they were set up in a station approach with an instructor. Students continued to work on science activities during the week following the lesson.

Objectives

1. Learn about the forces that hold a structure together and forces trying to rip it apart. Structural design is about efficiently transferring the maximum force with the minimal mass.
2. Build a bridge and a tower out of loose wooden blocks to hold a 2 litre bottle of water.
3. Build a bridge out of interlocking LEGO bricks to hold a 2 litre bottle of water. Make it as light as possible.

Background Information

All structures perform the function of transferring forces from one position in space to another.

A house encloses a volume of space, protecting the interior of the house from sun, wind, rain. A light is hanging from the ceiling. The ceiling is connected to the roof structure. The roof is held up around the outer edges by the walls, and the walls are supported by the outer foundation of the house. The force of gravity acting on the light is directed to the outer foundation of the house.

Similarly, our bodies have bones that are normally in compression, tendons and ligaments normally in tension. Our pelvis is a truss structure, like the roof of a house, which distributes force to distant points of support.

When we walk however, our bodies move in complex patterns of tension, compression and rotation.

Vocabulary

Gravity	The attractive force exerted by every object, but noticeable only with huge, planet-sized objects.
Compression	A pressing force acting to compress or shorten an object.
Tension	A pulling force acting to extend or stretch an object.
Friction	The drag between two objects rubbing against each other.
Beam	An object with a mass in the middle and supported at either end.
Deflection	The amount a beam bends under a certain load. Stiff beams bend less.

Materials

- Wooden blocks for building bridge and tower,
- Toy car to drive across the bridge.
- Cardstock marked as a roadway for the car to drive on.
- 1 litre plastic bottle of water
- 2 litre plastic bottle of water
- LEGO 2x4 bricks for building a bridge.
- LEGO flat plates to act as a roadway
- Toy car to drive across the bridge

In the Classroom

Introductory Discussion

1. Friction holds things together, applied forces try to take things apart. You will be building a bridge and tower from loose wooden blocks with limited friction to hold the structure together (no glue, tape, string, rubber bands allowed). Your structure is trying to support a given load. Gravity is pulling the load down, your bridge is holding the load up, and the bridge supports are holding the bridge up.

   Your bridge is trying to efficiently transfer the force of the load to the abutments on either side of the bridge. Efficiency is measured by the mass of the required bridge vs. the mass of the given load, less bridge is better. Since you have limited friction to work with, you have to find the best way to make it work for you.

   Your tower needs to be as tall and light as possible. Best design has largest enclosed volume with fewest materials, or fewest wooden blocks in this case. Gravity is pulling the blocks down, friction keeps the blocks together. Try to find the best design to build an efficient building. The friction holding the lower levels of your tower together increases as you add levels to the top of your tower.

   LEGO bricks interlock with each other making a single, strong lightweight structure. You can make lighter and more sophisticated structures with interlocking bricks than with stacked wooden blocks.

2. Short description of other items to discuss or review.
   - All structural design is a balance of strength vs. mass.
3. Summary of instructions for science experiment/activity.
   - Draw a diagram of your overall structure, and a close-up of the some structural details.
4. Briefly describe safety guidelines.
   - Keep the wooden blocks and LEGO bricks off the floor, otherwise you may trip over them.

Science Activity/Experiment

Stations are set up in the classroom. One or two adults can run the entire class.

Divide the students into four to five equal groups. Students spend 15 minutes at each station then move to the next station. Save some time at the end of each station time to discuss the student observations.

Challenge 1 – Bridges over Educational County

- Students look at examples of masonry arches and gravity bridges (built without tension elements) and try to build a bridge across a gap twice the length of the longest side of the wooden blocks. Students can only use the bare blocks, no glue, strings, rubber bands, etc.
- The toy car must be able to drive across the bridge deck. A thin cardboard strip is used as a road deck for the top of the bridge. The students try to build a bridge with the least vertical height that can support a 1 litre bottle of water, and a 2 litre bottle of water.
- Challenge 1 can be repeated with Lego bricks.

Challenge 2 – Reach for the Skyscraper

- Students try to build the highest tower with the greatest enclosed volume, lightest construction, and greatest stability.
- The tower can only be assembled from the loose wooden blocks, no glue, tape, or rubber bands allowed. What arrangement of blocks allows the greatest enclosed volume and greatest stability per level?
- Once you are finished, count the number of blocks and calculate the volume of your structure. What is the ratio of volume (cm^3) per block? Write your ratio on the sheet for comparison to the other teams. At the end of the class the team with the highest ratio will be announced. How does your building compare?
- You are trying to enclose the most space at the highest altitude, while using the least amount of materials, least mass. You are trying to efficiently hold the materials in space, transferring the forces due to gravity efficiently down to the ground.
- Challenge 2 can be repeated with Lego bricks.

Science Journal: Students will record their observations at each station to find the best team's bridge, tower and vehicles.

Closure Discussion

Examples of questions to ask students:

1. What are the characteristics of the most efficient bridge?
2. What are the characteristics of the most efficient tower? How can you make your tower taller and still more stable?

References

1. http://www.pbs.org/wgbh/buildingbig/bridge/basics.html

Extension of Lesson Plan

1. Look at a series of stone, metal, and suspension bridges (London Tower Bridge, Sydney Harbor bridge, Golden Gate, etc). Identify the tension and compression elements of the bridges.
2. Build a bridge out of wooden blocks that spans three or four times the length of a single block.
3. See a video of the Tacoma Narrows bridge collapse. How can a small breeze make a new strong bridge collapse? Compare the Tacoma Narrows bridge to the Lion's Gate bridge (before and after renovation). The Tacoma Narrows was built after the Lion's Gate bridge, and designed to avoid some of the Lion's Gate bridge features. What were those features?