Science Unit: ***Structures***

Lesson 8: ***Building Sturdy Shapes***

Summary:	In this lesson, students explore the use of **triangular cross bracing** in buildings, bridges and other structures. They use strips of plastic (or stiff paper) and brads to construct various polygons and **compare and contrast their rigidity and strength**. Students then test the effect of reinforcing their polygons with triangular cross-braces.
School Year:	2013/2014
Developed for:	Champlain Heights Annex Elementary School, Vancouver School District
Developed by:	Ingrid Sulston (scientist); Mona Francis and Ramona Smith (teachers)
Grade level:	Presented to grades 2/3; appropriate for grades 1 – 7 with age appropriate modifications
Duration of lesson:	1 hour and 20 minutes
Notes:	This lesson is a more robust version (though with significantly more prep time) of the "How Strong are Different Shapes?" activity in Lesson 7 (Structures and Loads) of the Structures unit, Scientist in Residence Program: www.scientistinresidence.ca/pdf/physical-science/Structures/SRP_Structures_Lesson_7.pdf

Objectives

Students will be able to:

- Manipulate rods and connectors to build polygons
- Discover the (widely) varying strength of different shapes
- Reinforce shapes by dividing them into triangles with cross-bracing

Background Information

Buildings and bridges have a frame that keeps the structure rigid and supports its weight. In bridges this frame is often visible, but in buildings it is usually hidden behind the walls and roof. Strong rods (often steel or wood) are fastened together to build these frames, in shapes that are known to be sturdy. It is not immediately obvious what shapes might be the strongest until building and testing several different shapes. Ref. 1.

Vocabulary

Frame:	The skeletal framework of a structure that is sometimes covered with an outer skin.
Rod:	Long straight piece that make up a frame.
Fastener:	Device for connecting the ends of rods.
Regular polygon:	A chain of straight lines of equal length joined into a loop with equal internal angles, to form a regular shape such as a triangle, square, pentagon, hexagon etc.

Materials

- short plastic strips, eight per student pair: 2cm x 10cm with a hole at each end (see "Template for plastic strips" following this lesson)
- long plastic strips, five per student pair, 2cm x 22cm, with one hole at one end and a series of holes along the other half (see "Template for plastic strips" following this lesson)
- brads (split pins), eight per student pair
- baggies, one per student pair, to contain strips and brads
- Preparing the plastic strips: the plastic strips should be made from sturdy, flexible plastic sheets, such as a portfolio cover, plastic place mat, or thin plastic chopping board. They can be sliced with a paper cutter. Punch the holes with a small hole punch with a 3mm diameter (the holes of larger hole punches will allow too much wiggle in the shapes).
- Strips could also be made from thick paper, but they will not last as long.
- worksheet, one per student (see "Making sturdy shapes" worksheet following this lesson, ref. 2)

In the Classroom

Introductory Discussion

1. Show students an image of a local bridge with a visible frame, and ask if they have seen or been over this bridge, or one like it. Tell them that the frame is strong and keeps the bridge rigid, even with the force of all the cars and trucks driving over it.
2. Show students an image of a frame of a house, and ask if they have seen anything like this on a construction site in their neighborhood. Tell them that behind the walls and under the roof of every building there is a frame like this one that supports the weight of the building and everything in it.
3. Point out the steel/wooden beams that make up the frame of the bridge/house. Tell students that these beams are fastened together in shapes that are strong, which can distribute and balance the forces on the structures, so that they do not fall down.
4. Explain to the students that they will be building their own regular polygons, from rods and fasteners, and testing them for strength, to find out which shapes are the sturdiest.
5. Processes of science that the students will focus on: mechanical manipulation, counting, collecting data, recording results, classification, concluding.

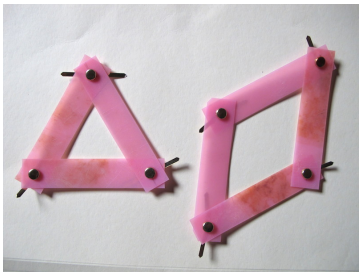
Science Activities

(1) Activity: Testing shapes for strength

Purpose of Activity: For students to test the strength of various simple polyhedral shapes

Methods and Instructions:
This activity is modified from ref. 3.
Students will work in pairs.
Set-up prior to experiment: assemble kits for each student pair - a baggie containing eight short plastic strips and eight brads

- While the class is still in one group, show the students the rods and fasteners that they will work with (the short plastic strips and the brads), and demonstrate how to fasten the plastic strips together to make the outside of a shape, with three or more sides. Then demonstrate how to test the strength of their shape by laying it on the table and gently pushing it from one side (see photos below).



- Ask the students to return to their desks. Distribute kits containing eight short plastic strips and eight brads to each student pair. Distribute one worksheet to each student.
- Students are instructed to make a triangle, a square, then any other simple polygons they like. The shapes should be a simple outline of a shape, with no cross bracing. (Students will be able to build up to an eight-sided octahedron with their kit.) Students should draw each shape in a box on their worksheet, name it if they can, and record the number of sides.
- After testing it for strength, they also record on their worksheet how strong and sturdy it is compared to their other shapes (for example using a star system). Polygons that hold their shape well (typically the triangle) are recorded as being the most sturdy (e.g. three stars). Polygons that easily distort and lose their shape (most of the other shapes) are recorded as being the least sturdy (e.g. one star).
- Students add the shapes they have built to a class chart, with names and number of sides, until all shapes built are listed for all to see.
- Students are asked, pair by pair, which shape they built was the most sturdy, and how sturdy the other shapes were. Record the sturdiness next to the appropriate shape on the class chart. (Some students' data may be different from others, as sometimes the brads are tight enough to restrict the movement of the plastic strips. However all results are valid, as they are what the students observed, and are added to the data. The outlier data points are not the majority so are not included in the discussion of class results.)
- Summarize the class chart: the triangle should be the shape that most often has three stars. Other shapes will vary in their rankings, but should usually rank below the triangle.
- Discuss why the triangle is the strongest shape: a triangle will hold its shape even when forces are applied to it from any direction. The shape of a triangle can only be changed by

changing the length of its sides, so if its sides stay rigid (do not buckle) the triangle is stable. A force on a triangle is spread around the shape, as compression (pushing forces) and tension (pulling forces), and these forces are balanced. In comparison, a force on a square or other shape with more sides can change the shape by collapsing the corners.

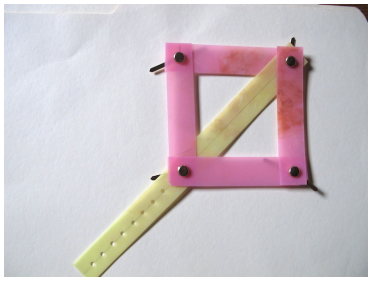
(2) Activity: Reinforcing shapes to make them strong

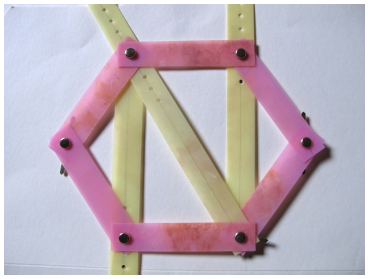
Purpose of Activity: For students to strengthen weak shapes by dividing them into triangles

Methods and Instructions:

Students work in the same pairs as the previous activity.

1. Ask students how they might make the weak shapes (from the previous activity) stronger. If prompting is needed, ask them which was the strongest shape (triangle), then how this shape might be made within the weak shapes.
2. Distribute five long plastic strips to each student pair at their desks.
3. Ask students to make their original shapes, then add cross braces to reinforce the weak shapes and make them strong. The photos below show some examples of the many possible outcomes.





4. Ask students to retest the reinforced shapes for strength, and look for the shapes (usually triangles) that have been made from the original, larger shape.

Closure Discussion

Students bring one of their reinforced shapes to a group discussion, and show the triangles that are within it. If there is any weakness in a shape still, ask students how this could be strengthened, and point out the additional triangles that are made.

Look again at the images of the bridge and building. Ask students to find the shapes within the frame, noticing that many or all of the shapes are triangles. Engineers have learned that triangles are strong shapes, so build them into any large structure to keep it rigid and strong.

References

- Caney, Steven. 2006. Steven Caney's Ultimate Building Book. p. 164 onwards. Running Press Kids.
- Lawson, Jennifer. 2001. Hands on Science: Materials and Structures. p.42. Portage and Main Press (Peguis Publishers).
- AIMS Education Foundation. 2012. Hardhatting in a Geo-World. p. 17. "Working out the Wiggles" in the Structures chapter.
- Ritchie, Scot. 2011. Look at That Building: A First Book of Structures. Kids Can Press