The Shape of Things

Objectives

- Students will read about eggs and dome construction, based on the shape of an egg.
- Students will conduct an experiment to demonstrate the strength of the egg.
- Students will conduct an experiment to demonstate how air passes through an eggshell.

Materials

- raw eggs
- markers
- rulers
- bowls
- small triangular file
- large, flat surface to place eggshells on for testing
- hardcover books
- magazines or lightweight books

Procedure

1. Hand out copies of the experiment page included with this lesson, "How Strong is an Eggshell?"
   —Read and discuss the information about the structure of an egg related to arch and dome construction.
   —Ask students to list examples of dome construction with which they are familiar (the old golden dome building on NW 23rd and the First Christian Church in Oklahoma City are two examples).
   —Demonstrate the experiment.
   —Divide the class into groups and provide the materials needed for the experiment.
   —Students will follow the instructions to complete the experiment.
   —Compare group results.
   —Students will calculate the average mass supported, per eggshell, for each group's set of eggshells.
   —Students will calculate the overall average mass supported, per eggshell, by calculating the average for the three sets of eggshells.
   —Students will calculate the standard deviation to see how much variability there was in the results.
   —Students will make bar graphs of their results.
2. Students will work in groups to plan and build arches or dome structures.
   —Students will journal their progress
   —Students will present their structures to the class and explain

Oklahoma Academic Standards

GRADE 6
Life Science: 1-1,2
Number & Operation: 1.3; 3.1,2,3,4; 4.4; Measurement: 3.1,2; Data & Probability: 1.1,2

GRADE 7
Motion & Stability: 2-4. Life Science: 1-4,5,8; 3-2; 4-6
Algebra: 2.1,2,3. Data & Probability: 1.1; 2.3

GRADE 8
Matter & Interactions: 1-3; Forces & Interactions: 2-1; Life Science: 1-7

the process they used.

3. Explain that eggshells have holes or pores to allow air to pass through the eggshell to the chick developing inside. Students will conduct the following experiment to demonstrate:
   —Add ink, methylene blue solution or food coloring to a container of ice water.
   —Immerse an unbroken egg at room temperature in the ice water.
   —Leave the egg in the solution for three minutes.
   —Remove the egg, and dry it gently with a paper towel.
   —Carefully crack the egg.
   —Observe the small dots of color on the inside of the shell.
   —Pour out the contents of the eggshell.
   —Examine the remaining eggshell. Larger and more numerous dots of color will appear at the large end, the air cell end. dots of color will also appear randomly throughout the other parts of the eggshell.
   —Examine the shell under a microscope.
   —Record your observations.

How Strong is an Eggshell?

The eggshell is a hard, three-layered container composed of **calcium carbonate**. Its purpose is to protect the enclosed **embryo** from the weight of the parent's body while the bird develops inside.

An eggshell is a natural example of an **arch**. One end of the shell has a larger, rounder arch, and the other end is narrower and more pointed. It is pretty easy to crack an eggshell if you tap it against a hard surface. But if you interlock your fingers and try to squeeze an egg lengthwise to break it, you will find that it can withstand more force than you might expect.

Arches have been used as important elements in structural engineering for thousands of years. For example, more 2,000 years ago Romans used the arch to give support for **aqueducts** and other large stone structures. The shape of the arch distributes the forces to the weight-bearing **piers** that support the arch, and this is similar for the arch of the eggshells as well. This in turn eliminates some tension stress in the structure. Overall, the arch's shape allows it to support a relatively large amount of **mass** being placed on top of it.

The extraordinary strength of the eggshell also inspired one of the most beautiful architectural forms in the world—dome construction. With dome construction, weight is distributed evenly around a central point, like the large end, or air cell end, of an egg. St. Peter's Basilica in Rome is one of the oldest and most famous examples of dome construction. Other famous domed buildings include the US Capital in Washington, DC, and the Palazzo dello Sport in Rome, Italy, designed for the 1960 Olympic Games.

Domes today are constructed with a variety of materials—steel, aluminum, reinforced concrete, glued laminated wood or plastic.

Vocabulary

arch— a usually curved part of a structure that is over an opening and serves as a support

aqueduct— an artificial channel for water; especially : one for carrying a large quantity of flowing water

calcium carbonate— a solid substance found in nature as limestone and marble and in plant ashes, bones, and shells and used especially in making lime and portland cement

compressive— the capacity of a material or structure to withstand loads tending to reduce size, as opposed to tensile strength, which withstands loads tending to elongate

dome— a large rounded roof or ceiling shaped like half of a ball

embryo— an animal in the early stages of development that are marked by cleavage, the laying down of the basic tissues, and the formation of primitive organs and organ systems

mass— the quantity of matter in a body

pier— an upright supporting part (as a pillar or buttress) of a building or structure

Work in groups to conduct the following experiment to test the strength of an eggshell.

MATERIALS
3 raw eggs
Pencils or markers
Ruler
Bowls
Small triangular file
large, flat surface to place eggshells on for testing
hardcover books
magazines or lightweight books

Oklahoma Ag in the Classroom is a program of the Oklahoma Cooperative Extension Service, the Oklahoma Department of Agriculture, Food and Forestry and the Oklahoma State Department of Education.

- Use a marker to mark a line all the way around one of the eggs, dividing the egg halfway between its two pointed ends. Use a ruler to determine the halfway point as you make the line. This line is where the eggshell will be cut. It should approximately be at the egg's widest point (width-wise, not length-wise).
- Carefully crack the eggshell at the pointy end. Make a small hole and drain the contents of the egg into a bowl. Rinse the empty eggshell with water. Be sure to thoroughly clean any surface the raw eggs touch (including the shells and your hands) with soap and water because they can carry salmonella.
- Use the triangular file to score the eggshell on your marked line, all the way around. Follow your marked line carefully, and be sure not to hold the empty egg so tightly that it cracks.
- Carefully break the eggshell back to the scored line you created. Slowly break off small pieces of the shell, one at a time, working your way around.
- Repeat this process two more times so that you have prepared a total of three eggshells. Each prepared eggshell should be the same height.
- Note that it is okay if the edges of the eggshells are a little jagged, but if any prepared eggshell half develops big chips or hairline cracks, you will want to start over with a fresh egg. There should be no cracks or big chips weakening your prepared eggshells.

- Place the three prepared eggshells on a flat surface, such as a dinner plate, with the open end facing down. Equally space them apart on the surface so that they form an equilateral triangle.
- Carefully lay a hardcover book on top of the three prepared eggshells. The book should be centered over the eggshells so that the mass will be distributed evenly among them.
- One at a time, carefully add magazines (centered on top of the book) to see how much mass the eggshells can support.
- Continue adding magazines until the eggshells crack and break.
- Use a kitchen scale to measure the combined weight of the book and magazines that the eggshells supported without breaking. Record the weight.

- Compare your group's results with those of the other groups in your class.
- Calculate the average mass supported, per eggshell, for each set of eggshells.
- Calculate the overall average mass supported, per eggshell, by calculating the average for the three sets of eggshells.
- Calculate the standard deviation to see how much variability there was in the results.
- Make a bar graph of your results. On the y-axis (the vertical axis), put the mass (in grams) that the eggshells supported per eggshell. On the x-axis (the horizontal axis), you can put either all three eggshell sets (as three separate bars) or the average of the three sets (as one bar). If you calculated the standard deviation, you include that on your graph as well.
- Overall, how much mass could each eggshell usually support? Did you see much variation between your three different eggshell sets?

Activity adapted from "Structural Science: How Strong are Eggshells?," Scientific American, http://www.scientificamerican.com/article/structural-science-how-strong-are-eggshells/

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