NATURE Sunday Academy Lesson

Title: Structures & Buckling

Description:

The purpose of this activity is to build a structurally sound tower with a favorable strength-to-weight ratio using only the materials provided and the criteria given. Students will have limited time to use the internet to research the various designs and come up with what they believe is the best one. One possible technique for building the tower would be to build each side (either 3 or 4) and then attach each side together.

Students could also take a ground up approach and build all of the sides of the tower at the same time. Students should discover what shapes are the strongest in the design of a physical structure. A contest to see who can build the tower with the highest strength-to-weight ratio will be conducted at the end of the activity.

Cultural Connection:

Objectives:

- Students will be able to construct 3D structures from 2D designs

Standards covered:

- Explain the components of a scientific investigation (e.g., hypothesis, observation, data collection, data interpretation, communication of results, replicable)
- Explain how models can be used to illustrate scientific principles
- Explain how scientific principles have been used to create common technologies (e.g., household appliances, automotive parts, agricultural equipment, textiles, fabrics, computers, Internet resources, CD-ROMs)
- Identify questions and concepts that guide scientific investigations
- Explain how scientific investigations can result in new ideas
- Standard 3: Students understand the basic concepts and principles of physical science.
- Explain how science advances through legitimate skepticism
- 12.6.1 Understand the role of technology in applying scientific knowledge to meet human needs and wants
- Models
- Interpret the effect of balanced and unbalanced forces on the motion of an object (e.g., convection currents, orbital motion, tides)
- 12.2.6 Identify and analyze alternative explanations to scientific problems 12.1.2
- Understand how scientists create and use models
- 12.2.7 Use knowledge and skills from other academic disciplines to solve problems in science
- Analyze data found in tables, charts, and graphs to formulate conclusions
- Identify the role of scientists in theoretical and applied science (e.g., careers, employment possibilities)
- Use data from scientific investigations to accept or reject a hypothesis
- Apply the law of conservation of energy to a variety of situations

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Session Organization:

11:00-11:15	Cultural connection
11:15-11:30	Background information
11:30-12:30	Activity 1
12:30-1:00	Lunch
1:00 - 2:00	Activity 1 (continued)
2:00 - 2:30	Activity 2
2:30 – 3:30	Test your towers!

Materials List:

- Markers
- Large sheets of paper (newspaper, bulletin board paper)
- Glue gun
- 10 - 1/4 x 1/4 inch balsa wood strips (per group)
- 1 - 1/8 inch balsa wood sheets (1/8” x 4” x 36”, per group)
- 8.5” x 11” printing paper
- 6” curved tweezers (optional)
- Kite string (optional)
- Rulers or meter stick
- Utility Knives (for students, if possible, otherwise one for the teacher)
- Newspaper (to glue on)
- Scrap wood (to cut on)

<u>Vocabulary – Definitions</u>

Buckling:	When a column fails by bending at some point in the height of the column, usually towards the midpoint caused by a vertical force.
Lateral Force:	A force that impacts a structure horizontally (i.e. wind and earthquakes).
Deflection :	The amount a structure bends or moves from its "at rest" position.
Civil Engineering:	The field of engineering pertaining to non-moving structures such as roads, sewers, towers, buildings, and bridges.
Strength-to-Weight Ratio:	This is the ratio of the amount of weight a structure can hold to the mass of the structure itself.

Activity 1:

Summary

Students will build their own towers using some of the techniques they have learned. The materials will consist of balsa wood and glue. General guidelines are provided, but the students will have a lot of freedom with their design to encourage them to implement what they have learned about structural engineering.

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Groups are only allowed to use 10 balsa sticks. The 1/8”x 36” balsa sheet should be divided amongst the groups. Each group will only need portion for their base and the apex of the tower. Instructors will decide the best method to use in order to divide equal amounts to each group.

Engineering Connection

Students are placed in the role of civil engineers for balsa wood towers in this activity.

Safety

Several safety Issues must be taken into account when building the towers. Also, students or teachers will be using utility knives which are very sharp. They should be warned to cut down, and away from other people and themselves. They must be supervised at all times. Glue from glue gun will be hot and touching it can cause burns. Students should be careful not to get any on their skin.

Note: If there is not enough supervision for students to use utility knives, 1/8 inch square balsa wood strips may be used. These can be cut with scissors.

Requirements

- The balsa ***sheet should not be used to gain height.*** It should be limited for use as the base, weight platform (apex), and to reinforce the rod structure (gussets).
- The tower is ***limited to a base 8 inch by 8 inch.***
- The minimum ***height requirement is 15 inches.***
- The maximum ***height of tower can be 48 inches.***
- The amount of glue sticks that can be used is ***limited to two (2).***

Procedure

1. Divide students into groups of 3-4.

2. Allow 15 minutes to research on the internet possible ideas for strongest structural designs.

3. What shape of tower are you going to use for your project?

4. Why did you elect to use this shape?

5. How high to you plan on building your structure? (*Make sure you have enough material in your kit to build your tower. You may have to decrease sacrifice dimensions in order to make sure the structural integrity of your tower is best.*)

6. Sketch your tower design on butcher paper. *It is important to realize there is a limited supply of balsa sticks, so make sure your design is well thought out.*

7. Get your supplies and don't forget about the safety techniques. (see Safety Issues)

8. Make sure to properly cut and glue two pieces of balsa wood together.

9. Begin to build the towers on your own.

10. If you finish early, you may decorate your towers.

11. When you look around, do other groups' projects look like they may last under stress better than yours? (*Which group's tower do you think will hold the most weight?*)

12. What is the height of your completed structure? Is it designed like the model you sketched in question 6. (*Put your answers in inches.*)

13. Test each tower to see how much it weighs, and how heavy a load it can handle. In order to test the load, place your tower into the test frame provided. Then, use masses to carefully place a load on top.

14. Calculate your score based on the following equation:

$$Score = \frac{Height\ of\ Tower^2 \times Critical\ Load}{Mass\ of\ Tower}$$

where height of tower is in inches, critical load is in pounds, and mass of tower is in ounces.

Construction Tips

Balsa sheet is easily cut using a scissors; rods are best cut when first scored and then broken. Students should wait until the hot glue is set and has become rigid before applying an additional member; this can be facilitated by blowing onto the hot glue.

Questions

1. Which shapes/structures seem to be the strongest while using the least material?

2. If you were going to tell someone how to build a strong and light tower, what would you tell them?

3. Using the equation $P_{cr} = \frac{\pi^2 IE}{L^2}$ or $\frac{P_{cr}L^2}{\pi^2 E} = I$, where $\frac{P_{cr}L^2}{\pi^2 E} = I$ (*NOTE: With the second equation, we are reducing the chance of error for I by utilizing all of the known variables.)*

   E is the modulus of elasticity of the material (balsa)

   $E_{Balsa} = 3.4GPa$ (*Pa=N/m*^{2})

   I is the minimum moment of inertia

   $I_{triangle} = \frac{1}{36}bh^3$

   $I_{rectangle} = \frac{1}{12}bh^3$

   L is the unsupported length of the column.

   Calculate the value of P_{cr} for your team and also put the values in for the other teams. *Use a calculator or the Buckling calculator in the link below.*

   http://www.engineersedge.com/calculators/ideal-pinned-column-buckling-calculator-1.htm

Team 1	
Team 2	
Team 3	
Team 4	
Team 5	
Average	

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Activity 2:

Materials

- 4 sheets of 8.5” x 11” copy or printing paper
- Glue gun
- Scissors
- Wood blocks or books to hold your structure
- Pennies (supplied by your teacher) for weights
- Other sources of weights (preferably of uniform size)
- An electronic weight scale

Procedure

1. Make two stacks of books of equal height.
2. Place them 6 inches apart.
3. Make a bridge by putting a sheet of paper across the books.
4. Put some pennies on the bridge. How many pennies can the bridge support before it falls down?
5. What happens if the pennies are in the center of the bridge or spread across the bridge?
6. How can you make the bridge stronger? Do it!
7. Test your bridge again by adding pennies one at a time. How many pennies can your bridge support?
8. How can you change the design of your bridge to support more pennies?
9. Now using all four sheets of paper, design a bridge that will hold more weight than any of the other groups.