+Physical Science

Activity 5

Designing and Constructing a Load-Bearing Structure

Overview

We rely on many structures to bear loads. Examples such as bridges, chairs, shelves, tall buildings, and even our own legs must support weight consistently and effectively. But where do the human-designed examples come from? Who designs these structures and how do they do it? In this activity, students get to apply science and mathematics as they get a hands-on and process-oriented experience of engineering, architecture, and design. First, they explore the properties of wire as a sculptural medium, and then they utilize some of that knowledge as they devise and build a load-bearing structure using nothing but 10 pipe cleaners.

Processes/Skills

- Observing
- Measuring
- Predicting
- Describing
- Inferring
- Experimenting
- Communicating
- Developing spatial reasoning
- Constructing
- Comparing
- Reflecting
- Recognizing shapes and patterns

- Problem solving
- Analyzing
- Creating
- Designing
- Inquiring
- Applying
- Cooperating

Recommended For

Grades 5–8: Small-group instruction
Adjust for grades 5 and 6 by considering the specific shapes of load-bearing structures in detail during Procedure 2. Examine the question, What sorts of designs are most likely to be successful and why?

Time Required

1–2 hours

Materials Required for Main Activity

- Various wiry materials: pipe cleaners (two different colors) and/or actual wire (copper wire, baling wire, galvanized wire, steel wire, thick wire, thin wire, etc.)
- Wire snippers (several pairs)
- Pliers (several pairs)
- Art books with photos of sculptures and/or actual pieces of sculpture
- Photos or illustrations of towers
- Lots of pipe cleaners (at least 15 per student group, of various colors if possible)
- Scissors
- Metric rulers
- Lots of pennies (or other small, standardized weights such as washers or fishing weights)
- Plastic cups
- Balances/scales

Connecting to the Standards

NSES

Grade 5–8 Content Standards:

Standard A: Science as Inquiry

- Abilities necessary to do scientific inquiry (especially thinking critically, using evidence, and applying mathematics)
- Understanding about scientific inquiry (especially emphasizing the value of evidence and mathematics)

Standard E: Science and Technology

- Abilities of technological design (especially identifying, implementing, and evaluating a design solution)
- Understanding about science and technology (especially that science and technology work together, and that technological designs have limitations)

NCTM

Standards for Grades 3–8:

- Geometry (especially identifying, naming, comparing, and applying three-dimensional shapes)
- Measurement (especially understanding and applying the metric system)
- Problem Solving (especially applying strategies to solve problems)
- Reasoning and Proof (especially engaging in thinking and reasoning)

Safety Considerations

Basic classroom safety practices apply. Be certain to instruct students in the proper and safe use of wire snippers, pliers, and scissors before conducting this activity (or simply presnip wire into suitable lengths). In Step 1, thin wire (20 gauge or less) is preferable from a safety standpoint because it is easier to work with and is less likely than thicker wire to have sharp ends when snipped.

Activity Objectives

In this activity, students

- design and construct their own load-bearing structures out of pipe cleaners; and

- identify and communicate successful and unsuccessful strategies, shapes, designs, and patterns related to the construction of load-bearing structures.

Main Activity, Step-by-Step Procedures

1. Begin the activity with an open exploration of wire as a medium for sculpting. Offer the students various wiry materials: pipe cleaners (of varied colors, if possible) and/or actual wire (of varied thickness, or gauge). If you do choose to include wire, you can find it in your hardware store in a wide variety of forms: copper wire, baling wire, galvanized wire, steel wire, thick wire, thin wire, and so on. If you use wire, you'll also need some pliers and snippers. Pipe cleaners can be cut with scissors. Thin wire is easier (and therefore safer) to bend, cut, and manipulate. Demonstrate to students that by twisting the wire together it can be formed into nearly any shape. Ask them to use their imaginations to decide what they would like to create. Show some photos of sculptures to stimulate their imaginations. You might ask all students to sit with their eyes closed, take a few calming breaths, and visualize their sculptures. Then let everyone get busy making a boat, a car, a building, an animal, a tree, or whatever they wish. Some might enjoy sculpting their interpretation of an abstract concept (such as "knowledge" or "peace") or a personal feeling. Compare and discuss the projects when completed. Ask students what they liked about sculpting with wire and how they feel about their creations.
2. Ask students, "Can you think of some structures that have to bear weight?" Possible answers might include the wooden frame of a house, a table, the human femur bone, a ladder, a column, the steel girders in a skyscraper, a tree trunk, and so on. Photos and/or illustrations would be helpful here. Students could even draw their own pictures of some of the structures. Generate and record as many responses as possible. Ask, "What characteristics do all these load-bearing structures have in common? How do they differ? What do you notice about their shapes? Are there any ways in which their shapes are similar or different? How does the structure of something that must bear a relatively heavy load differ from that of something that must only support a light load?"
3. Explain to the class that student groups will design and build their own load-bearing structures out of pipe cleaners. The challenge is this: Can each group design and build a structure that will hold a plastic cup containing 50 pennies (or other small weights,

totaling approximately 140 g) at least 10 cm off the table top, using nothing but 10 pipe cleaners? Explain that there will be a classwide competition for the structure that can hold the most pennies at least 10 cm off the table top. The following ground rules should be explained and discussed to make sure that the students understand:

- You may not use any materials other than the pipe cleaners, but you don't have to use all 10 if you don't need them.
- Your structure may not be attached to the table and may not touch or lean against anything but the table.
- The structure must support the cup of 50 pennies for at least 10 seconds, which the referee (the teacher) must time.
- You will have 30 minutes for trial-and-error "design time" and 45 minutes to construct the "official" structure. You'll get 5 "trial-and-error" and 10 "official" pipe cleaners. (It's a good idea to make sure that the two sets of pipe cleaners are different colors to eliminate accidental mixing of extra materials into the official structure.)

4. Each group should receive 5 practice pipe cleaners, a cup with a sealed bag containing pennies, a metric ruler, and a pair of scissors. Give students 30 minutes to plan their structure, encouraging each group to brainstorm together and consider a range of possible designs. An important part of this process will be to consider the geometric aspects of the design possibilities; for instance, what are the advantages of various shapes, including square, rectangle, triangle, or column? Remind students that in a brainstorming session the idea is to generate as many ideas as possible without judging them as good or bad. The final design is then chosen from that list of ideas. Suggest that they sketch potential structural plans on paper before actually building.

5. When the practice time is up, give each group the 10 official pipe cleaners and let them begin creating their final structure. Circulate among groups and offer encouragement, but only offer design suggestions to alleviate especially high frustration levels. Don't offer too much help; this exercise allows students to develop their own means of problem solving, and too much teacher assistance will diminish that process. Test each group's structure for its 50-penny-supporting capability as requested. Be sure that each group has a structure to enter in the classwide competition.

STANDARDS

SCIENCE
Abilities necessary to do scientific inquiry
Abilities of technological design

MATH
Geometry
Measurement
Problem solving
Reasoning and proof

SCIENCE
Understanding about scientific inquiry
Understanding about science and technology

6. When the 45-minute time period is up, ask all groups to stop work and to gather around for the competition. Take one structure at a time and test for its ability to support the cup of pennies. Keep adding pennies (in increments of 10) until only one structure remains. How many pennies could it hold before it collapsed? Weigh the pennies to find out how many grams they represent. Engage the class in a discussion of successful and unsuccessful shapes, designs, and patterns. Explore the conclusions that can be drawn about the effective design of load-bearing structures.
7. If time and student interest permit, allow groups to confer as you rechallenge them for a second try at building a strong load-bearing structure. Often the second time around, using the same rules, procedures, and materials, is when many students really "get it."

Discussion Questions

Ask students the following:

1. Why do load-bearing structures need to be designed carefully?
2. How is mathematics important in designing/engineering load-bearing structures? For instance, what patterns or shapes were useful and how did you identify them?
3. Which load-bearing designs are also aesthetically/artistically pleasing? That is, is art important in designing/engineering load-bearing structures? Why? Under what circumstances would the aesthetic appearance of such a structure become important?
4. What else would you like to know about load-bearing structures? How could you find answers to your questions?

Assessment

Suggestions for specific ways to assess student understanding are provided in parentheses.

1. Were student groups able to successfully design and construct their own load-bearing structures out of pipe cleaners? (Use observations made during Procedures 3–6 as performance assessments.)
2. Could students identify and communicate about successful and unsuccessful strategies, shapes, designs, and patterns related to construction of load-bearing structures? That is, were they able to draw effective conclusions about designing load-bearing structures? (Use

student responses to Discussion Questions 1–4 as embedded assessments or as writing prompts for science journal entries.)

RUBRIC 5.1
Sample rubric using these assessment options

	Achievement Level		
	Developing 1	Proficient 2	Exemplary 3
Were student groups able to successfully design and construct their own load-bearing structures out of pipe cleaners?	Unsuccessfully attempted to design and construct a load-bearing structure	Successfully designed and constructed a load-bearing structure	Took a leadership role in the successful design of their team's structure
Were students able to draw effective conclusions about designing load-bearing structures?	Attempted to draw significant conclusions about structural design, but were unable to do so	Drew several significant conclusions about the design of their own structure	Clearly explained and discussed several significant conclusions about their own and others' structural designs

Other Options and Extensions

1. Try different but related challenges: Have students build a structure that elevates the load only to a 5 cm height and determine how the maximum weight supported compares with that of the 10 cm version. Then students should build a structure that elevates the load to a 15 cm height and do the same comparison. Instruct students to graph "height" versus "maximum weight supported" and look for a relationship between these two variables.
2. Homework: Ask students to make a list of load-supporting structures found in their home, neighborhood, and community.
3. Explore ways to make more wire sculptures. Students should consider making wire mobiles and/or creating sculptures that go along with a favorite book or story. Also encourage students to try making geometric/arithmetic sculptures (e.g., all triangles, or using squares of increasing sizes).

Resources

Adams, B. 2006. London Bridge is falling down. *Science and Children* 43 (8): 49–51.

Anderson, J. 1972. Aestheometry…Constructions in space mathematics. *Science and Children* 10 (1): 31–32.

Junior Engineering Technical Society. 1989. Engineering science in the classroom. *Science and Children* 26 (8): 20–23.

Kajander, A. E. 1999. Creating opportunities for children to think mathematically. *Teaching Children Mathematics* 5: 480–486.

Martin, S., J. Sharp, and L. Zachary. 2004. Thinking engineering. *Science and Children* 41 (4): 18–23.

Pace, G., and C. Larsen. On design technology. *Science and Children* 29 (5): 12–15, 16.

Scarnati, J. 1996. There go the Legos. *Science and Children* 33 (7): 28–30.

Toll, D., and S. Stump. 2007. Characteristics of shapes. *Teaching Children Mathematics* 13 (9): 472–473.