Chapter 3

ACTIVITIES

The activities in this chapter are designed to give students direct experience with designing and evaluating different kinds of packaging and structures. The activities were created and tested by classroom teachers. Many of their experiences with these or similar activities are described in Chapter 4, "Stories."

Activities 1-7 deal with kinds of packaging materials and dispensing devices. Activities 8-13 deal with building and testing the strength of cardboard structures. The activities are designed to give students experience with many of the concepts discussed in Chapter 2, "Concepts."

All of the activities are correlated to standards in Science, Math, and English Language Arts. The standards are listed by number with each activity; the standards themselves are listed at the end of the chapter.

ACTIVITIES AT A GLANCE

Level	Activity Title	Page	What Students Learn About Packaging & Other Structures		
			Categorizing	Analyzing/Testing	Design/Redesign
Introductory	Exploring and Categorizing Packages	44	×		
	Classifying Bags	48	×		
	Packing a Bag	51		×	×
	It Fits Just Right	53			×
Intermediate	How Strong Is This Bag?	54		×	×
	How Do You Package a Fragile Object?	57		×	
	Which Pump Dispenser Works Best?	60		×	
Advanced	How Does the Shape of a Column Affect Its Strength?	66		×	
	How Does the Shape of a Shelf Affect Its Strength?	73		×	×
	How Does the Type of Cardboard Affect the Strength of a Shelf?	76		×	×
	How Does the Direction of the Corrugations Affect Its Strength of a Shelf?	78		×	×
	How Does the Type of Glue Affect the Strength of a Laminated Shelf?	81		×	×
	How Does the Support Method Affect the Strength of a Shelving Unit?	83		×	×

Activity No 1

Exploring and Categorizing Packages

Grade Level
K-6

Prerequisites
Understanding the concepts of categories and sorting

Overview
This is an early childhood activity that involves children in exploring and categorizing some of the many different kinds of packages they see in their daily lives.

Concepts
- Packaging comes in a wide variety of forms, sizes, shapes, materials, and functions
- Examples of packaging can be sorted into groups according to a variety of criteria

Vocabulary
- Handle
- Packaging
- Plastic
- Paper

Skills
- Observing, comparing, and contrasting differences in materials
- Classifying objects according to shape, function, composition, and other criteria
- Counting and measuring using manipulatives
- Listening attentively and speaking using appropriate vocabulary

Standards
- Benchmarks for Science Literacy: 1B
- Standards for the English Language Arts: 12
- National Science Education Standards: A
- Principles and Standards for School Mathematics: A1

Time Needed
Three or four periods

Materials
- Large assortment of clean, empty packaging materials such as boxes, cartons, plastic containers, paper and plastic bags, plastic bottles, and jugs
- Worksheet #1A (K-2) or #1B (3-6)

Pre-Activity Preparation
- Ask friends, family, and colleagues to help you collect examples of packaging. Place the items in an area of the classroom where students can see them. When students ask you about the collection, encourage them to speculate about what the items are and what they have in common.
- Always review safety issues regarding plastic bags and any other objects you think could pose a risk if mishandled.

Procedure, Grades K-2
1. Have a brainstorming session with the whole class about packaging. Record students' responses on an experience chart. Begin by asking such questions as:
   - "What do you think the word packaging means?"
   - "Can you name some examples of packaging?"
2. To review and reinforce students' understanding of sorting and creating categories, play "Guess My Rule." Gather a collection of various items, such as toys, counters, blocks, pencils, crayons, and so on. Sort them into groups (e.g., according to

color, use, material) and ask students to guess the "rule" for creating the groups. In other words, "What do the items in each group have in common?" To reinforce the concept, keep the categories simple and let the students add other items to the groups that match the criteria. Discuss the different ways objects can be sorted into groups.

3. Divide the class into groups of four and give each group several packaging items. Each group should have items that can be grouped together based on a variety of criteria—e.g., type of material (paper, plastic), kind of container (box, bag, bottle, jar), product contained in the package (food, cleaning supplies), and so on. Give the groups time to examine the items carefully and talk about what they see.
4. Ask the groups to organize their packaging materials into piles, according to the kinds of materials they are. Ask the groups to explain what's in each pile and why they're grouped together.
5. Distribute copies of Worksheet #1A to students. Ask them to draw one item from each grouping to identify the group. They then tally the number of examples of packaging items they put into that category. Work with younger students as necessary to help them record their findings.

Adaptation for Grades 3-6

1. As homework, ask students to bring examples of packaging materials from home.
2. With the whole class, discussing the meaning of "packaging" and list examples.
3. Divide students into cooperative learning groups and have them sort a collection of packaging items into categories. Encourage them to identify items that could belong to more than one category—e.g., a plastic juice container can be classified as "plastic," "bottle," and "beverage container."
4. Distribute Worksheet #1B. When students have completed the worksheet, bring the class together to share and discuss students' work.
5. As a follow-up homework assignment, ask students to find 10 examples of packaging at home or elsewhere, draw each one, and describe each package and what it is used for.

Worksheet #1A (Grades K-2)

Exploring and Classifying Packages

Name/Group ____________________ Date ____________

Show your groups and how many are in each group.

Worksheet #1B (Grades 3-6)

Exploring and Classifying Packages

Name/Group ______________________ Date ____________

What is packaging? ______________________

List some different types of packaging things you know. ______________________

List the categories into which the packaging items in your collection can be sorted. Under each category, describe the items that belong in that category. ______________________

Activity No 2

Classifying Bags

Grade Level
2-4

Prerequisites
- Basic knowledge of categorizing principles
- Knowledge of using charts and graphs to display data

Overview
This activity builds on Activity #1: "Exploring and Categorizing Packages." Students classify a collection of bags, and make a chart or graph showing the number in each category.

Concepts
- Items can be grouped or classified based on characteristics they have in common.
- Data from an investigation can be displayed graphically using charts and graphs.

Vocabulary
- Category
- Classify

Skills
- Classifying objects based on material, function, size, shape, and/or other criteria
- Collecting, organizing, and presenting data in chart or graph form
- Using spoken and written language
- Problem-solving

Standards
- Benchmarks for Science Literacy: 1A, 1B, 2A, 9A
- Standards for the English Language Arts: 12
- National Science Education Standards: A
- Principles and Standards for School Mathematics: A1

Time Needed
Two to four periods

Materials
- Variety of paper and plastic bags of different colors, shapes, and sizes (e.g., paper grocery bags, other small and large paper bags, plastic grocery bags,other small and large plastic bags, assorted shopping bags, etc.)—at least 12 for each group of four students
- Chart paper
- Pencils, crayons,
- Rulers
- Worksheet #2 (at least one for each group of four students)

Procedure

1. If necessary, play the following game to review the meaning of "category" and "classify." Call a number of students to the front of the classroom who happen to be wearing the same color clothing. Ask the class what the members of this group have in common: "What's my rule for choosing these students? What is the category they all belong to?" As necessary, repeat the game using objects that have the same color, size, shape, purpose, etc.
2. Show students several types of bags and ask them to come up with ways of classifying or categorizing them. Record their answers and explanations on chart paper.
3. Divide the students into groups of four. Provide each group with at least a dozen bags and a worksheet.
4. Explain that each group should examine its bags, discuss what the bags have in common and how they are different from one another. Then they should place the bags into groups based on specific criteria.
5. The groups record their work on Worksheet #2 by listing and describing the categories, and then creating a chart to show the number of bags they placed in each category.

Tips

- Encourage students to look at the different ways the handles are made and attached to the bags.
- As an alternative or extension, have students classify groups of other packaging items such as boxes and bottles.

Worksheet #2

Classifying Bags

Name/Group ______________________________ Date ______________

How many bags do you have? ______________________________

____

How many groups or categories of bags did you make? ______________________________

____

____

____

Write a name for each category. ______________________________

____

____

____

____

Make a chart or graph showing how many bags there are in each category.

Activity No 3

Packing a Bag

Grade Level
Pre K-2

Prerequisites
Understanding of the concept of fair testing—using the same testing conditions for each test

Overview
This early childhood activity engages children in finding out how many blocks different types of bags can hold. They will also see the effect of the packing method on the survival of the bags. Because this activity will result in a lot of broken bags, it is a natural lead-in to bag repair activities.

Concepts
- Fair testing—a method of comparing things by testing them all in the same way.
- Design/shape, material, conditions of use, and other variables affect the strength and durability of a bag.

Vocabulary
- Fair testing
- Equal
- Same
- Different

Skills
- Measuring
- Classifying
- Problem-solving
- Drawing conclusions and making inferences based on data
- Using written and spoken language

Standards
- Benchmarks for Science Literacy: 1A. 1B, 2C
- Standards for the English Language Arts: 12
- National Science Education Standards: A
- Principles and Standards for School Mathematics: M1, DA & P3

Time Needed
Two 45-minute periods

Materials
- Two identical bags (paper or plastic) to use for fair testing demonstration
- Blocks, about 15 each of several different sizes
- Chart paper
- Sets of three or four plastic and paper bags of different sizes and styles—one set for each small group of students

Procedure: Day 1
1. Prepare ahead of time to demonstrate the concept of fair testing. Determine the number of identical blocks it takes to cause a particular paper or plastic bag to break. Use two bags of that kind, the blocks you used to cause the bag to break, and an equal number of smaller/lighter blocks for the following demonstration.
2. Label one of the identical bags A and the other B. Ask students to count with you as you place the large blocks in Bag A, one at a time. After each block, lift the bag to show that it is able to carry the weight

Keep adding blocks until the bag breaks. Write the number of blocks it took to break the bag on the front of Bag A. Then have students count with you as you add the same number of the smaller blocks to Bag B, one at a time. As before, lift the bag after each block. After you add the last block to Bag B and before you lift it, ask students, "What do you think will happen when I lift the bag?" Record their answers on chart paper. When you lift Bag B after the last block to show that the bag does not break, ask questions to encourage students to think about what happened. Record their answers on chart paper.

- "How many blocks did I put in Bag A?"
- "What happened to Bag A when I put the last block in?"
- "How many blocks did I put in Bag B?"
- "What happened to Bag B when I put the last block in?"
- "If I put the same number of blocks in both bags, why didn't Bag B break?"
- "What's the difference between Bag A and Bag B?"
- "What's the difference between the blocks I put in Bag A and the blocks I put in Bag B?"
- "If I wanted to test to see if one of these bags is stronger than the other one, what should I do differently next time?"

Record all of the students' answers to the last question.

3. Show students several bags of different sizes and/or materials. Label each bag (e.g., A, B, C, D). Ask students, "Which bag do you think will hold more blocks without breaking?" Record students' predictions and reasons on chart paper. Tally the number of students who choose each bag as the strongest.

Procedure: Day 2

1. Use your chart paper notes to review the previous day's work with students.
2. Divide students into small groups. Give each group a set of the bags you discussed and labeled on Day 1. Label the bags A, B, C, etc., as you did on Day 1.
3. Tell students their job is to test each bag to see which one holds the most blocks without breaking. Remind them that they need to use the same kinds of blocks for each bag. When a bag breaks, students count the number of blocks it took to break the bag and they write that number on the bag. (Help younger students with the counting and recording, as necessary.)
4. When a bag breaks, ask students to examine it carefully to find out what part(s) of the bag broke. Ask them to talk about why that part might have broken first.
5. Give groups time to experiment with different ways of placing the blocks in the bag or with different bags. Record the results of each experiment.
6. Follow-up with a discussion about what students discovered. Start with questions like these:
   - "What did we do to figure out which bag holds the most blocks without breaking?"
   - "Why did we have to use the same kinds of blocks for each bag we tested?"
   - "What made the bags break?"
   - "Does it matter how we put the blocks in the bag? Is there a way to put the blocks in so that the bag holds more blocks?"
   - "Can you think of ways to make these bags stronger?"

Tips

- Circulate among the groups as they work so you can ask questions and hear discussions that reveal what students do and don't understand.
- Encourage students to describe and discuss their processes and ideas at every step.
- Older students might graph the results of their bag tests.

Activity No 4

It Fits Just Right!

Grade Level
Pre K-2

Prerequisites
- Knowledge and understanding of the purposes of packaging
- Ability to use problem-solving strategies

Overview
Students try to create an object that is just the right size and shape to fit in an odd-shaped package.

Concepts
- There is a relationship between the size and shape of a container and the size and shape of its contents.
- Packages can be made to fit items of a particular size and shape.

Vocabulary
- Package
- Shape
- Fit

Skills
- Applying spatial awareness to problem-solving
- Observing and comparing the physical properties of objects
- Using spoken language

Standards
- Benchmarks for Science Literacy: 1A, 1B
- Standards for the English Language Arts: 12
- Principles and Standards for School Mathematics: G1, G4

Timed Needed
One period

Materials
- Variety of containers with non-standard shapes, such as "Baci" and "Toblerone" candy boxes, "L'Eggs" pantyhose containers, partition trays for TV dinners, cookie cartons with dividers to fit the shape of the cookies, and so on
- Clay or plasticene
- Chart paper and markers

Procedure
1. Begin a discussion with the whole class by asking students if they have ever had trouble getting a book to fit in a backpack. Brainstorm examples of things that are too small, too big, or the wrong shape to fit in a package. Record students' answers and ideas on chart paper.
2. Show students some of the odd-shaped packaging materials you've collected. Ask them to imagine what kinds of objects would fit in those packages and what wouldn't fit. Ask them to explain how they can tell whether an object would fit or not.
3. Divide students into small groups. Give each group one of the packages and a lump of clay or plasticene. Ask students to make an object that they think will fit in the box or packaging partition.
4. When each group has a shape they think will fit, let them try it. If it doesn't fit, ask them to try to explain why and describe what they have to do to make it fit. Repeat this for each trial.
5. When each group has an object that fits in the packaging, have them share their processes with the other groups.

Activity No 5

How Strong Is This Bag?

Grade Level
3-6

Prerequisite
Knowledge of "fair test" principles

Overview
This is an upper-elementary-grade version of Activity #3, "Packing a Bag." Students use weights to test the strength of different types of bags. As an extension activity, students can redesign the bags to make them stronger.

Vocabulary
- Fair test
- Prediction
- Factor
- Condition

Concepts
- The strength of a bag is determined by a combination of factors, including design, materials used, and construction method.
- A "fair test" requires controlling variables so that test results can be compared.

Skills
- Collecting, organizing, and presenting data
- Making and testing predictions
- Designing and conducting an experiment, including controlling variables and analyzing results
- Measuring
- Communicating using written and spoken language

Standards
- Benchmarks for Science Literacy: 1A, 1B, 2A, 9A
- Standards for the English Language Arts: 12
- National Science Education Standards: A, B
- Principles and Standards for School Mathematics: DA & P1, DA & P3, C3, M1

Time Needed
Four to six periods

Materials
- Chart paper
- Construction paper
- Pencils and markers
- Plastic and paper bags (4 different kinds of bags for each small group of students)
- Rulers, tape measures
- Bathroom scale
- Heavy books, blocks, other objects that can be used as weights
- Worksheet #5

Procedure
1. Begin a brainstorming session with the whole class by asking questions like these:
   - Have you ever had a bag break on the way home from the store?
   - What part of the bag broke
   - Why do you think it broke?
   - What do you think could be done to prevent bags from breaking like that?"

   Encourage speculation and discussion, and record students' responses on chart paper.

2. Choose two shopping bags that are about the same size but are different in other ways—shape, material, construction. Ask students which bag would hold more weight. Encourage students to explain their reasons for thinking one bag or the other would hold more. Tell students they are going to become bag testers.
3. Review the concept of fair testing—using exactly the same conditions for every bag tested.
4. Divide the students into small groups. Provide each group with four different bags labeled A, B, C, and D. Give each group member a copy of Worksheet #5.
5. Review the worksheet and explain the assignment to students: They are to work together in teams to design a fair test that will determine which of their four bags is the strongest. Each team will:
   - examine and describe each bag;
   - predict which bag will be strongest and explain their reasons;
   - design a test that will show the relative strength of the bags;
   - carry out the test;
   - record and analyze the results;
   - organize the data in a graph or chart;
   - present the test results to the class.
6. After each group presents its test results to the class, allow time to discuss the design, the results, and possible reasons for the results. Questions like these will help get the discussion started:
   - Was this a fair test?
   - If not, how could it be changed to make it a fair test?
   - What factors make a bag weak or strong?

Extensions

- Challenge students to design tests that allow them to compare bag strength under various conditions—e.g., when the bags are wet, placing different kinds of items in the bags, using different packing techniques, and so on.
- Ask each group to examine carefully the way in which each bag failed, and to redesign their bags to make them stronger.

Tip

To read about one teacher's experience with this activity, see Chapter 4 ("Stories"), page 111.

Worksheet #5

How Strong Is This Bag?

Name/Group ______________________________ Date ______________

Bag Descriptions

Describe the four bags that you will test. Measure them and write down the measurements. Describe their shapes, what they're made of, how they're made, and anything else you notice.

Bag #1 ______________________________

____

____

Bag #2 ______________________________

____

____

Bag #3 ______________________________

____

____

Bag #4 ______________________________

____

____

Prediction

Which bag do you think is the strongest? ____ A ____ B ____ C ____ D

Why do you think that one is the strongest? ______________________________

____

Test

Describe the test you will use to find out which bag is the strongest ______________________________

____

Test Results

Based on your test, which bag is the strongest? ______________________________

____

Activity No 6

How Do You Package a Fragile Object?

Grade Level
4-6

Prerequisites
- Understanding of packaging materials
- Understanding of categorizing
- Understanding of fair test principles

Overview
Students test different kinds of cushioning materials and different ways of arranging them in order to protect the fragile contents of a package.

Concepts
- Packaging is designed to meet different needs and solve different problems.
- Comparing and evaluating several solutions to the same problem requires the use of the principles of fair testing.
- The composition and arrangement of different materials affect their ability to protect fragile objects in packages.

Vocabulary
- Fair test
- Fragile
- Cushioning

Skills
- Analyzing and solving problems
- Reasoning
- Using written and spoken language
- Collecting, organizing, and interpreting data
- Using charts and graphs to present data

Standards
- Benchmarks for Science Literacy: 1B, 3B, 8B
- National Science Education Standards: A, E
- Standards for the English Language Arts: 12
- Principles and Standards for School Mathematics: DA & P1, DA & P3, C3, M1,

Time Needed
Four to six periods

Materials
- Variety of cushioning materials such as foam rubber, Styrofoam sheets and "peanuts," newspaper, bubble wrap, cloth, towels, cotton
- Fragile objects such as chalk, thin bread sticks, cookies
- Variety of unbreakable packaging containers (small boxes, milk containers, padded envelopes)
- Measuring tape
- Tape
- Paper
- Pencils and markers
- Worksheet #6

Procedure
1. Place some fragile objects—cookies, breadsticks, pieces of chalk—in a small, clear plastic bag and seal the bag. Ask students what they think will happen to the contents if you drop the bag. Once students have offered their ideas, drop the bag on a hard surface from a height of at least three feet. Show the package to the students again so they can see that the contents are broken.

2. Ask students to brainstorm ways the same items could be packaged so they wouldn't break when the package was dropped. Record their responses on chart paper.
3. Divide students into small groups. Explain that their job is to test different ways of packaging fragile objects in order to determine which method does the best job of protecting the objects when the package is dropped.
4. Review the rules of fair testing. Remind students that each test must be conducted under the same conditions—in this case, each package must contain the same type of fragile object and must be dropped from the same height.
5. Provide all groups with at least three different packaging containers, several different kinds of cushioning materials, fragile items (e.g., cookies, breadsticks, pieces of chalk), and a copy of Worksheet #6. Go over the worksheet with the class to make sure everyone understands what to do. Help groups figure out how to make sure they drop all packages from the same height—e.g., pushing each package gently off a table or a shelf.
6. Allow two or three class periods for groups to set up, conduct, and record the results of their tests. Observe the groups as they work and help them record each test accurately and completely—kind of container, kind and amount of cushioning material, condition of the fragile item after each test.
7. All presentations should be visual, including demonstrations and references to charts and/or graphs.

Tips

For one teacher's experience with this activity, see Chapter 4, "Stories," page 108. An egg is often used in this kind of activity, but cookies, breadsticks, or chalk are less messy and also less wasteful, since broken cookies and breadsticks can still be eaten, and broken chalk can still be used.

Worksheet #6

Testing Fragile Objects

Name/Group ______________________________ Date ______________

Packaging Used	Height	Type of Material (cushion)	Condition of Fragile Object

Activity №7

Which Pump Dispenser Works Best?

Grade Level
5–6

Prerequisites
- Understanding of "fair testing" principles
- Knowledge of experimental design, including isolating variables

Overview
This is a product testing activity, in which students formulate their own criteria for the "best" pump. Then they conduct systematic tests to find out how well a variety of pumps meet the criteria. They also try the pumps on different liquids, to see whether the best pump for a fluid like water is also most effective with a viscous fluid such as ketchup.

Concepts
- Different kinds of fluids have different viscosities
- Variables that can affect the functioning of a pump or spray dispenser include the viscosity of the liquid and the design of the device

Vocabulary
- Viscosity
- Pump
- Dispenser
- Stroke

Skills
- Using problem-solving strategies to design an experiment
- Measuring
- Creating and collecting data
- Analyzing data and drawing conclusions from evidence
- Representing data on charts or graphs

Standards
- Benchmarks for Science Literacy: 1A, 1B, 9A
- Standards for the English Language Arts: 12
- National Science Education Standards: A
- Principles and Standards for School Mathematics: DA & P1, DA & P3, C3, M1,

Time Needed
10 to 14 periods

Materials
- Pump and spray dispensers from the tops of containers for water, soap, lotion, mustard, ketchup, liquid cleaners, and so on—one push pump and one spray dispenser for each small group of students
- Liquids of different viscosities, such as water, milk, liquid detergent, ketchup, mustard
- Basins or buckets
- Plastic cups
- Newspaper, paper towels
- Construction paper
- Colored pencils, markers
- Meter sticks or yardsticks
- Measuring cups or graduated cylinders
- Rulers
- Chart paper
- Worksheets #7A, #7B, #7C

Procedure
1. Divide the students into groups. Give each group two pumps—one spray pump used for water or other thin liquids and one pump used for thick liquids such as liquid hand soap or dishwashing detergent, mustard, or ketchup; a ruler;

paper; and colored pencils. Ask students to examine the pumps and liquids carefully, draw the pumps, and write down their observations, focusing on these questions:

- How is the spray pump different from the push pump?
- How does each pump work?
- What is each pump used for?
- How is water different from liquid detergent, mustard, or ketchup?

2. Bring the groups together and have students share their observations with the whole class. Continue with a brainstorming session about the question, "How could we figure out which kind of pump works best for different kinds of liquids—water, milk, liquid detergent, ketchup?" Help students come up with several testing strategies—e.g., measuring how much liquid comes out with each pump; counting the number of times the pump has to be pressed or squeezed (i.e., the number of strokes) in order to remove a certain amount of liquid from a container; and so on. Record all of the students' ideas on chart paper.
3. Distribute copies of Worksheets #7A, 7B, and 7C to all students. Explain that students will work in their groups to test the pumps to determine which pump works best for different kinds of liquids. In their groups, students discuss methods for testing the pumps for different liquids. Each group should agree on a method for testing the two kinds of pumps with different kinds of liquids. Have each student complete Worksheet #7A.
4. Give each group three or four liquids to test with the two kinds of pumps. (See Tips, below.) Have an assortment of plastic measuring cups, graduated cylinders, and measuring spoons available. Allow one or more class periods for students to design, carry out, and document their tests, and analyze their data.
5. Each group prepares their test results to present to the class in the form of a chart or graph. Set aside class time for group presentations.
6. Follow-up student presentations with a discussion of the findings, using questions like these to get the discussion going:
   - Does the size of the tube affect the way a pump works for a particular kind of liquid?
   - Would making the tube bigger make it work better for thick liquids?
   - What are some other ways packages are designed to help you get the contents out of the container?

Tips

- Students need to test several different kinds of liquids with each pump. Try to provide each group with two relatively thin liquids, such as water and milk, and two relatively thicker liquids, such as liquid detergent and ketchup.
- Avoid using lotions and oils for this activity, since they make the pumps difficult to clean and reuse.
- This is a messy activity. Cover students' workspaces with newspaper, and have plenty of paper towels and sponges available for cleanup.

Worksheet #7A

Pump Test Predictions and Procedures

Name/Group ______________________ Date ____________

Problem:

What are you trying to find out? ______________________

____

____

Hypothesis:

List the liquids you will test. Then predict which kind of pump (spray or push) will work best for each liquid.

Liquid: ______________________

Prediction: ______________________

Liquid: ______________________

Prediction: ______________________

Liquid: ______________________

Prediction: ______________________

Liquid: ______________________

Prediction: ______________________

Procedure:

How will you test the pumps? What steps will you follow? ______________________

____

____

____

Worksheet #7B

Pump Test Data

Name/Group Date

Create a chart or data table to record the data you collected.

Worksheet #7C

Pump Test Findings and Analysis

Name/Group _______________________________ Date _______________

List each liquid you tested and the pump that worked best for each one.

Liquid: _______________________________

Pump that worked best for this liquid: _______________________________

Why do you think this pump worked better for this liquid? _______________________________

Liquid: _______________________________

Pump that worked best for this liquid: _______________________________

Why do you think this pump worked better for this liquid? _______________________________

Liquid: _______________________________

Pump that worked best for this liquid: _______________________________

Why do you think this pump worked better for this liquid? _______________________________

Liquid: _______________________________

Pump that worked best for this liquid: _______________________________

Why do you think this pump worked better for this liquid? _______________________________

What else did you learn from doing this experiment? _______________________________

____

____

____

Part Two

Cardboard Structures

Overview

This unit consists of six activities that look systematically at some of the variables involved in constructing cardboard structures. Each activity examines a different variable through a controlled experiment. The variables are:

- the shape of a shelf or beam;
- the type of cardboard used;
- the orientation of the cardboard "ribs";
- the type of glue used to laminate sheets of cardboard together; and
- the method used to support the shelves or beams.

In addition, the first activity also teaches the principles of a controlled experiment or "fair test."

Some of the variables studied in this unit could be very important in the design of a usable classroom shelving unit, display stand, chair, or table. Each activity could also be the basis for a science fair project.

Prerequisites

- Knowledge of the principles of a "fair test"
- Experience in measuring weight and length
- Knowledge of geometric shapes

Vocabulary

- Structure
- Force
- Load
- Stability
- Tension
- Compression
- Beam
- Column
- Balance
- Center-of-mass
- Lamination
- Support

Concepts

- The strength and point at which a structure fails depend on variables including the shape of beams and columns, type and use of materials, construction methods
- Different parts of a structure are subject to different forces

Skills

- Identifying variables
- Collecting and organizing data
- Using problem-solving strategies in mathematics and language arts
- Measuring
- Drawing conclusions
- Presenting results in written and spoken language

Standards

- Benchmarks for Science Literacy: 1A, 1B, 3B, 8B, 12A
- National Science Education Standards: A, B, E
- Standards for the English Language Arts: 12
- Principles and Standards for School Mathematics: DA & P1, DA & P3, C3, M1, G1

Grade Level

5-6

Time Needed

3 to 5 periods for each activity

Activity Sequence:

#8: How Does the Shape of a Column Affect Its Strength?

#9: How Does the Shape of a Shelf Affect Its Strength?

#10: How Does the Type of Cardboard Affect the Strength of a Shelf?

#11: How Does the Direction of the Corrugations Affect the Strength of a shelf?

#12: How Does the Type of Glue Affect the Strength of a Laminated Shelf?

#13: How Does the Support Method Affect the Strength of a Shelving Unit?

Activity No 8

How Does the Shape of a Column Affect Its Strength?

Overview

In this activity, students investigate the relative strength of columns of different shapes and discover the importance of controlling variables in a test or experiment.

Materials

- Paper of assorted sizes and shapes (for preliminary construction)
- Shape templates (pages 69-72)
- Tape or glue
- Weights for load testing (tiles, washers, or marbles)
- Bucket or coffee can
- Square pieces of cardboard large enough to support a can or bucket
- Worksheet #8

Procedure

1. A column is a vertical piece whose purpose is to support parts of a structure, such as a building, a platform, or a bookshelf. The legs of tables and chairs also work as columns. Find a structure in the classroom or nearby in the school that has support columns. This could be part of the room or building, a raised platform, a large table, or a bookshelf. Ask students to observe the columns carefully, and answer questions like these:
   - What purpose do these columns serve in this structure? What are they holding up?
   - What would happen if one or more of the columns were removed?
   - What would happen if the columns weren't strong enough to do their job of supporting the structure?
   - What makes a column strong? Is it the length, the diameter, the material, the shape, or a combination of those?
   - How would we measure the length of a column?
   - How would we measure the circumference or perimeter of a column?
   - What kinds of materials can columns be made of?
   - What shapes can columns be?

   Regarding the latter question, show columns that are in the shape of a circle, a square, a rectangle, and a triangle. You can find some of these in furniture or in the structure of a building, or make them out of paper or cardboard for demonstration purposes.

   Record students' answers so they can return to them later after they've done some tests to learn more about this topic.
2. Draw four shapes on the chalkboard: square, triangle, rectangle, and circle. Take a vote among students on which of these shapes they think would make the strongest column. Ask them to give their reasons for their choices. Don't label answers as right or wrong. Instead, record their ideas and tally up the votes for each shape for future reference.
3. Ask students to work in pairs to construct the four different-shaped columns out of paper and use them to test their hypotheses. Don't specify any rules or guidelines for the sizes of the columns or the construction techniques. Make paper of different weights and sizes available, but don't suggest which one should be used. Let students make all the decisions regarding the columns. The only requirement is that one must be round, one must be square, one must be rectangular, and one must be triangular.
4. Distribute copies of Worksheet #8 to each team. On the worksheet, have them identify this as "Test #1." Once students have constructed their columns, have them measure the length and enter the measurements on Worksheet #8. They should also enter the construction material used for each column.

5. The next step is for students to test the columns for strength and record the results. The test consists of centering a square platform of cardboard on top of the column, holding the column securely and making sure it is exactly vertical, placing the can on top of this platform, and adding weights (identical washers, tiles, or marbles) to the can until the column buckles. One student can hold the column upright at its base while the other places the cardboard platform on top, places the empty can on the platform, then adds the weights to the can, one at a time. Students should count the number of weights added in each test to determine the point at which the column buckles.
6. Make a simple chart on the board or chart paper to compare the results of all student teams. Tally how many columns of each shape were found to be the strongest in the preliminary tests. If a clear winner emerges, ask student teams who identified that shape as the strongest to share their data with the class:
   - Length of column
   - Material used
   - Point of failure

   Ask students to compare and discuss similarities and differences among these variables.
7. Discuss the meaning of these preliminary tests, starting with these questions:
   - Why didn't every team get the same result?
   - Do these tests really reveal which shape makes the strongest column?
   - Were these fair tests—that is, were the variables (such as length, width, type of paper) the same for each test?
8. Review the principles of fair testing with students. Have them identify what would be necessary to make these fair tests for the strongest shape—that is, controlling all variables so that the only difference among the columns being tested is the shape. This requires using the same materials, making columns of the same length, and using the same platform, can, and weights to test for strength.
9. Once the principles of a fair test have been established, set aside class time for students to perform their tests again. Distribute more copies of Worksheet #8 to student teams and have them identify this as "Test #2." Make copies of the templates on pages 69-72 and distribute them to students. Point out that it's important to follow the template directions carefully so that all columns are folded and taped in the same way.
10. Have students make the columns and perform the tests again. Remind them to follow the principles of fair testing in all cases—all variables must be the same except the shape of the column.
11. Students once again fill out the worksheet and present their findings to the class. Compare and discuss the findings, which should reveal the round column to be the strongest. If there are results that don't agree with this finding, have students analyze their test procedures and conditions to look for evidence that fair test guidelines were not followed.

Extensions

- Challenge students to create a graph of their test data and to rank the four shapes from strongest to weakest.
- As homework, have students look for examples of columns they see in their homes and community, and also find pictures of columns in newspapers and magazines and bring them to class. Set aside class time to discuss the shapes, materials, and functions of the columns students identify.

Worksheet #8

Which Shape Makes the Strongest Column?

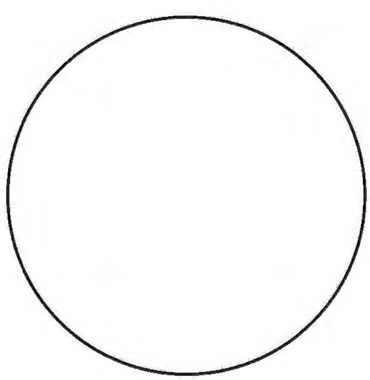
Name/Team ______________________________ Date ______________

Test #__________

Shape of Column	Length of Column	Construction Material	Number of Weights That Caused Failure
Circle			
Square			
Rectangle			
Triangle			

1. Which column was the strongest? ____ Circle ____ Square ____ Rectangle ____ Triangle
2. Why do you think that one is the strongest? ______________________________
3. Was it the same length as the other columns? ____ Yes ____ No
4. Was it made of the same material as the other columns? ____ Yes ____ No
5. How do you think the answers to questions 3 and 4 affected the test results? ______________________________

(tape here)



To make a circular column, tape this edge of paper to the line at the other end.

(fold here and tape)

(fold here)

(fold here)

(fold here)

To make a square column, fold at the lines and tape this edge of paper to the line at the other end of the paper.

↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

(TAPE HERE but DO NOT FOLD AT THIS LINE!)

(fold here)

(fold here)

(fold here)

(fold here)

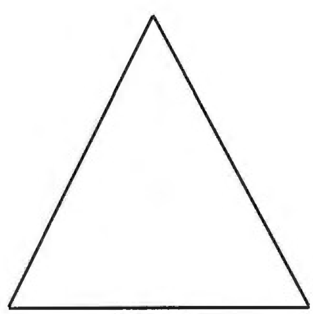
To make a rectangular column, fold at the lines and tape this edge of paper to the line at the other end of the paper.

↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

(fold here and tape)

(fold here)

(fold here)



To make a triangular column, fold at the lines and tape this edge of paper to the line at the other end of the paper.

↓ ↓ ↓ ↓ ↓ ↓ ↓ ↓

Activity № 9

How Does the Shape of a Shelf Affect Its Strength?

Overview

Students conduct tests to determine which shape will produce the strongest shelf.

Materials

- Cardboard (to make square, rectangular, and trapezoidal shelves)
- Strong, wide cardboard columns (two per group) that the shelves will be attached to for testing
- Glue
- Heavy weights for load testing
- Meter stick
- Worksheet #9

Procedure

1. Explain that the goal of this activity is to find the shape that makes the strongest shelf: square, rectangle, or trapezoid. Students will work in teams to test the shapes and compare their results.
2. Divide students into small groups. Assign a shape to each group. At least two groups should test each shape so that results can be compared.
3. Provide groups with materials for making shelves—cardboard for the shelves, cardboard support columns, glue or tape for attaching shelves to columns. If students are cutting their own cardboard, provide them with dimensions so that all shelves tested have the same surface area—required to make this a fair test.
4. Review methods for testing shelf strength. There are two options:
   - *Drop method:* Using the meter stick as a guide, students drop a standard weight onto the center of the shelf from 5 cm. above it. They repeat this test, dropping the same standard weight from heights that increase in 5 cm. increments, until the shelf gives way from the impact.
   - *Gradual method:* Students load the shelf by gradually adding weight to the center of the shelf, until it fails.
5. Distribute Worksheet #9. Have students conduct the tests and record their findings in the appropriate place, depending on the test method used.
6. Bring the groups together and ask each group to share its results. Create a chart on the board or chart paper to show the results for each shape from each group. Compare and discuss the results, starting with these questions:
   - Which shape was the strongest?
   - Did each group have similar results?
   - If different loading methods were used with the same shape, do the results from both types of test agree?

   Encourage discussion on whether the "drop" method or the "gradual" method better reflects the way a shelf would be loaded in practice.

Tips

- Monitor the groups' work to make sure students glue or tape the shelves securely to the columns. If glue is used, it should be allowed to dry overnight. If the shelves aren't attached securely to the columns or if the glue isn't dry, the supports could fail before the shelves do.
- The surface area should be the same for each shape. You can assure this by giving students the dimensions for cutting the shelves, or by precutting the cardboard pieces yourself. Alternatively, the students can calculate the dimensions themselves, as a math exercise. Other variables that should be kept the same include the type of cardboard and the support method.
- The simplest approach is to have each group test a different shape and then compare results. A more thorough but time-consuming approach is to allow each group to test all three shapes.
- In order for this to be a fair test, there are a number of variables that must be kept constant, such as the surface area of the shelves. Review the concepts of a controlled experiment.
- If you use the "gradual" method of testing, you may need to make the shelf longer so that it requires a reasonable amount of weight to make it fail.

Worksheet #9

How Does the Shape of a Shelf Affect Its Strength?

Name/Group ______________________________ Date ______________

Test Method: Drop

Shape of Shelf	Dropped 5 cm.	Dropped 10 cm.	Dropped 15 cm.	Dropped 20 cm.

Test Method: Gradual

Fill in the shelf shape beng tested. Enter the amount of weight loaded onto the shelf that caused the shelf to fail.

Shape of Shelf	Number of Weights at Which the Shelf Failed

Activity No 10

How Does the Type of Cardboard Affect the Strength of a Shelf?

Overview

Students conduct tests to determine which type of cardboard produces the strongest beam or shelf.

Materials

- Three or four common types of cardboard of different weights and thicknesses, large enough to make rectangular beams approximately 6 cm. x 30 cm.
- Weights for load testing (washers, tiles, or marbles)
- Bucket or can
- Worksheet #10

Procedure

1. Explain that the goal of this activity is to find out which type of cardboard makes the strongest shelf. Students will work in small groups to test different kinds of cardboard.
2. Divide students into small groups. Assign a type of cardboard to each group. At least two groups should test each type of cardboard so that results can be compared.
3. Provide groups with materials for making the rectangular beams (shelves). If students are cutting their own cardboard, provide them with dimensions—6 cm. x 30 cm.—so that all cardboard beams tested have the same surface area—required to make this a fair test. Remind students of the principles of the fair test and review the variables in this test that must be kept constant.
4. Have groups test each piece of cardboard using this procedure:
   - Use the cardboard rectangle to make a "bridge" between two desks or two stacks of books.
   - Place the bucket or can at the center of the cardboard.
   - Gradually add tiles or washers (or other appropriate weights) to the bucket, until the shelf collapses. Keep track of the number of weights added.
   - Record the number of weights that cause the cardboard "bridge" to fail on Worksheet #10.
5. Bring the groups together to report, compare, and discuss the test results.

Tips

- You will probably want to limit the types of cardboard to three or four types that are large enough to work with and readily available.
- To save time and to insure that all cardboard rectangles are the same size, you may want to pre-cut the cardboard pieces yourself. If you have students cut their own cardboard, monitor them carefully to make sure they are using cutting tools safely and to make sure the pieces tested are all the same size.
- The simplest approach would be to have each group test one or two different materials, then compare results. A more thorough but time-consuming approach would be to allow each group to test all three or four materials.

Worksheet #10

How Does the Type of Cardboard Affect the Strength of a Shelf?

Name/Group ______________________________ Date ______________

Type of cardboard tested:

____

Dimensions of cardboard shelf:

____

Kind of weights used to test strength:

____

Number of weights that caused the shelf to fail:

____

Activity № 11

How Does the Direction of the Corrugations Affect the Strength of a Shelf?

Overview

Students conduct tests to determine which way of orienting the corrugations will produce the strongest shelf.

Materials

- Three 6 cm. x 30 cm. pieces of cardboard per group
- Glue
- Tiles, washers, or marbles for the load testing
- Bucket or large can for holding weights
- Worksheet #11

Procedure

1. Provide students with square samples of corrugated cardboard and let them examine them carefully. Discuss the structure of corrugated cardboard. Help students observe that the middle layer has "ribs" that all run in the same direction. Ask these questions and record students' answers. Encourage students to speculate and give reasons for their answers.
   - Would a cardboard shelf be stronger if these ribs were running the long way or the short way?
   - If three pieces of cardboard are glued together to make a stronger shelf, should all of the pieces have their ribs running the same way, or should they be alternated? If they should alternate, what should the order be?
2. Divide students into small groups. Provide each group with two 6 cm. x 30 cm. "shelves" made of the same kind of corrugated cardboard. In one shelf, the ribs of the cardboard run from end to end of the shelf—the long way; in the other, the ribs run across the shelf—the short way.
3. Distribute copies of Worksheet #11. Have all groups test the strength of each shelf following this procedure:
   - Use the cardboard shelf to make a "bridge" between two desks or two stacks of books.
   - Place the bucket or can at the center of the cardboard.
   - Gradually add tiles or washers (or other appropriate weights) to the bucket, until the shelf collapses. Keep track of the number of weights added.
   - Record the number of weights that cause the cardboard "bridge" to fail.
4. Bring the groups together to present, compare, and discuss the results. They should discover that cardboard is stronger when its ribs run the long way.
5. Pose the next question: If three pieces of cardboard are glued together to make a stronger shelf, should all of the pieces have their ribs running the same way, or should they be alternated? If they should alternate, what should the order be? Record students' responses. Encourage them to speculate and to explain the reasons for their answers.
6. Explain to students that they are going to design and test a model of a laminated shelf made from three 6 cm x 30 cm pieces of corrugated cardboard. A laminated shelf is assembled by gluing three layers of shelving material together.

7. Have each group choose one of the laminated shelf patterns listed under Test #2 on Worksheet #11. "Long/long/long" means all three layers have their ribs running the long way, etc. Make sure that at least one group is testing each design. Have all groups make and test their shelf designs using this procedure:
   - Choose a shelf design and check it off on Worksheet #11.
   - Create the laminated shelf by gluing three pieces of 6 cm. x 30 cm. corrugated cardboard together.
   - Use a book as a weight to hold the pieces together and allow the assembled shelf to dry, preferably overnight.
   - Use the laminated shelf to make a "bridge" between two desks.
   - Place the bucket or can at the midpoint of the shelf.
   - Add weights, one at a time, until the shelf collapses.
   - On Worksheet #11, record the number of weights that caused the collapse.
8. Bring the groups together to present, compare, and discuss the test results. The results should show that the pattern long/long/long makes the strongest shelf.

Tips

- To save time, you may want to prepare the cardboard ahead of time, or you can allow students to cut their own cardboard. All shelf pieces must be the same size and made of the same type of corrugated cardboard. You need enough pieces with the ribs running the long way, and enough oriented the short way, so that all variations can be tested.
- Review the principles of fair testing. To insure that this is a fair test, all teams should use the same amount of glue to create their laminated shelves, the same types of buckets or cans, and the same types of weights.

Worksheet #11

How Does the Direction of the Corrugations Affect the Strength of a Shelf?

Name/Group ______________________________ Date ______________

Test #1: Single-Layer Shelf

Shelf Description	Number of Weights at Which Shelf Failed
Ribs running the long way	
Ribs running the short way	

Test #2: Three-Layer Laminated Shelf

Shelf Design Tested (check one)	Number of Weights at Which Shelf Failed
[ ] Long/long/long	
[ ] Long/long/short	
[ ] Long/short/long	
[ ] Long/short/short	
[ ] Short/long/short	
[ ] Short/short/short	

Activity № 12

How Does the Type of Glue Affect the Strength of a Laminated Shelf?

Overview
Students conduct tests to determine which glue will produce the strongest shelf.

Materials
- Glue of different types, such as wood glue, white school glue, mucilage, stick glue, rubber cement, art glue, fabric glue, etc.
- Three 6 cm. x 30 cm. pieces of cardboard per group
- Tiles, washers, or marbles for load testing
- Bucket or large can for holding weights
- Worksheet #12

Procedure
1. Explain to students that the goal of this activity is to find the glue that will make the strongest laminated shelves. Students will work in groups to test the strength of different glues used to create a two-layer laminated shelf.
2. Divide students into small groups. Provide each group with two identical 6 cm. x 30 cm. cardboard shelves and a standard amount of one type of glue. In this test, the directions of the cardboard ribs, the size, and type of cardboard must all be the same, as must the amount of glue used.
3. Distribute copies of Worksheet #12. Have all groups conduct a test on one type of glue using the following procedure:
   - On Worksheet #12 check the type of glue being tested.
   - Carefully use all the glue provided to glue the two cardboard layers together.
   - Put weights on the shelves and allow them to dry, preferably overnight.
   - When the glue is dry, use the laminated shelf to make a bridge between two desks or two stacks of books.
   - Place a can or bucket in the center of the shelf and add tiles, washers, or other weights, one at a time, until the shelf collapses.
   - On Worksheet #12 record the number of weights at which the shelf collapses.
4. Bring the groups together to present, compare, and discuss the results. Use these questions to spark discussion:
   - Would we get the same results with a different type of cardboard?
   - Would the same glue still be strongest if it were used for a different purpose, such as making a column or supporting a shelf?

Tips
- At least two groups should test each type of glue, so the results can be compared.
- To save time and insure that this is a fair test, you might want to prepare the cardboard layers ahead of time.
- Pre-measure the same amount of glue for each group.
- When using rubber cement or any other glue with a strong odor, make sure there is plenty of ventilation.

Worksheet #12

How Does the Type of Glue Affect the Strength of a Laminated Shelf?

Name/Group ______________________________ Date ______________

Type of Glue Tested (check one)	Number of Weights at Which Shelf Failed
[ ] Wood glue	
[ ] White school glue	
[ ] Mucilage	
[ ] Stick glue	
[ ] Rubber cement	
[ ] Art glue	
[ ] Fabric glue	
[ ] Other (describe)	

Activity № 13

How Does the Support Method Affect the Strength of a Shelving Unit?

Overview

Students conduct tests to determine which type of support will produce the strongest shelf unit.

Materials

- Cardboard to build one model unit for each group (sides and back only)
- Shelves from previous activities
- Three narrow strips of cardboard to serve as supports (two for the sides and one for the back)
- White school glue
- Tape
- Tiles, washers, or marbles to use as weights for load testing
- Bucket or large can for holding weights
- Worksheet #13

Procedure

1. Explain to students that they are going to test different methods for supporting the shelves of a cardboard shelving unit to figure out which method works best. Students will work in groups to choose and test different methods.
2. Brainstorm ways that shelves might be supported in a shelving unit. Have students look around the room to see how the shelves are supported in bookcases, closets, storage cabinets, etc. Record all of the students' ideas on the board or chart paper. If students need help, suggest these methods:
   - Strips of cardboard are glued to sides and back of unit and the shelves then rest on these strips.
   - Shelves are glued directly to the backs and sides of the unit.
   - Tape is used to hold the shelves directly to sides and back of unit.
3. Divide students into small groups and distribute copies of Worksheet #13. Let each group choose the attachment method they will test. Make the necessary materials available.
4. Give groups time to attach shelves to the shelving unit frame you have provided. When the unit is complete, the group uses the can or bucket with weights to test the unit for strength. They then record their results on Worksheet #13.
5. Bring the groups together to present, compare, and discuss the results.

Tips

- For this activity you will need to prepare a model unit for each group consisting of the back and sides only.
- In order for this to be a fair test, variables must be kept the same for all trials: the dimensions and materials used in the frame; the size of the shelves and materials used.

Worksheet #13

How Does the Support Method Affect the Strength of a Shelving Unit?

Name/Group ______________________________ Date ______________

Describe the method you will use to attach the shelves to the shelving unit.

Describe what happened when you tested the strength of your shelving unit.

How could you improve the design of your shelving unit?

Standards for Activities

Activity #1: Exploring and Categorizing Packages

Benchmarks for Science Literacy
Benchmark #1B: Describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.

Standards for the English Language Arts
Standard #12: Students use spoken written language to accomplish their own purposes.

National Science Education Standards
Content Standard A: Students should develop abilities necessary to do scientific inquiry.

Principles and Standards for School Mathematics
Algebra Standard A1: Understand, patterns, relations, and functions.

Activity #2: Classifying Bags

Benchmarks for Science Literacy
Benchmark #1A: Results of similar scientific investigations seldom turn out exactly the same. Sometimes this is because of unexpected differences in the things being investigated.
Benchmark #1B: Scientific investigations may take many different forms including observing what things are like or what's happening somewhere, collecting specimens for analysis, and doing experiments.
Benchmark #2A: Mathematics is the study of many kinds of patterns, including numbers and shapes and operations on them. Sometimes patterns are studied because they help to explain how the world works or how to solve practical problems.
Benchmark #9A: Simple graphs can help to tell about observations.

Standards for the English Language Arts
Standard #12: Students use spoken, written, and visual language to accomplish their own purposes.

National Science Education Standards
Content Standard A: Students should develop abilities necessary to do scientific inquiry.

Principles and Standards for School Mathematics
Algebra Standard A1: Understand, patterns, relations, and functions
Data Analysis and Probability Standard DA & P1: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

Activity #3: Packing a Bag

Benchmarks for Science Literacy

Benchmark #1A: When a scientific investigation is done the way it was done before, we expect to get a very similar result.

Benchmark #1B: People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.

Benchmark #2C: Numbers and shapes can be used to tell about things.

Standards for the English Language Arts

Standard #12: Students use spoken, written, and visual language to accomplish their own purposes.

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.

Principles and Standards for School Mathematics

Measurement Standard M1: Understand measurable attributes of objects and the units, systems, and processes of measurement.

Data Analysis and Probability Standard DA & P3: Develop and evaluate inferences and predictions that are based on data.

Activity #4: It Fits Just Right!

Benchmarks for Science Literacy

Benchmark #1A: When a scientific investigation is done the way it was done before, we expect to get a very similar result.

Benchmark #1B: People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.

Standards for the English Language Arts

Standard #12: Students use spoken, written, and visual language to accomplish their own purposes.

Principles and Standards for School Mathematics

Geometry Standard G1: Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.

Geometry Standard G4: Use visualization, spatial reasoning, and geometric modeling to solve problems.

Activity #5: How Strong Is This Bag?

Benchmarks for Science Literacy
Benchmark #1A: When a scientific investigation is done the way it was done before, we expect to get a very similar result.
Benchmark #1B: People can often learn about things around them by just observing those things carefully, but sometimes they can learn more by doing something to the things and noting what happens.
Benchmark #2A: Mathematics is the study of many kinds of patterns, including numbers and shapes and operations on them. Sometimes patterns are studied because they help to explain how the world works or how to solve practical problems.
Benchmark #9A: Simple graphs can help to tell about observations.

Standards for the English Language Arts
Standard #12: Students use spoken, written, and visual language to accomplish their own purposes.

National Science Education Standards
Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard B: Students should develop an understanding of properties of objects and materials.

Principles and Standards for School Mathematics
Data Analysis and Probability Standard DA & P1: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
Data Analysis and Probability Standard DA & P3: Develop and evaluate inferences and predictions that are based on data.
Connections Standard C3: Recognize and apply mathematics in contexts outside of mathematics.
Measurement Standard M1: Understand measurable attributes of objects and the units, systems, and processes of measurement.

Activity #6: How Do You Package a Fragile Object?

Benchmarks for Science Literacy
Benchmark #1B: Describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.
Benchmark #3B: There is no perfect design.
Benchmark #8B: Discarded products contribute to the problem of waste disposal. Sometimes it is possible to use the materials in them to make new products, but materials differ widely in the ease with which they can be recycled.

National Science Education Standards
Content Standard A: Students should develop abilities necessary to do scientific inquiry.
Content Standard E: Students should develop abilities of technological design and understanding about science and technology.

Standards for the English Language Arts
Standard #12: Students use spoken, written, and visual language to accomplish their own purposes.

Principles and Standards for School Mathematics
Data Analysis and Probability Standard DA & P1: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
Data Analysis and Probability Standard DA & P3: Develop and evaluate inferences and predictions that are based on data.
Connections Standard C3: Recognize and apply mathematics in contexts outside of mathematics.
Measurement Standard M1: Understand measurable attributes of objects and the units, systems, and processes of measurement.

Activity #7: Which Pump Dispenser Works Best?

Benchmarks for Science Literacy
Benchmark #1A: When a scientific investigation is done the way it was done before, we expect to get a very similar result.
Benchmark #1B: Describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.
Benchmark #9A: Simple graphs can help to tell about observations.

Standards for the English Language Arts
Standard #12: Students use spoken, written, and visual language to accomplish their own purposes.

National Science Education Standards
Content Standard A: Students should develop abilities necessary to do scientific inquiry.

Principles and Standards for School Mathematics
Data Analysis and Probability Standard DA & P1: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.
Data Analysis and Probability Standard DA & P3: Develop and evaluate inferences and predictions that are based on data.
Connections Standard C3: Recognize and apply mathematics in contexts outside of mathematics.
Measurement Standard M1: Understand measurable attributes of objects and the units, systems, and processes of measurement.

Activities #8-13: Cardboard Structures

Benchmarks for Science Literacy

Benchmark #1A: When a scientific investigation is done the way it was done before, we expect to get a very similar result.

Benchmark #1B: Describing things as accurately as possible is important in science because it enables people to compare their observations with those of others.

Benchmark #3B: There is no perfect design.

Benchmark #8B: Discarded products contribute to the problem of waste disposal. Sometimes it is possible to use the materials in them to make new products, but materials differ widely in the ease with which they can be recycled.

Benchmark #12A: Students should keep records of their investigations and observations and not change the records later. Students should offer reasons for their findings and consider reasons suggested by others.

National Science Education Standards

Content Standard A: Students should develop abilities necessary to do scientific inquiry.

Content Standard B: Students should develop an understanding of properties of objects and materials.

Content Standard E: Students should develop abilities of technological design and understanding about science and technology.

Standards for the English Language Arts

Standard #12: Students use spoken, written, and visual language to accomplish their own purposes.

Principles and Standards for School Mathematics

Data Analysis and Probability Standard DA & P1: Formulate questions that can be addressed with data and collect, organize, and display relevant data to answer them.

Data Analysis and Probability Standard DA & P3: Develop and evaluate inferences and predictions that are based on data.

Connections Standard C3: Recognize and apply mathematics in contexts outside of mathematics.

Measurement Standard M1: Understand measurable attributes of objects and the units, systems, and processes of measurement.

Geometry Standard G1: Analyze characteristics and properties of two- and three-dimensional geometric shapes and develop mathematical arguments about geometric relationships.