
Elementary School Teacher Guide



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Elementary School

Introductory Science Experiments

Teacher Guide

21st Century Science

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Contents

Elementary School	1
Introduction	vii
Normal Laboratory Safety Procedures	xiii
Master Materials List.....	xvii
Activity by PASCO Sensors.....	xxviii
Grades K-1	1
1. Heavy and Heavier	3
2. Near and Far.....	9
3. Mixing Water.....	17
4. Light and Dark	23
5. Exploring Temperatures	31
6. Hot and Cold	45
7. Weather Instruments	51
Grades 2-3	59
8. Freezing and Melting Water	61
9. Conservation of Matter.....	73
10. Hunting with Light.....	85
11. Investigating Sound Levels.....	107
12. Feeling and Measuring Temperature	117
13. Cars and Heat.....	131
14. Observing Clouds.....	143
15. Can Plants Survive without Light and Water?.....	161
Grades 4-5	175
16. Temperature and Change	177
17. The Water Cycle	193
18. Conductor or Not?.....	205
19. Electric Circuits	215
20. What Is an Electromagnet?.....	231
21. Determining Sound Levels	239
22. Keeping Warm	253
23. Heating Land and Water.....	267
24. Chemical Reactions	281
25. Weather Station.....	301
26. Dew and Frost.....	319
27. Microclimates.....	335
28. How a Greenhouse Works: Light	347
29. How a Greenhouse Works: Heat	363

Introduction

PASCO scientific's probeware and laboratory investigations move students from the low-level task of memorization of science facts to higher-level tasks of data analysis, concept construction, and application. For science to be learned at a deep level, it is essential to combine the teaching of abstract science concepts with "real-world" science investigations. Hands-on, technology-based, laboratory experiences serve to bridge the gap between the theoretical and the concrete, driving students toward a greater understanding of natural phenomenon. Students also gain important science process skills that include: developing and using models, carrying out investigations, interpreting data, and using mathematics.

At the foundation of teaching science are a set of science standards that clearly define the science content and concepts, the instructional approach, and connections among the science disciplines. The Next Generation Science Standards (2012)© are a good example of a robust set of science standards.

The Next Generation Science Standards (NGSS) position student inquiry at the forefront. The standards integrate and enhance science, technology, engineering, and math (STEM) concepts and teaching practices. Three components comprise these standards: Science and Engineering Practices, Disciplinary Core Ideas, and Crosscutting Concepts. The lab activities in PASCO's 21st Century Science Guides are all correlated to the NGSS (see <http://pasco.com>).

- The Science and Engineering Practices help students to develop a systematic approach to problem solving that builds in complexity from kindergarten to their final year in high school. The practices integrate organization, mathematics and interpretive skills so that students can make data-based arguments and decisions.
- Disciplinary Core Ideas are for the physical sciences, life sciences, and earth and space sciences. The standards are focused on a limited set of core ideas to allow for deep exploration of important concepts. The core ideas are an organizing structure to support acquiring new knowledge over time and to help students build capacity to develop a more flexible and coherent understanding of science.
- Crosscutting Concepts are the themes that connect all of the sciences, mathematics and engineering. As students advance through school, rather than experiencing science as discrete, disconnected topics, they are challenged to identify and practice concepts that cut across disciplines, such as "cause and effect". Practice with these concepts that have broad application helps enrich students' understanding of discipline-specific concepts.

PASCO's lab activities are designed so that students complete guided investigations that help them learn the scientific process and explore a core topic of science, and then are able to design and conduct extended inquiry investigations. The use of electronic sensors reduces the time for data collection, and increases the accuracy of results, providing more time in the classroom for independent investigations.

In addition to supporting the scientific inquiry process, the lab activities fulfill STEM education requirements by bringing together science, technology, engineering, and math. An integration of these areas promotes student understanding of each of these fields and develops their abilities to become self-reliant researchers and innovators. When faced with an idea or problem, students learn to develop, analyze, and evaluate possible solutions. Then collaborate with others to construct and test a procedure or product.

Information and computer tools are essential to modern lab activities and meeting the challenge of rigorous science standards, such as NGSS. The use of sensors, data analysis and graphing tools, models and simulations, and work with instruments, all support the science and engineering practices as implemented in a STEM-focused curriculum, and are explicitly cited in

NGSS. PASCO's lab activities provide students with hands-on and minds-on learning experiences, making it possible for them to master the scientific process and the tools to conduct extended scientific investigations.

About the PASCO 21st Century Science Guides

This manual presents teacher-developed laboratory activities using current technologies to help you and your students explore topics, develop scientific inquiry skills, and prepare for state level standardized exams. Using electronic-sensor data collection, display and analysis devices in your classroom fulfills STEM requirements and provides several benefits. Sensor data collection allows students to:

- observe phenomena that occur too quickly or are too small, occur over too long a time span, or are beyond the range of observation by unaided human senses
- perform measurements with equipment that can be used repeatedly over the years
- collect accurate data with time and/or location stamps
- rapidly collect, graphically display, and analyze data so classroom time is used effectively
- practice using equipment and interpreting data produced by equipment that is similar to what they might use in their college courses and adult careers

The Data Collection System

In this manual, “data collection system” refers to the system employed by students to record, visualize, and analyze sensor data during their experiments. The system consists of all components necessary to connect a sensor to a device containing the software that detects the sensor measurement and collects, records, and displays this data.

Some systems, such as the Xplorer GLX® or SPARK Science Learning System™, are stand-alone systems. These contain built-in software applications, and students simply attach a sensor and begin collecting data. Other systems use a computer or tablet with downloaded software applications. In these systems a USB or Bluetooth® interface is used to connect a sensor to the device. Software options for these include SPARKvue® and PASCO Capstone™ software.

The activities are designed so that any PASCO data collection system can be used to carry out the procedures.

Getting Started with Your Data Collection System

To help you and your students become familiar with the many features of your data collection system, start with the tutorials and instructional videos that are available on PASCO's website (www.pasco.com).

Included on the storage device accompanying your manual is a Scientific Inquiry activity that acts as a tutorial for your data collection system. Each data collection system (except for PASCO Capstone) has its own custom Scientific Inquiry activity. The activity introduces students to the process of conducting science investigations, the scientific method, and introduces teachers and students to the commonly used features of their data collection system. Start with this activity to become familiar with the data collection system.

Teacher and Student Guide Contents

All the teacher and student materials are included on the storage device accompanying the Teacher Guide.

Activity Components

Teacher Information and the completed Student Activity Worksheets are in the Teacher Guide binder. It contains the information to guide the teacher with selecting, planning, and implementing the activity. Listed on the first page of each activity are the objectives, procedural overview, time requirements, and materials.

Kindergarten to Grade 3. For kindergarten through third grade, each activity has three components: Teacher Information, completed student response sheet, and the student response sheet. Only the teacher has the written procedure for the activity. Student response sheets for kindergarten and first grade contain illustrations related to the concept of the activity. Student response sheets for second and third grades may contain a combination of prediction questions, blank graphs, multiple choice (text and or illustrations), true/false, and vocabulary questions.

Grades 4 to 5. For fourth grade and fifth grades, each activity has two components: Teacher Information and Student Activity Worksheets. Student Activity Worksheets contain the written procedure and an assessment component. The Teacher Information contains the complete student version with the answers.

Student Activity Worksheets begin with a driving question, providing students with a consistent scientific format that starts with formulating a question to be answered in the process of conducting a scientific investigation. Activity worksheets also include 1) the materials list, 2) safety precautions, 3) the procedure for carrying out the activity, collecting and recording data, and analyzing results, and 5) a combination of multiple choice, true/false, and vocabulary questions. The Student Activity Worksheets are included in electronic format on the storage device that accompanies this manual.

The following table lists the sections in the components of each grade level. For kindergarten through third grade students have a student response sheet.

Elementary School: Student Handout Masters

Student response sheet (K-1)	Student response sheet (2-3)	Student Activity Worksheet (4-5)
Title	Title	Title
Predict	Predict	Driving Questions
Draw	Draw	Materials
Circle picture choices	Test your prediction	Safety
	Conclusions	Investigation
		Get Started
		Let's Explore
		Explain It
		Tell Me More
		Sum It Up
		Assessment
		Key Term Challenge
		True/False
		Multiple Choice

Activity components for each grade level

Teacher Information (K-1)	Teacher Information (2-3)	Teacher Information (4-5)
Title	Title	Title
Recommended Grade Level	Recommended Grade Level	Recommended Grade Level
Objectives	Objectives	Objectives
Procedural Overview	Procedural Overview	Procedural Overview
Time Requirement	Time Requirement	Time Requirement
Materials	Materials	Materials
	Activity at a Glance	Activity at a Glance
	Get Started	Get Started
	Let's Explore	Let's Explore
	Explain It	Explain It
	Tell Me More	Tell Me More
	Sum It Up	Sum It Up
Safety	Safety	Safety
Preparation	Preparation	Preparation
Background	Background	Background
		Pre-Activity Discussion with Driving Question and Variables
Activity with Answer Key and Teacher Tips	Activity with Answer Key and Teacher Tips	Activity with Answer Key and Teacher Tips
Driving Question	Driving Question	
Get Started	Get Started	Get Started
Let's Explore	Let's Explore	Let's Explore
Explain It	Explain It	Explain It
Tell Me More	Tell Me More	Tell Me More
Sum It Up	Sum It Up	Sum It Up
		Assessment
		Multiple Choice
		True/False
		Key Term Challenge
Further Investigations	Further Investigations	Further Investigations
Student response sheet	Student response sheet	

Electronic Materials

The storage device accompanying this manual contains the following:

- Complete Teacher Guide and Student Guide: Handout Masters (with Student Activity Worksheets for grades four and five, and student response sheets for kindergarten to third grade in PDF format
- Student Activity Worksheets of the activities for grades four and five and student response sheets for kindergarten to grade three in an editable format (Microsoft® Word 97–2003 format).
- DataStudio, PASCO Capstone, and SPARKvue help is available in the software application itself.

International Baccalaureate Organization (IBO*) Support

IBO Diploma Program

The International Baccalaureate Organization (IBO) uses a specific science curriculum model that includes both theory and practical investigative work. While this lab guide was not produced by the IBO and does not include references to the internal assessment rubrics, it does provide a wealth of information that can be adapted easily to the IB classroom.

By the end of the IB Diploma Program students are expected to have completed a specified number of practical investigative hours and are assessed using the specified internal assessment criteria. Students should be able to design a lab based on an original idea, carry out the procedure, draw conclusions, and evaluate their own results. These scientific processes require an understanding of laboratory techniques and equipment as well as a high level of thinking.

Using these Labs with the IBO Programs

The student versions of the labs are provided in Microsoft Word and are fully editable. Teachers can modify the labs easily to fit a problem-based format.

For IB students, pick one part of the internal assessments rubrics to go over with the students. For example, review the design of the experiment and have students explain what the independent, dependent, and controlled variables are in the experiment. Ask students to design a similar experiment, but change the independent variable.

Delete certain sections. As students become familiar with the skills and processes needed to design their own labs, start deleting certain sections of the labs and have students complete those parts on their own. For example, when teaching students to write their own procedures, have the students complete one lab as it is in the lab guide. In the next lab, keep the Sequencing Challenge, but have students write a more elaborate procedure. Finally, remove both the Sequencing Challenge and the Procedure sections and have students write the entire procedure.

Encourage students to make their own data tables. Leave the procedure, but remove the data tables and require the students to create them on their own. In another lab, leave the driving question and procedure, but remove the analysis questions and have students write their own analysis, conclusion, and evaluation.

Use only the driving question. As students' progress through their understanding of the structure of an experiment, provide them with just the driving question and let them do the rest. Some of the driving questions are too specific (they give the students the independent variable), so revise them appropriately.

Extended inquiry. After students complete an activity in the lab guide, use the extended inquiry suggestions to have the students design their own procedure, or the data collection and processing, or both.

About Correlations to Science Standards

The lab activities in this manual are correlated to a number of standards, including United States National Science Education Standards, the Next Generation Science Standards, and all State Science Standards. See <http://pasco.com> for the correlations.

Global Number Formats and Standard Units

Throughout this guide, the International System of Units (SI) or metric units is used unless specific measurements, such as air pressure, are conventionally expressed otherwise. In some instances, such as weather parameters, it may be necessary to alter the units used to adapt the material to conventions typically used and widely understood by the students.

Reference

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NGSS Lead States. 2013. Next Generation Science Standards: For States, By States. Washington, DC: The National Academies Press.

Normal Laboratory Safety Procedures

Overview

PASCO is concerned with your safety and because of that, we are providing a few guidelines and precautions to use when exploring the activities in our Elementary School Science guide. This is a list of general guidelines only; it is by no means all-inclusive or exhaustive. Of course, common sense and standard laboratory safety practices should be followed.

Regarding chemical safety, some of the substances and chemicals referred to in this manual are regulated under various safety laws (local, state, national, or international). Always read and comply with the safety information available for each substance or chemical to determine its proper storage, use, and disposal.

Since handling and disposal procedures vary, our safety precautions and disposal comments are generic. Depending on your lab, instruct students on proper disposal methods. Each of the activities also has a Safety section for procedures necessary for that activity. Convey these procedures to your students.

General Lab Safety Procedures and Precautions

- Follow all standard laboratory procedures.
- Absolutely no food, drink, or chewing gum is allowed in the lab.
- Wear protective equipment (for example, safety glasses, gloves, apron) when appropriate.
- Do not touch your face with gloved hands. If you need to sneeze or scratch, take off your gloves, wash your hands, and then take care of the situation.
- Wash your hands after handling samples, glassware, and equipment.
- Know the safety features of your facility such as eye-wash stations, first-aid equipment, or emergency phone use.
- Insure that loose hair and clothing are secure when in the lab.
- Handle glassware with care.
- Insure you have adequate clear space around your lab equipment before starting an activity.
- Do not wear open-toe shoes in the laboratory.
- Allow heated objects and liquids to return to room temperature before moving.
- Never run or joke around in the laboratory.
- Do not perform unauthorized experiments.
- Students should work in teams of 2 or more in case of trouble and help is needed.
- Keep the work area neat and free from any unnecessary objects.

Water Related Safety Precautions and Procedures

- Keep water away from electrical outlets.
- Keep water away from all electronic equipment.

Chemical Related Safety Precautions and Procedures

- Many chemicals are hazardous to the environment and should not be disposed of down the drain. Always follow your teacher's instructions for disposing of chemicals.
- Wear eye protection, lab apron, and protective gloves when handling acids. Splash-proof goggles are recommended. Either latex or nitrile gloves are suitable. Use nitrile gloves if you have latex allergy.
- Read labels on all chemicals and pay particular attention to hazard icons and safety warnings.
- Wash your hands before and after a laboratory session.
- If any solution comes in contact with skin or eyes, rinse immediately with a copious amount of running water for a minimum of 15 minutes.
- Follow the teacher's instructions for disposing of chemicals and handling substances.
- Check the label to verify it is the correct substance before using it.
- Never point the open end of a test tube containing a substance at yourself or others.
- Use a wafting motion when smelling chemicals.
- Do not return unused chemicals to their original container.
- Keep flammable chemicals from open flame.

Dangerous or Harmful Substance Related Lab Safety Precautions

- Use caution when working with acids.
- Use appropriate caution with matches, burning splints, and other hot materials.
- When an activity calls for warm water, do not use temperatures above 35 °C (95 °F) for children in grades K–1, or above 40 °C (104 °F) for children in grades 2–3, or above 49 °C (120 °F) for children in grades 4–5.
- Be careful using a knife or scalpel.

Outdoor Safety Precautions

- Practice appropriate caution around water bodies, steep terrain, and harmful plants or animals.

- Treat plants, animals and the environment with respect.
- Inspect all equipment for damage (cracks, defects, etc.).
- Require students to use a buddy system and specify the procedure to use in case of trouble.

Other Safety Precautions

- If water is boiled for an experiment involving heat, make sure it is never left unattended. Remember, too, that the hot plate will stay hot well after it is unplugged or turned off.
- Any injury must be reported immediately to the instructor, an accident report has to be completed by the student or a witness.
- If you are suffering from any allergy, illness, or are taking any medication, you must inform the instructor. This information could be very important in an emergency.
- Try to avoid wearing contact lenses. If a solution spills in your eye, the presence of a contact lens makes first aid difficult and can result in permanent damage. Also, organic solvents tend to dissolve in soft contact lenses, causing eye irritation. If contact lenses must be worn, use a style of goggles called “eye cup.”

Additional Resources

- Flinn Scientific
- The Laboratory Safety Institute (LSI)
- National Science Education Leadership Association (NSELA)/Safe Science Series

Master Materials List

Italicized entries indicate items not available from PASCO. NOTE: These activities may also require protective gear for each student (for example, safety goggles, gloves, apron, or lab coat).

Teachers can conduct some lab activities with sensors other than those listed here. For assistance with substituting compatible sensors for a lab activity, contact PASCO Teacher Support (800-772-8700 inside the United States or <http://www.pasco.com/support>).

Lab	Title	Materials and Equipment	Qty
Kindergarten – First Grade			
1	Heavy and Heavier Use a force sensor to learn about the property called weight that can be measured, and to recognize that an object's weight is not necessarily related to its size.	Data Collection System PASPORT Force Sensor with hook installed Container (bucket or basket) to attach to the force sensor hook Toy car, truck, or other vehicle Balloon, inflated and tied Apple, potato, or other small fruit or vegetable Melon, eggplant, or other large fruit or vegetable Polystyrene (foam) packing material, picnic cooler, or purchased polystyrene craft material, as large as possible String, to hang the container on the force sensor hook	1 1 1 1 1 1 1 Several pieces
2	Near and Far Use a motion sensor to describe the position of an object as being near or far from another object and to recognize that an object in motion changes its position.	Data Collection System PASPORT Motion Sensor Large playground ball Meter stick	1 1 1 1
3	Mixing Water Use a temperature sensor to understand that mixing hot and cold water results in a new temperature that is between the hot and cold.	Data Collection System PASPORT Temperature Sensor Small paper cups (2) Large paper or plastic cup Ice water, approximately 5 °C Warm water, approximately 40 °C Towels	1 1 2 1 200 mL 200 mL Several

Activity by PASCO Sensors

4	Light and Dark Use a light sensor to determine how light is related to what the students see.	Data Collection System PASPORT Light Sensor PASPORT Sensor Extension Cable Strips of construction paper, 3 cm × 8 cm (1 in. × 3 in.), different colors or colored wooden craft sticks	1 1 1 1
5	Exploring Temperatures Use a temperature sensor to explore temperature changes to observe the property of temperature, and to learn that temperature is a measure of how hot or cold something is compared to a standard scale (has both teacher demonstration and student groups). Teacher Demonstration	Mobile Data Collection System PASPORT Temperature Sensor Mobile Data Collection System PASPORT Temperature Sensor Bag of clothing, warm- and cold-weather clothing Large outdoor thermometer Paper meter (construction paper or paper plates and a brad) Paper thermometer (can be written on) Thermometer, oral	1 1 Variety 1 1 1 1
6	Hot and Cold Use a temperature sensor to observe the property of temperature, and that this property can be measured using a thermometer or temperature sensor.	Data collection system PASPORT Temperature Sensor Buckets or containers for ice cubes and bottles Towels Ice cubes Plastic water or soda bottles filled with warm water (no warmer than 30 °C or 86 °F), tightly capped	1 1 2 Several Several Several
7	Weather Instruments Use a weather sensor to make measurements to determine weather conditions and to develop the language for describing weather conditions.	Mobile Data Collection System PASPORT Weather Sensor PASPORT Sensor Extension Cable Leaf Feather	1 1 1 1 1

Grade 2 – Grade 3			
8	Freezing and Melting Water Use a temperature sensor to measure the temperature of water in different forms and to learn that water can exist in different forms and can be changed from one form to another by heating or cooling.	Data Collection System PASPORT Temperature Sensor Ice cubes weighing 0.5 g or less Small paper cup Snack size plastic bag, re-sealable, 16.5-cm × 8.25-cm Tape Spoon Rock salt-ice bath (ice to fill a utility tub half full; 300–400 g of rock salt, tap water to cover ice) Paper towels Water Projection system (for the teacher only) Ice chest (for the teacher only)	1 1 Enough to half-fill the paper cup 1 1 1 piece 1 2–3 per class 1 per student 15 mL 1 1
9	Conservation of Matter Use a force sensor to determine that the weight of a whole object is the same as the sum of the weight of each part that makes up the whole object.	Data Collection System PASPORT Force Sensor, with hook attached Bag to attach to force sensor hook Objects of varying weights, 1 to 5 pounds such as a textbook, bottle of water, large box of crayons, hand weight, an orange, a hammer Flashlight (containing D batteries) Object made of parts, 1 to 5 pounds, such as a student backpack, a lunch box, a large bolt with a nut and washer attached, tool box Projection system (for the teacher only)	1 1 1 4 1 1 1
10	Hunting with Light Use a light sensor to compare how organisms, including humans, are able to see and compare that to what an electronic light sensor can detect. Teacher Demonstration	Data Collection System PASPORT Light Sensor Paper, solid colors Tissues Paper, plain white Crayon, dark colored Large eye diagram (photocopy) Large pictures of animal eyes (photocopy)	1 1 3 per group 1 per person 2 per person 1 1 1
11	Investigating Sound Levels Students recognize that continuous sound is made by vibrating objects, and can be described by its pitch and volume. Students explore different continuous sounds by studying the changing volume	Data Collection System PASPORT Sound Level Sensor PASPORT Sensor Extension Cable Sheet of paper to make a sound tube, 21-cm × 28-cm (8.5-in. × 11-in.)	1 1 1 1

[illegible]

15	Can Plants Survive without Light and Water? Use a light sensor to explore weather or not plants need light and water to survive and what adaptations help them survive. Teacher Demonstration	Data Collection System PASPORT Light Sensor Ruler Data Collection System PASPORT Light Sensor Potted plants, young plants, all the same kind Roots of plants Leaves of plants, a variety Growing light (optional) Markers Ruler	1 1 1 1 8 A variety A variety 1 A variety 1
Grade 4 – Grade 5			
16	Temperature and Change Use a temperature sensor to determine the effect of temperature on the time it takes for a sugar cube to dissolve or an antacid tablet to react with vinegar. Teacher Demonstration Preparation	Data Collection System PASPORT Temperature Sensor Beaker, 250-mL Stir rod Tape, ~3 in. piece Sugar cube Water, room temperature Water, cold Water, hot Beaker, 600-mL Antacid tablet piece, ~ 0.5 g Vinegar, room temperature Vinegar, hot Ice Data Collection System PASPORT Temperature Sensor Wooden block Ice cube, 0.5 g or less Tape, ~3 in. piece Balance Projection system Bucket to hold ice water Thermos® Balance	1 1 1 1 Several 3 300 mL 200 mL 200 mL 1 3 200 mL 100 mL 300 mL 1 1 1 2 1 1 1 1 1 1

17	The Water Cycle Use a weather sensor to measure the conditions in a water cycle model.	Data Collection System	1
		PASPORT Weather Sensor	1
Teacher Demonstration		PASPORT Sensor Extension Cable	1
		Utility lamp with clip (with a 60-W or 75-W incandescent bulb)	1
		Scissors	1
		Clean 2-L soda bottles	3
		Ice cubes	~350 mL
		Transparent packing tape	~2 m
		Meter stick	1
		Data Collection System	1
		PASPORT Weather Sensor	1
		PASPORT Sensor Extension Cable	1
		Scissors	1
		Ice cubes	~350 mL
		Permanent marker, black or dark color	
		Assembled water cycle tower	1
		Clean 2-L soda bottles	3
		Razor blade or sharp knife	
		Transparent packing tape	~2 m
18	Conductor or Not Use a voltage sensor to test the conductivity of different materials.	Data Collection System	1
		PASPORT Voltage Sensor	1
		AA-cell battery fully charged	1
		Holiday mini-light bulb with wire ends stripped	1
		Alligator clips	2
		Wire, 20 cm, with stripped ends	2
		Masking tape	~30 cm
		Paper clip	1
		Penny	1
		Plastic spoon	1
		Eraser	1
		Piece of chalk	1
		Clay	1
19	Electric Circuits Use a voltage sensor to measure the voltage across elements in series and in parallel in an electric circuit.	Data Collection System	1
		PASPORT Voltage Sensor	1
		AA-cell battery	2
		Miniature holiday light bulbs with stripped wire ends	2
		Masking tape,	~30 cm
		Wide rubber band	1
		Alligator clip or other pieces of wire with stripped ends	2
20	What is an Electromagnet? Use a voltage sensor to determine the strength of an electromagnet with different numbers of coils and different magnitude of the voltage source.	Data Collection System	1
		PASPORT Voltage Sensor	1
		AA-cell battery	2
		Paper clip	10 to 15
		Alligator clip	2
		Scissors	1
		Masking tape	~20 cm
		Large iron nail, 3 to 4 inches long	1
		Insulated bell wire, 22 to 26 gauge with ends stripped of insulation for 5 cm	1 m

Master Materials and Equipment List

21	Determining Sound Levels Use a sound level sensor to measure the sound levels from different objects, to determine the source of sound, and to find the relationship of vibration to sound level.	Data Collection System PASPORT Sound Level Sensor Balloon, cut open to make a drumhead Can opener (teacher use only) Drinking straw Notebook or copy paper Paper clip Paper or plastic cup, 350-mL (12-oz) Paper towel Pliers (teacher use only) Rubber band Scissors Square plastic food storage container, 1-qt Tin can, open at both ends Water	1 1 1 1 1 3 to 4 sheets 1 1 2 to 3 sheets 1 2 to 3 1 1 1 1 ~300 mL
22	Keeping Warm Use a temperature sensor to understand which materials conduct heat and which don't, and why they do or don't.	Data Collection System PASPORT Temperature Sensor Cup with cold water Cup with hot water Funnel Insulating clothing materials such as cotton, Polartec®, and wool Paper towels Rubber band (optional) Tape (optional) Test tube rack Test tubes Water, hot Data Collection System PASPORT Temperature Sensor Clothing items, articles of wool, synthetic fleece such as Polartec, real or synthetic fur, down, cotton, and polyester or acrylic fibers; a mitten and a glove Projection system	1 1 1 1 A variety 2 to 3 1 Several pieces 1 2 ~500 mL 1 1 A variety 1

23	Heating Land and Water Use a temperature sensor to determine a property of materials that allows some to heat up faster than other materials and then draw conclusions about water's influence on a region's climate.	Data Collection System	1
		PASPORT Temperature Sensor	1
		Construction paper, skin-tone (8 cm × 12 cm) (3 in. × 5 in.)	1
		Dry sand and other materials, such as grass, dirt, foil, waxed paper, wood, chocolate, milk, material, glass, ground charcoal, paint, or any other materials that would provide a variety of textures and surfaces	40 mL to 50 mL
		Meteorology records on the Internet	A variety
		Meter stick	1
		Petri dish or small shallow dish or jar lid	2
		Scissors	1
		Table or stool to clamp lamp	1
		Utility lamp with clip, 75 W, 100 W, or sunlamp	1
		Water, room temperature	40 mL to 50 mL
		World map or globe	1

Master Materials and Equipment List

24	Chemical Reactions	Data Collection System	1
	Use a temperature sensor to measure the change in temperature as two substances chemically react.	PASPORT Temperature Sensor	1
		Sugar cube	1
		Beaker half full of water	1
		Steel wool, ~1 g	2
		Beaker	Any size
		Cracker on a paper towel	1
		Bowl, big enough to hold water from beaker half full of water	1
		Balance (optional)	1
		Water	200 mL
		Beaker, 250-mL	2
		Beaker, 50-mL	1
		Stir rod	1
		Plastic spoon	1
		Tape	1 roll
		Sugar	5 g
		Alum	5 g
		Ammonia	30 mL
		Paper towel	1
		Tincture of iodine	15 drops
		Cracker	1
		Sugar cube	1
		Cheese	Any amount
		Notebook paper	Any amount
		Potato slice	Any amount
		Paper towel	Several
		Steel wool, ~1 g each ²	2
		Distilled white vinegar with 4 to 8% acidity	75 mL
		Baking soda	~2 g
	Teacher Demonstration	Beaker half full of water	2, any size
		Stir rod	1
		Plastic spoon	1
		Effervescent antacid tablet	1
		Table salt	5 g
		Balance (optional)	1

25	Weather Station Use a weather sensor to measure temperature, dew point, humidity and atmospheric pressure over a period of time and determine any correlation between the data collected to observable weather conditions.	Mobile Data Collection System	1
		PASPORT Weather Sensor	1
		PASPORT Sensor Extension Cable	1
		USB flash drive	1
		Weather Journal	1
		White plastic milk container with lid, 1.89 liter (0.5 gallon)	1
		Index card cut to 2-cm × 6-cm	1
		3-meter wooden stake	1
		Hammer	1
		Duct tape	1
		Masking tape	1
		Plastic utility tub	1
		Brick	1
		String	1 m
		Computer with Internet weather websites bookmarked	1
		Computer overhead projection system	1
		Grounded outdoor extension cord	1
		Clouds poster	1
		Weather maps	Several
		Utility knife	1
26	Dew and Frost Use a fast-response temperature sensor and a model to simulate the weather conditions responsible for the formation of dew and frost.	Data Collection System	1
		PASPORT Fast Response Temperature Sensor	1
		PASPORT Weather Sensor	1
		Beaker, 250-mL or cup or jar of similar size	1
		Stirring stick or spoon	1
		Crushed ice	180 mL
		Water, distilled	125 mL
		Salt	20 mL
		Rubber band	1
		Soda bottle terrarium	1
		Data Collection System	1
		PASPORT Temperature Sensor	1
		Potting soil	500 mL
		Gravel, vermiculite or perlite	200 mL
		Large bowl to mix the soil	1
		Pie pan	1
		Plastic storage bag, gallon sized, re-sealable	1
		Soda bottle, clear, cleaned, 2-L	1
		Small plants of the same variety	3
		Scissors	1
		Tape	Several pieces
		Water, warm	100 mL
		Dry ice, broken up	1 block
		Tongs for handling the dry ice	1

Master Materials and Equipment List

27	Microclimates Use a weather sensor to compare the temperature and humidity of various sites and determine the reason for any variations.	Mobile Data Collection System PASPORT Weather Sensor Notebook and pencil	1 1 1 each
	Teacher Demonstration	Data Collection System PASPORT Temperature Sensor PASPORT Weather Sensor Ecochamber or terrarium or house plants	1 1 1 1
28	How a Greenhouse Works: Light Use a temperature sensor to determine how light or brightness depends on the angle at which the sun's light strikes the surface of the ground and how this changes throughout the day.	Data Collection System PASPORT Light Sensor Reflector lamp or desk lamp with 60-watt incandescent light bulb Shoebox or cardboard box of comparable size White legal size typing paper, white butcher paper or white bulletin board paper, 21 cm × 28 cm (8.5 in. × 11 in.) Clear or transparent plastic wrap, 30-cm (12 in.) Wax paper, 30-cm (12 in.) Glad Press 'N Seal® Wrap, 30-cm (12 in.) Any other translucent material, such as parchment paper, paper towels, or sheer material, 30-cm (12 in.) Scissors Protractor Pencil Transparent adhesive tape Metric ruler and a meter stick	1 1 1 1 2 to 3 sheets 1 piece 1 piece 1 piece 1 piece 1 1 1 ~30 cm 1
	How a Greenhouse Works: Heat Use a temperature sensor to measure the heat generated in a model greenhouse by altering the types of material that light passes through.	Data Collection System PASPORT Temperature Sensor Greenhouse models from the "How a Greenhouse Works: Light" activity Light source such as a swivel desk lamp or reflector lamp with a 60-watt incandescent bulb Electric heating pad Scissors Metric ruler or meter stick Adhesive tape Clear plastic wrap, 30-cm (12 in.) Wax paper, 30-cm (12 in.)	1 1 1 1 1 1 1 ~30 cm 1 piece 1 piece

Activity by PASCO Sensors

This list shows the sensors and other PASCO equipment used in the lab activities.

Items Available from PASCO	Activity Where Used
Data Collection System	1, 2, 3, 4, 6, 8, 9, 10, 11, 12, 15, 16, 17, 18, 19, 20, 21, 22, 23, 24, 26, 27, 28, 29
Mobile Data Collection System	5, 7, 13, 14, 25, 27
PASPORT Fast Response Temperature Sensor	26
PASPORT Force Sensor	1, 9
PASPORT Light Sensor	4, 10, 15, 28
PASPORT Motion Sensor	2
PASPORT Sensor Extension Cable	4, 7, 11, 17
PASPORT Sound Level Sensor	11, 21
PASPORT Temperature Sensor	3, 5, 6, 8, 12, 13, 16, 22, 23, 24, 26, 27, 29
PASPORT Voltage Sensor	18, 19, 20
PASPORT Weather Sensor	7, 14, 17, 25, 26, 27

Grades 2-3

8. Freezing and Melting Water

Recommended Grade Levels: 2 – 3

Objectives

Students recognize that water can exist in different forms and can be changed from one form to another by heating or cooling.

Procedural Overview

To understand this content, students:

- Measure the temperature of their hand and the temperature of an ice cube
- Allow ice to melt in their hand and explain that heat from their hand caused the ice to melt
- Measure the temperature of a rock salt-ice bath and room temperature water
- Freeze room temperature water by placing it in a rock salt-ice bath

Time Requirement

■ Teacher Preparation	10 minutes
■ Get Started	10 minutes
■ Let's Explore	20 - 30 minutes
■ Explain It	15 - 20 minutes
■ Tell Me More	20 - 30 minutes
■ Sum It Up	10 minutes

Materials

☐ Data collection system	☐ Spoon
☐ Temperature sensor	☐ Rock salt-ice bath (2 - 3 per class) ²
☐ Ice cubes, in a small paper cup ¹	☐ Paper Towels
☐ Snack size plastic bag, re-sealable 16.5 cm × 8.25 cm	☐ Water, ~15 mL
☐ Tape	☐ Projection system (for the teacher only)
	☐ Ice chest (for the teacher only)

¹The ice cubes should each weigh about 0.5 g or less. Very small crushed ice will be about this size. Use enough ice cubes to fill the small paper cup about halfway.

²Combine rock salt, ice, and water in a plastic utility tub to create the rock salt-ice bath. Refer to the Preparation section for step by step instructions.

Activity at a Glance

Get Started

- ☐ Engage students by talking about life experiences they have had with water in different forms – ice, liquid water, or steam.

Let's Explore

- ☐ Have the students predict what will happen to an ice cube when it is placed in the palm of their hand.
- ☐ Students measure the temperature of their hand and the temperature of ice.
- ☐ Students describe what happened to the ice cube that was placed in their hand.

Explain It

- ☐ Define the term melting and explain that melting occurs when (enough) heat is added to an object.
- ☐ Explain that ice is the solid form of water and it exists in cold environments and water is the liquid form of water which exists in warm environments.
- ☐ Review the following vocabulary with the students: temperature, temperature sensor, solid, liquid, melting, and freezing.

Tell Me More

- ☐ Have the students predict how they can make water freeze.
- ☐ Students measure the temperature of the rock salt-ice bath and room temperature water.
- ☐ Students describe what happened when they put their water in the rock salt-ice bath.

Sum It Up

- ☐ Review with the students the different forms of water and melting and freezing.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

Let's Explore

Fill a small paper cup half full with crushed ice. Prepare one cup of crushed ice for each student group. Store the cups in the ice chest until they are used.

Tell Me More

Prepare 2 or 3 rock salt-ice baths for your students. Follow the steps below to make each rock salt-ice bath:

1. Fill a plastic utility tub half full with ice.
2. Add about 2 cups (300 – 400 grams) of rock salt to the ice.

3. Add enough water to cover the ice.
4. Stir the rock salt-ice bath to dissolve as much of the salt as possible.

Background

Forms of Matter

Matter exists in three main forms: solid, liquid, and gas. The form that matter exists in depends on the temperature of the environment it is in. For example, water exists as a solid (ice) when the temperature is 0°C or lower, as a liquid when the temperature is between 0°C and 100°C , and has a gas (vapor) when the temperature is 100°C or higher.

Changing Forms of Matter

Matter can change from one form to another form by adding and removing heat. Melting is the process of matter changing from a solid to a liquid and boiling is the process of matter changing from a liquid to a gas. Both melting and boiling require that heat be added. All matter will melt and boil at a unique temperature called the melting point and boiling point. Water, for example melts at 0°C and boils at 100°C . At the melting and boiling point two forms of matter exist simultaneously.

Matter can also change from one form to another by having heat removed (cooling). Freezing is the process of matter changing from a liquid to a solid and condensation is the process of changing from a gas to liquid. Both freezing and condensing require that heat be removed from the matter.

Temperature and Heat

The terms heat and temperature are used differently in everyday conversation than they are in science. In everyday conversation heat is the quality of being hot or having a high temperature and temperature is a measure of the amount of heat present in an object. The definitions are very similar and in many cases the words are used interchangeably. This activity sets the stage for the students to understand the scientific difference between heat and temperature, but still uses the common definitions that students are familiar with. Developmentally, elementary school aged students are not ready to differentiate between heat and temperature.

In science, the terms heat and temperature are different. An understanding of the atomic nature of matter is necessary to understand the difference between heat and temperature. Matter is made up of particles (atoms or molecules) that are constantly moving. Since the particles are moving they have kinetic energy. Temperature is a measure of the average kinetic energy of the particles in a substance. Hot objects contain particles that move fast and therefore have high temperatures. Cold objects, on the other hand, contain particles that move slower and therefore have lower temperatures. Temperature can easily be measured using a temperature sensor or thermometer.

Heat is the transfer of energy from one object to another because of a difference in temperature. Heat is different than temperature in two main ways. First of all, heat cannot be measured directly. Heat is often confused with temperature because temperature changes are used to indirectly measure heat. The second difference is that an individual object does not contain heat. For energy to transfer, two objects, with different temperatures, must be present. Energy from the hotter object will transfer to the cooler object. Although individual objects do not contain heat, they do contain thermal energy. Thermal energy is the total internal kinetic energy of all the particles that make up an object.

Activity with Answer Key and Teacher Tips

There is a box next to each step. (□) If you find it helpful, place a check mark in the box after you complete that step.

Driving Questions

This activity investigates the following questions:

- What are the different forms of water?
- How does water change from a solid to a liquid and from a liquid back to a solid?

Get Started

1. ☐ Have a discussion with your students about their experiences with the different forms of water (ice, liquid water, and water vapor or steam).

Q Where do we find water?

Q Can water be found in different forms (solid, liquid, gas)?

Q Where have you seen solid water (ice)?

Q Where have you seen liquid water?

Q Does water exist as a gas? How do you know?

2. ☐ Ask your students if they have ever noticed water on the grass or windshields of cars when they come to school in the morning. Explain to the students that this water is called dew. Ask the students what happens to the dew on mornings when it is very cold outside?

On very cold mornings, the dew freezes into ice (frost).

3. ☐ Ask the students, what happens to the ice on the grass after the sun comes up?

When the sun comes up, it warms the earth and the ice (frost) will melt. If you live in a very cold area, where frost can stay all day, be sure to direct student thinking to times when the frost will melt.

4. ☐ Have your students brainstorm ideas about how water changes from one form to another.

Q How can liquid water be changed into ice (solid water)?

Q How can ice (solid water) be changed into liquid water?

Q What is the difference between liquid water and ice (solid water)?

Let's Explore

In this section the students explore melting.

5. ☐ Ask your students to predict what will happen to an ice cube when it is placed in the palm of their hand. Have the students make their prediction and explain their thinking on the student response sheet under student response 1.
6. ☐ Use your classroom projection system to guide the students through the following steps to determine the temperature of their hand:
 - a. Start a new experiment on the data collection system.
 - b. Connect the temperature sensor to the data collection system.
 - c. Create a digits display of temperature.
 - d. Begin data recording.
 - e. Have the students place the tip of the temperature sensor in the palm of their hand.
 - f. Have the students wait until the temperature stabilizes (about a minute) and then stop data recording.
6. ☐ Have the students write the temperature of the ice cube under student response 2.
7. ☐ Ask the students whether they think the temperature of the ice cube will be greater than, lower than, or equal to the temperature of their hand.

The students should predict that the temperature will be lower than their hand because an ice cube feels cold.
8. ☐ Pass out a small paper cup half full of ice cubes and a paper towel to each student.
9. ☐ Have the students measure the temperature of the ice cubes:
 - a. Begin data recording.
 - b. Have the students submerge the tip of the temperature sensor in the cup of ice.
 - c. Have the students wait until the temperature stabilizes (about a minute) and then stop data recording.
10. ☐ Have the students write the temperature of their hand under student response 2.
11. ☐ Direct the students to place the ice cube in their hand and watch what happens.
12. ☐ Continue to have the students hold their ice cube until it has completely melted.
13. ☐ As students hold the ice, guide the students in a discussion to help them recognize that water exists as a solid (ice) and as a liquid (water).
 - Q What form of water is ice?
 - Q Is the form of water changing?
 - Q What is happening to your ice cube?

14. ☐ Once the ice cube has melted have the students clean up using their paper towel.
15. ☐ Have the students describe what happened when the ice cube was placed in their hand under student response question 3.

Explain It

Help your students understand that water can exist in different forms depending on the temperature of the environment the water is in. Also help the students to understanding that adding heat (warming) causes ice to melt while removing heat (cooling) causes water to freeze.

16. ☐ Have the students review what happened when the ice was placed in their hand.

Teacher Tip: One way to have students review is to have them turn to a neighbor and listen to what the neighbor says. Then when you call upon students, they tell you what their neighbor described.

17. ☐ Explain to the students that when a solid changes into a liquid this is called melting. Review with the students that ice is the solid form of water and the liquid form of water is simply called water.

Q What do we call the solid form of water?

Q Does ice exist in environments that are cold, warm, or hot?

Q What do we call the liquid form of water?

Q Does liquid water exist in environments that are cold, warm, or hot?

18. ☐ Explain to the students that adding (enough) heat to a solid will cause the solid to melt. Ask the students to think about where the heat came from that caused their ice cubes to melt.

The heat came from our hands (and the air). Look at the temperature data below to confirm this answer.

19. ☐ Remind the students that temperature is a measure of hotness and coldness and therefore, can be used to help us explain why the ice cube melted in our hands.
20. ☐ Ask the students to share their temperature data with the class. As the students share the temperature of their hand and the temperature of the ice record the values on a large table in front of the class.

Object	Student 1	Student 2	Student 3	Student 4	Student 5
Temperature of your hand:	31.6 °C	33.8 °C	35.6 °C	32.3 °C	34.9 °C
Temperature of the ice cubes:	1.6 °C	2.0 °C	1.0 °C	1.4 °C	2.4 °C

21. ☐ Ask the students how the temperature of their hand compared to the temperature of the ice. Which was hotter?

The temperature of the hand is much warmer than the temperature of the ice. Our hands are hotter than ice.

22. ☐ Help the students draw the following conclusions:

- Ice is the solid form of water and exists in cold environments.
- Water is the liquid form of water and exists in warm environments.
- Heating causes melting to occur.
- In this activity, the heat from our hand caused the ice cube to melt.

23. ☐ Now transition your students into the concept of freezing. Ask the students how liquid water can be changed into a solid (ice).

The students may suggest that the water will freeze if it is placed into a freezer or if it is placed outside on a very cold winter day. The students should realize that water has to be placed in a cold environment in order to freeze.

24. ☐ Have the students discuss freezing and melting by asking the following questions:

- Q What is freezing?
- Q What is melting?
- Q How are freezing and melting similar?
- Q How are freezing and melting different?

25. ☐ Review the following vocabulary words with your students. Relate each of the vocabulary words to the ice cube melting activity that the students just completed.

Temperature	A measure of hot and cold
Temperature sensor	An electronic tool that is used to measure temperature
Solid	A form of matter with definite shape and volume (example: ice)
Liquid	A form of matter with that takes the shape of its container and has a definite volume
Melting	To change from a solid to a liquid
Freezing	To change from a liquid to a solid

Tell Me More

In this section the students explore freezing. In this section, you will need 2 to 3 tubs of a rock salt-ice mixture for the students to share.

Freezing and Melting Water

26. ☐ Ask your students to predict how they can make water freeze. Have the students record their answer and explain their thinking on the student response sheet under student response 4.
27. ☐ Show the students the rock salt–ice bath and explain that adding salt to the ice water makes the water much colder than a normal ice–water mixture. Explain to your students that the method of adding rock salt to ice was used to make ice cream in the olden days.
28. ☐ Have the students measure the temperature of the rock salt–ice bath. Guide them through this process as necessary:
- a. Start a new experiment on the data collection system.
 - b. Connect the temperature sensor to the data collection system.
 - c. Create a digits display of temperature.
 - d. Begin data recording.
 - e. Have the students submerge the tip of the temperature sensor in the rock salt–ice bath.
 - f. Have the students wait until the temperature stabilizes (about a minute) and then stop data recording.
29. ☐ Tell the students to write the temperature of the rock salt–ice bath under student response 5.
30. ☐ Have the students pour one spoonful of water into a snack size, re-sealable, plastic bag.
31. ☐ Direct the students to take the temperature reading of the water in their bag. Guide them through this process as necessary.
32. ☐ Tell the students to write the temperature of their water under student response 5.
33. ☐ Have the students make sure that their plastic bag is completely sealed and then have them write their name on a piece of tape and use that piece of tape to secure their bag of water to the tub so that the water in the bag is completely submerged beneath the rock salt–ice mixture.
34. ☐ It will take between 10 and 15 minutes for the students' water to freeze. During this time guide the students through a discussion about what they expect to happen and why. The students should be able to explain that the temperature of the rock salt–ice bath is colder than the water and will therefore remove heat from the water. The students may or may not know that water freezes at 0°C . This is not the goal of this lab, but it may come up in the discussion.
- Q Do you think the rock salt–ice bath is cold enough to freeze the water in your bag? Why or why not?
- Q What form of water is in the bag?
- Q What form of water do you expect to form if the water is cold enough?

Q Is the rock salt-ice bath adding heat or removing heat from the water in your bag?
How do you know?

35. ☐ After 10 minutes, check the bags of water. Once the water has frozen have the students remove their bags from the rock salt-ice bath.
36. ☐ Allow the students a few minutes to observe the ice that has formed.
37. ☐ Have the students describe what happened to the bag of water that was placed in the rock salt-ice bath under student response 6.

Sum It Up

Review with the students what they have learned during this activity.

38. ☐ Review what the students have learned by having them answer the following questions:

Q What are two forms of water?

Q When does water exist as a solid?

Q When does water exist as a liquid?

Q What is melting?

Q What causes melting?

Q What is freezing?

Q What causes freezing?

Further Investigations

Have the students continue their exploration of melting and freezing by making ice cream or popsicles.

Have the students test whether or not the mass of water changes when it freezes or melts. The students should find that solid and liquid water have the same mass.

Incorporate the third form of matter, gases, by having the students explore boiling and evaporation. Have the students investigate what happens when water is left in an open container versus a closed container.

Have students use a mobile data collection system to find the temperature of the water in the school's drinking fountains and sinks.

1. What will happen to an ice cube when it is placed in your hand? Darken the circle of the best answer.

- ☐ Ⓐ The ice cube will melt.
- ☐ Ⓑ The ice cube will freeze.
- ☐ Ⓒ Nothing will happen to the ice cube.

Explain your thinking:

Because the ice gets hot in my hand. _____

2. Record the temperature data:

Temperature of your hand:	34.2 °C
Temperature of the ice cube:	1.4 °C

3. Describe what happened when an ice cube was placed in your hand.

The ice cube slowly melted. _____

The ice cube made my hand cold. _____

4. How can you make liquid water freeze? Circle the best answer.

- Ⓐ Add heat to the liquid (warm it)
- Ⓑ Remove heat from the liquid (cool it)
- Ⓒ Liquid water is not able to freeze

Explain your thinking:

I want the water to get colder.

5. Record the temperature data:

Temperature of rock salt-ice bath:	-3.7 °C
Temperature of the water:	22.5 °C

6. Describe what happened when the bag of water was placed in the rock salt-ice bath.

The water in my bag turned into ice.

9. Conservation of Matter

Recommended Grade Levels: 2 – 3

Objectives

Students determine that the weight of a whole object is the same as the sum of the weight of each part that makes up the whole object. Through this activity, students

- Learn that most things are made up of parts
- Observe properties of matter such as size, weight, and shape

Procedural Overview

To understand this content, students:

- Classify objects by weight (light objects versus heavy objects)
- Use a force sensor to graph the weight of different objects
- Compare the weight of the whole flashlight to the weight of all the pieces of the flashlight

Time Requirement

■ Teacher Preparation	10 - 15 minutes
■ Get Started	15 - 20 minutes
■ Let's Explore	20 -30 minutes
■ Explain It	15 - 20 minutes
■ Tell Me More	20 - 30 minutes
■ Sum It Up	15 - 20 minutes

Materials

☐ Projection system (for the teacher only)	☐ Objects of varying weights, 1 to 5 pounds (4) ¹
☐ Data collection system	☐ Flashlight (containing D batteries)
☐ Force sensor, with hook attached	☐ Object made of parts, 1 to 5 pounds ²
☐ Bag, to attach to force sensor hook	

¹The objects could be a textbook, bottle of water, large box of crayons, hand weight, an orange, hammer, and others.

²Ideas include a student backpack, a lunch box, a large bolt with a nut and washer attached, tool box, and others.

Activity at a Glance

Get Started

- ☐ Discuss with the students the meaning of the term “weight” by having the students classify objects as heavy (less weight) and heavier (more weight).
- ☐ Discuss how weight is measured and introduce the force sensor as a tool that is used to measure weight.
- ☐ As a class explore how the force sensor is used and interpret graphical data that is collected using the force sensor.

Let's Explore

- ☐ Ask students to identify and list as many parts of a flashlight as they can.
- ☐ Have the students make a prediction about how the weight of a flashlight compares to the weight of all the pieces of the flashlight.
- ☐ Have the students test their predictions using a force sensor (which measures weight). To do this, the students will graph the weight (force) of the whole flashlight and then the weight (force) of all the parts of the flashlight.

Explain It

- ☐ Explain the terms weight, whole, parts, and force (weight) sensor.
- ☐ Review the meaning of the data that was collected in the Let's Explore section.
- ☐ Explain to the students that scientists have to test an idea many times before it is accepted as a scientific theory or law. Then test the weight of a whole and its parts using another object.

Tell Me More

- ☐ Students are assigned an additional object that is made of parts to explore (such as a filled backpack, a lunch box, or a tool box).
- ☐ Students record the object they are testing, the parts it is made of, and a prediction of how the weight will compare between the whole object and the parts of the object.
- ☐ The students use the force sensor to determine the weight of the whole object and the object broken into its pieces. They record their results and write a conclusion about what they have learned.

Sum It Up

- ☐ The students share the results and conclusion from the Tell Me More section with the rest of the class.
- ☐ The students discuss what they have learned about weight, whole objects, and parts of objects.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

1. Set up the data collection system to display a graph of Force, pull positive versus Time:

- a. Starting a new experiment on the data collection system.
- b. Connect the force sensor to your data collection system.
- c. Create a graph of Force, pull positive on the y-axis and Time on the x-axis.
- d. Force is displayed in units of newtons. Optionally, change the units of force to pounds.

Note: Leaving the force measurement in newtons will result in larger numbers (and more whole numbers) that may be easier for the students to understand when showing the students that the sum of the parts equals the whole.

- e. Practice recording runs of data.
 - f. Practice hiding runs of data.
2. Practice connecting the data collection system to your classroom projection system and projecting the data you record in front of the class.

Background

Wholes versus Parts (Conservation of Matter)

The law of conservation of matter states that matter cannot be created or destroyed during any physical or chemical change (the law of conservation of matter does not apply to nuclear reactions, where matter may be changed to energy). Thus, when an object is broken into its parts, the weight of the whole object is equal to the sum of the weight of each part. This is an important concept for the students to develop because it prepares them for understanding the law of conservation of matter at the atomic level in chemical reactions and physical changes in later grades. This is also a great way of helping students understand that almost all things are made up of parts which will lead to the idea that some things are made up of parts that are too small to see without magnification.

Weight (versus Mass)

What is mass, and how is it related to weight? If you hold a watermelon at arm's length and shake it, you will find it more difficult to shake than if you were holding an inflated balloon. This would be true whether you were standing on the Earth, on the moon, or in space far from any planet or star. Mass is the amount of matter in an object. In common daily language we often hear the terms weight and mass used interchangeably. However, to scientists, weight is the pull of gravity on any object with mass. The more massive an object is, the more it weighs. In this activity, "heaviness" is actually "weight."

In this activity, the term weight is used instead of mass because mass is not generally understood by second and third grade students. Introducing the term mass too early may cause students to confuse the term mass with massive which may lead to misconceptions between the terms mass and size.

Force Sensor Explained

The force sensor measures pushes and pulls. In this activity, where it is used to find the weight of objects, it measures the pull of gravity on each object. Weight is what we call this pull. This is why you sometimes hear references to a person "weighing less on the moon" than on Earth. The

moon is smaller, and has less gravitational pull on objects because of this. The property that does not change is mass. If you actually did travel to the moon, your mass would remain the same, but gravity would pull you down with less force.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

How does the weight of a whole object compare to the weight of the parts of that object?

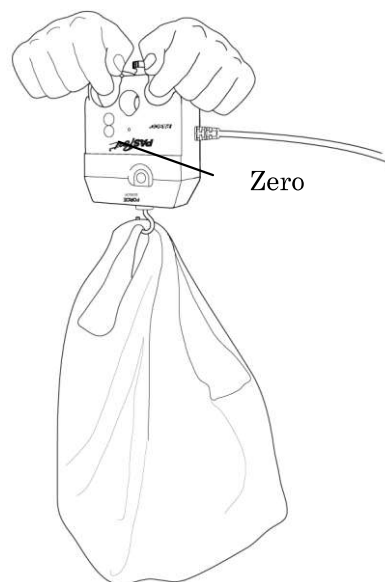
Get Started

1. ☐ Provide each student group with four objects of varying weights between 1 and 5 pounds (such as a textbook, a piece of fruit, a hammer, and a box of crayons). Have the students classify the objects as light (weight) or heavy.
2. ☐ Ask the students how they decided which objects were light weight) and which objects were heavy.
3. ☐ Explain to the students that heavy objects have a lot of weight and light objects have less weight. Then, ask the students how weight can be measured.

Weight can be measured using a scale or a balance such as a bathroom scale or a triple-beam balance).

4. ☐ Explain to the students that a force sensor, like a balance or a scale, can be used to measure weight. Show the students the force sensor and how it can be used to compare the weight of different objects.
 - a. Project a graph of Force, pull positive on the y-axis and Time on the x-axis in the front of the room.
 - b. Have a student hold the force sensor with a bag attached to it.
 - c. Have the student press the zero button on the force sensor.
 - d. Add an object the students classified as “light” to the bag. Then collect data for 30 seconds.
 - e. Explain to the students that the y-axis is measuring the force weight) of the object and state the weight (with units) of the object being measured. Then ask the students:

Q Where would you expect the graph of an object that weighs more (is heavier) to be



on this graph?

Q Where would you expect the graph of an object that weighs less (is lighter) to be on this graph?

Q Where would you expect the graph of an object that has the same weight to be on this graph?

Teacher Tip: If you are projecting on a whiteboard, write the name of the object on its graph and then write more weight above, less weight below, and equal weight next to the line. You can also write these words on pieces of paper and have the students tape them onto the projected graph.

- f. Remove the object from the bag and hold up an object that the students classified as “heavy” and ask the student to predict whether the graph will be above or below the first object tested.
- g. Add the object to the bag and then collect a run of data for about 30 seconds.
- h. Discuss the results with the students by asking the students:

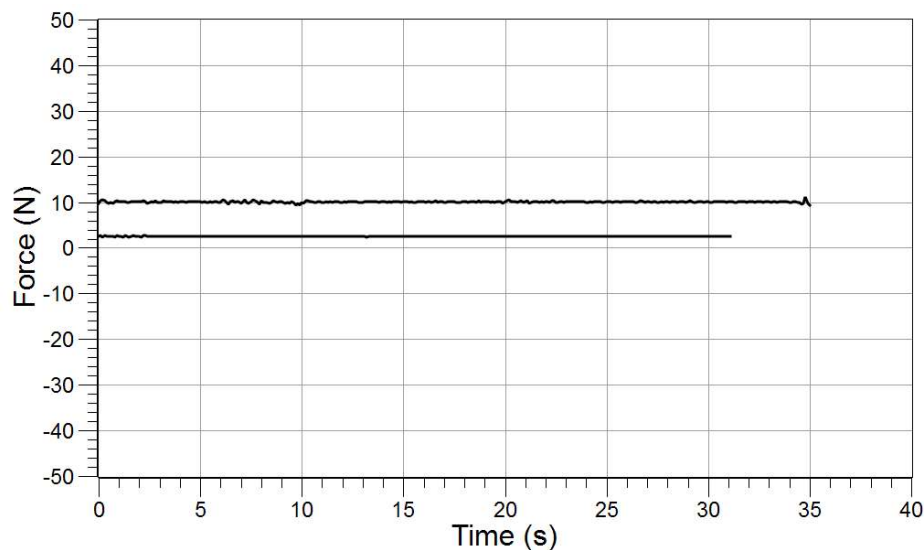
Q Was our guess correct?

Q Does object 2 have more weight or less weight than object 1? How do you know?

- i. Have the students predict which object is lighter than both and collect a run of data to determine if they were correct or not.

Sample Data:

Light and Heavy Objects



Let's Explore

5. ☐ Tell the students that many objects are made up of parts. Have the students pick an object that is made up of parts and list the parts.
6. ☐ Show the students a flashlight and ask them to identify as many parts of the flashlight as they can.

A flashlight is made up of a case, switch, light bulb, batteries, lens, and lid.

7. ☐ Ask the students whether or not taking the flashlight apart changes its weight. Have the students circle their prediction and explain their thinking on the student response sheet under student response numbers 1 and 2.
8. ☐ Have the students test their predictions using the force sensor. Guide the students through the following steps:
 - a. Turn on the data collection system and start a new experiment.
 - b. Connect a force sensor to the data collection system.
 - c. Create a graph of Force, pull positive on the y -axis and Time on the x -axis.
 - d. Place a bag on the hook of the force sensor.
 - e. Press the zero button on the force sensor.
 - f. Place the flashlight inside the bag.
 - g. Collect data for 60 seconds.
 - h. Remove the flashlight from the bag.
 - i. Take the lid off the flashlight and remove the batteries.
 - j. Place the lid of the flashlight in the bag.
 - k. Start collecting data.
 - l. Adjust the scale of a graph.
 - m. After 20 seconds, gently place the case of the flashlight into the bag.

Teacher Tip: If an object is dropped in the bag the graph will spike due to the acceleration with which the object hits the bag.

 - n. Wait 20 more seconds, and then gently place the batteries into the bag.
 - o. After 60 seconds, stop data collection.
 - p. Save the experiment.
9. ☐ Have the students copy the Force (weight) versus Time graph that they collected on under student response number 3.

10. ☐ Discuss the results with the students by asking the following questions:

Q What was the weight of your whole flashlight?

Q Was the weight of all the pieces together more than, less than, or equal to the whole flashlight? How do you know?

Q Why does the graph with the parts of the flashlight look like steps?

11. ☐ Have the students write their conclusion about the relationship between the weight of a whole flashlight and the weight of all the parts of the flashlight under student response number 4.

Explain It

12. ☐ Go over the following vocabulary words with your students. Relate each of the vocabulary words to the flashlight activity they just completed.

Weight	Heaviness
Whole	Together in one piece
Part	A piece of an object
Force sensor	An instrument that is used to measure weight

13. ☐ Project a graph of sample data collected in the Explore It section. Review with the students the graphs that were collected and what they mean:
- Hold up the whole flashlight and ask the students what part of the graph represents the whole flashlight.
 - Take the flashlight apart and ask the students to explain how each part and all the parts together are represented on the graph.
 - Explain to the students that the weight of the flashlight is the sum of the weight of each individual piece added together. Walk the students through math using the sample data displayed:

Whole flashlight: 4.0 N

Flashlight parts: lid – 0.2 N, case – 0.8 N, batteries – 3.0 N (0.2 N + 0.8 N + 3.0 N = 4.0 N)

- Conclude that the whole flashlight weighs the same as all the parts of the flashlight added together.
14. ☐ Ask the students to list other objects in the room that are made up of parts.
15. ☐ Pick one of the objects that the students suggest (that weighs between 1 and 5 pounds and can easily be taken apart) and use the force sensor to test that the weight of a whole object equals the weight of all the parts of an object.

Teacher Tip: Objects that weight less than one pound can still be broken into parts and the sum of the parts will still equal the weight of the whole object. To test light weight object, an instrument more sensitive than the force sensor is needed.

16. ☐ Explain to the students that scientists have to test an idea many times before it is accepted as a scientific law. So far your students have tested the idea that the weight of the whole object is equal to the sum of the parts. It still needs to be verified by testing it a lot more.

Tell Me More

17. ☐ Give each student group an object that is made up of parts and have each student draw the whole object and the parts of the object under student response number 5.
18. ☐ Have the students work together in their group to come up with a prediction. Have the students write their prediction under student response number 6.
19. ☐ Have the students test their predictions using the force sensor. Guide the students through this process. If needed, refer to the steps listed in the Let's Explore section above.
20. ☐ Have the students copy the Force (weight) versus Time graph that they collected under student response number 7.
21. ☐ Have the students work with their group members to analyze their results and write their conclusion under student response number 8.

Sum It Up

22. ☐ Have the students share the results and conclusion from the Tell Me More section with the rest of the class.
23. ☐ Ask the students what they have learned about weight, whole objects, and parts of objects.

Further Investigations

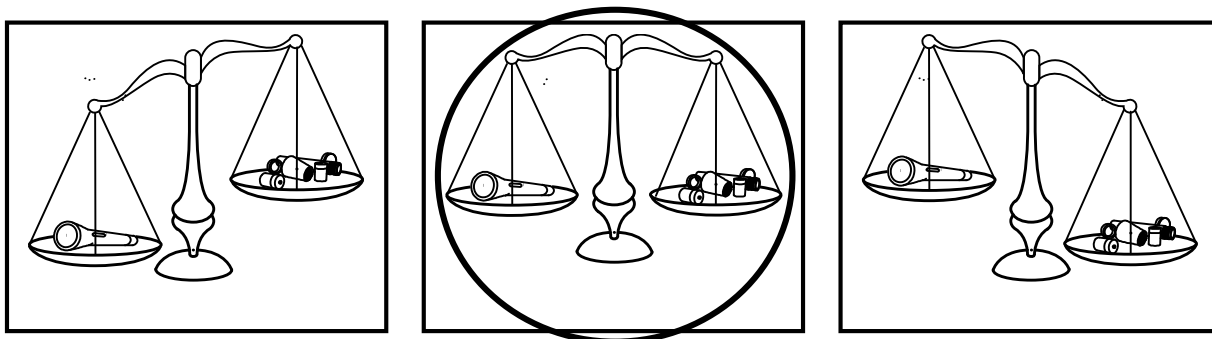
Have the students investigate the weight of ingredients in play dough and then mix the ingredients to make the play dough and weigh the final product. Take this a step further and investigate the properties of the individual ingredients and how they change when the final product is made.

Have the students investigate the conservation of matter during a phase change. Fill a 2-L bottle with water and weigh it. Then allow the water to freeze and weigh it again. The students should see that freezing and melting do not change the mass of the substance.

Further investigate the idea that most things are made of parts. Explain that sometimes the parts are too small to see without a magnification tool. Use magnifying glasses to look at the crystals that make up rocks or salt.

Have the students investigate whether or not changing the shape of an object (such as a piece of clay) changes its mass. Have the students weight a piece of clay. Then have the students shape the clay and weigh it again. The students should see that changing the shape of an object does not affect its mass.

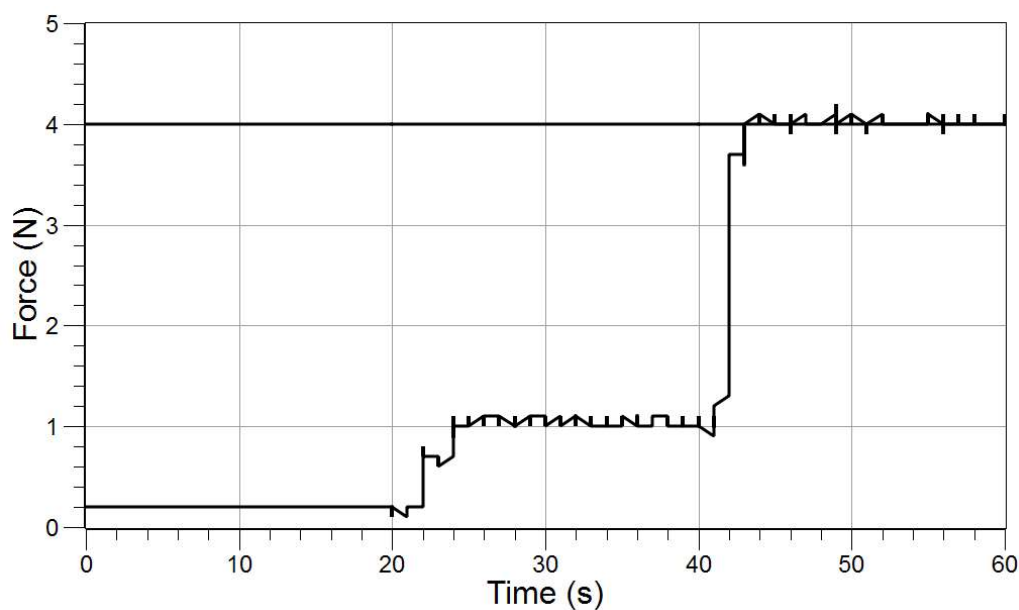
1. Predict: Circle the picture that you think best illustrates how the weight of a whole flashlight compares to the weight of all the pieces of a flashlight.



2. Explain your thinking:

The weight of each piece of the flashlight will equal the whole flashlight.

3. Draw the results from your experiment.



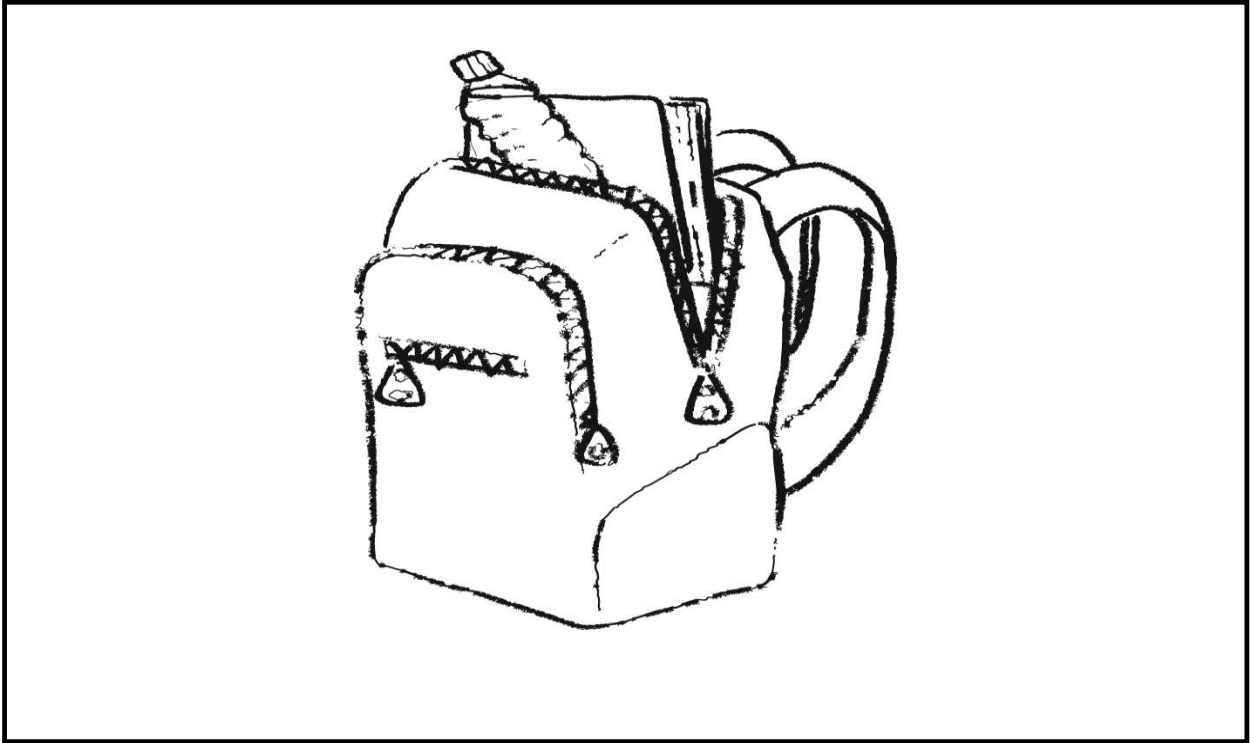
Whole flashlight and the Sum of the Flashlight Parts

4. Conclusion:

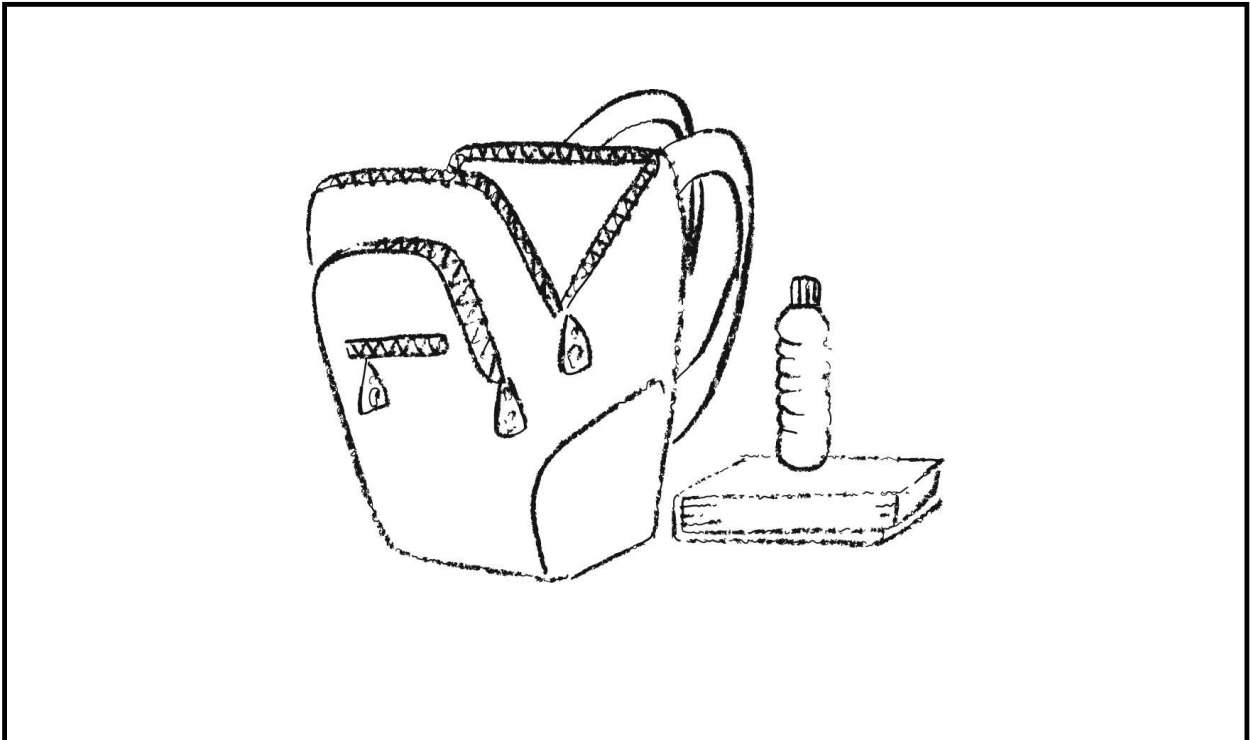
The weight of the whole flashlight equals the weight of all the parts.

5. Draw your object and the parts of your object.

Whole Object



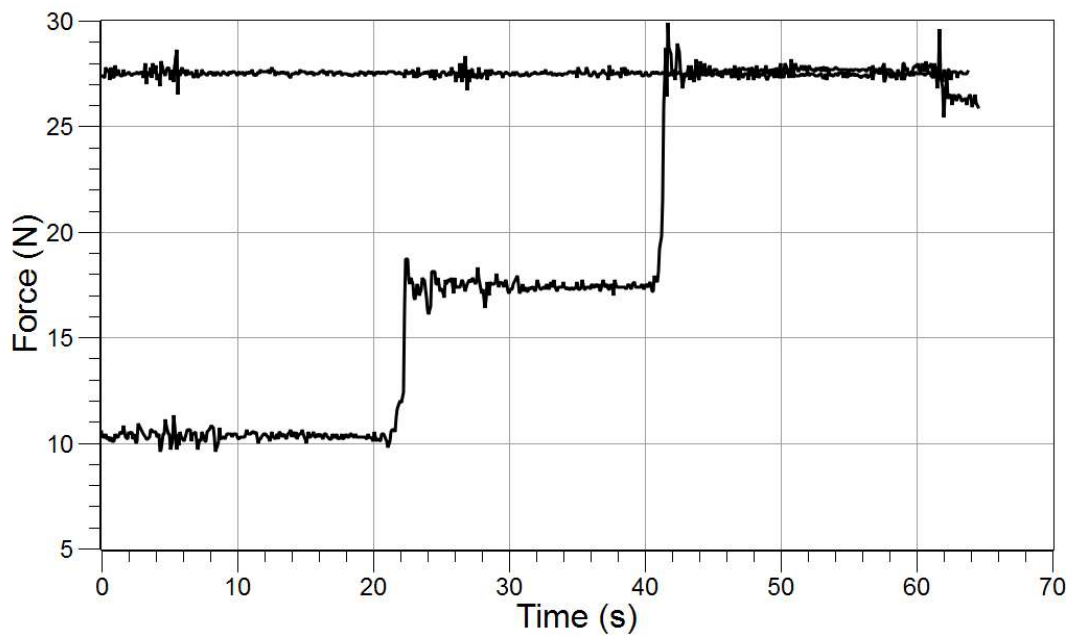
The Parts of My Object



6. The weight of the backpack will be
equal to the weight of all its parts.
(greater than, less than, equal to)

7. Draw the results from your experiment.

Whole flashlight and the Sum of the Flashlight Parts



8. Conclusion:

The weight of the backpack was equal to the sum of the weight of each part
of the backpack.

10. Hunting with Light

Recommended Grade Levels: 2 - 3

Objectives

Students compare how organisms, including humans, are able to see compared to what an electronic light sensor can detect. Through this activity, students:

- Learn the parts of the eye (iris, pupil, lens, pupil) and their functions
- Recognize that humans use light to see shape, color, size and brightness of matter
- Realize that light intensity measures the amount of light reflected or emitted by an object

Procedural Overview

To understand this content, students:

- Observe the eyes of other animals and discuss how the physical adaptations of their eyes help them survive
- Use the light sensor to measure the light intensity reflected from a variety of objects found in the classroom.
- Use the light sensor as an “eye” to hunt for an animal hidden on a paper.

Time Requirement

- | | |
|-----------------------|------------|
| ■ Teacher Preparation | 15 minutes |
| ■ Get Started | 30 minutes |
| ■ Let's Explore | 30 minutes |
| ■ Explain It | 20 minutes |
| ■ Tell Me More | 30 minutes |
| ■ Sum It Up | 20 minutes |

Materials

For teacher demonstration in the Get Started section:

- | | |
|---|---|
| ☐ Large eye diagram ¹ | ☐ Large pictures of animal eyes ¹ |
| ☐ Hand lens | ☐ Projection system |

¹Refer to the preparation section for obtaining these pictures.

For each student group:

- | | |
|--|---|
| ☐ Data collection system | ☐ Tissues, 1 per person |
| ☐ Light sensor ¹ | ☐ Paper, plain white, 2 per person |
| ☐ Objects ² (4) | ☐ Crayon, dark colored |

¹Set the sensitivity of your light sensor to the lowest level. If your light sensor has only one setting, you will have to do the activity outdoors.

²The students are given an opportunity to choose four objects. The objects should be small enough to fit on their desk.

Activity at a Glance

Get Started

- ☐ Discuss the parts of the eye (iris, pupil, lens, retina) and their functions.
- ☐ Students look at images of the eyes of other animals and discuss how the physical adaptations of their eyes help them survive.

Let's Explore

- ☐ Students list characteristics of what they see: shape, color, size, brightness.
- ☐ Students use the light sensor to explore the amount of light reflected by different surfaces. They learn that the light sensor measures brightness.

Explain It

- ☐ Explain to the students, that humans, other animals, and the light sensor “see” by having light enter their eyes.
- ☐ Differentiate between a light source and reflected light.
- ☐ Review the following vocabulary with the students: pupil, lens, iris, retina, reflect, brightness, light intensity.

Tell Me More

- ☐ Students cover their eyes with a tissue to learn about limited sight.
- ☐ Students try to find an animal hidden on a piece of paper by using their light sensor.

Sum It Up

- ☐ Students analyze their experience of “hunting with light” and relate the experience to what they have learned about light intensity in this activity.
- ☐ Students review how organisms, including humans, see compared to what an electronic light sensor can detect.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not look directly into a light source; you could damage your eyes.
- Do not move around the room with your eyes closed or covered unless a friend guides you.

Preparation

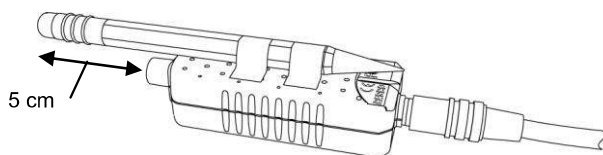
These are the materials and equipment to set up prior to the activity.

Get Started

- You will need the large illustrations of the human eye and the animal eyes provided at the end of the lab. You should copy them as large as possible. Alternatively, you can display the images on a computer projection system, or use a trade book of animal eyes. A third option would be to prepare a PowerPoint® of animal and human eyes.

Let's Explore and Tell Me More

- Set up your data collection systems in advance:
- Start a new experiment on the data collection system.
- Connect the light sensor to the data collection system.
- Display the light intensity in a digits display.
- Practice collecting a couple of runs of data.
- Project the digits display so that all the students can see it.
- Tape a pencil onto the light sensor, so the students will only hold the light sensor a standard distance from the objects they are measuring. A good distance is 5 cm.



Background

The Human Eye

Vision is a very powerful sense, and our eyes are complex and unique in the animal kingdom. Features that make our eyes unique include a full range of vision, binocular vision, and our ability to see in three dimensions. Only higher apes share the full range of vision that we possess. Binocular vision means that both eyes are able to focus on one point, and each eye sends

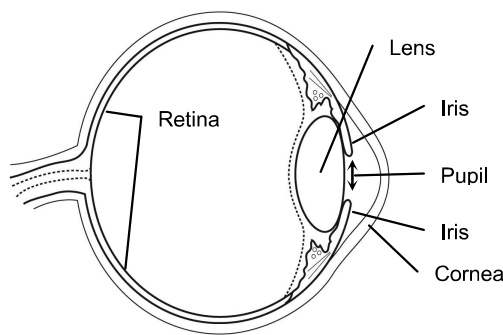
its data to the brain where it is combined with data from the other eye. This stereoscopic combination of perspectives allows us to place objects in three dimensions.

We see when light from a light source reflects off surfaces and enters our eye through the pupil, passes through the lens and falls on the retina in the back of the eye. Cells in the retina are stimulated and send their signal to the brain where the image is interpreted.

Some children think that our eyes beam out a light which helps us see. This idea is fed by comics of super heroes with laser vision. To help counter this misconception, guide students to realize that they can see in the dark once their eyes adjust to low light.

Parts of the Human Eye

The important parts of the eye for students to understand include the iris, the lens, the pupil, and the retina. The iris is the colored part of the eye and the color is an inherited characteristic. The pupil is the opening in the center of the iris which expands and contracts to let in less light when it is very bright out, and more light when you move into a dark room. A fun thing for students to watch is the expansion of the pupil (and the contraction of the iris) when a light is suddenly turned on after it has been dark. It is amazing to young children that the pupil is a hole in the eye covered by a thin clear film called the cornea.



The lens sits right behind the pupil. A hand lens, magnifying glass, or any convex lens can model the lens of the eye. The lens focuses light on the retina.

The retina is the back lining of the inside of the eyeball that contains special cells called rods and cones. When light enters the pupil and lands on any of these sensitive cells, they send a signal to the brain that allows you to understand what you are seeing. A healthy retina is critical for vision. You cannot see the retina by looking at your eyes in a mirror, so it is hard to talk about the retina with young children. Children can understand that the retina is the inside of the eye where the light goes after it enters the eye.

Summary of Animal Eyes and Vision

Animals have different kinds of eyes and see the world differently because of the shape of their lenses and pupils, the position of their eyes on their heads, and the complexity of their retinas. These are called physical adaptations and help the animal survive. You may want to get a book on animal eyes and leave it out for your students to use during this investigation.

The following animals have color vision: humans, chimpanzees and apes, birds, diurnal lizards (those active during the day), turtles, and some fish. Most other mammals see in shades of gray, including dogs. Most fish see everything with an amber hue. Bees and butterflies can perceive ultraviolet light, but see the color red as gray or black. Predators have eyes facing forward and prey animals have eyes on the sides of their heads. Some predators have pupils that converge into vertical slits to restrict the amount of light that enters the eye and allow them to focus directly on their prey.

Hoofed grazing animals have horizontal slits in their pupils to see the horizon better. This allows grazers to watch for predators on the horizon. Some animals have weak eyes or are blind if they live underground, like moles and shrews. Some animals have eyes up on stalks or tentacles to see around corners, like snails or lobsters. Insects and spiders have a variety of compound eyes

(more than one lens per eye) or multiple eyes (6 or 8 simple eyes per animal). The animals with the sharpest long range eyesight of all are birds of prey.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Questions

This activity investigates the following questions:

- What parts are eyes made of?
- How do organisms, including humans, see compared to what an electronic light sensor can detect?

Get Started

In this section students learn about the parts of the eye and compare the eyes of a variety of animals.

1. ☐ Have students pair up and look very closely into the eyes of their partner. The goal is to examine the iris and the pupil.
2. ☐ While students are paired, darken the classroom. It will be hard for them to continue to see details of their partners' eyes, but encourage them not to look away. At the count of three, turn on the lights and tell students to watch their partner's pupils contract.
3. ☐ Ask students what the black part that changed its shape is called. If they don't know write the word pupil on the board. Explain that it is an opening in the eye for light to go in. It is covered over by a clear film so dirt can't get into your eye, but light can.
4. ☐ Ask students' "Why do our pupils contract and expand?"

Students will say that pupils contract or expand to let in different amounts of light. Sometimes the light is too bright, so the pupil contracts to let in less light. Other times it is dark, so the pupil expands to let in more light. (Actually, the iris expands and contracts, changing the size of the pupil which is just an opening.)

5. ☐ Show the diagram of the human eye and point out the pupil and the iris.
6. ☐ Have the students look at their partners eyes again and discuss the following questions:

Q Look at one iris. Is it all the same color or many different colors?

Q Compare the iris in both of your partner's eyes. Are they identical?

Q Look at the pupils in both of your partner's eyes. Are they identical?

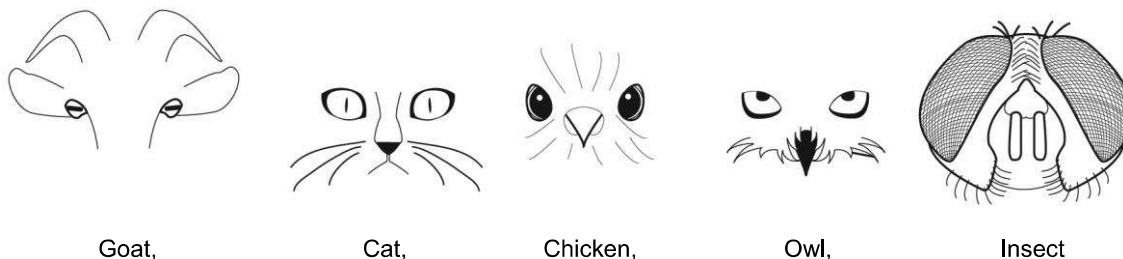
7. ☐ Explain to the students that while irises are different from person to person the pupils are all the same.
8. ☐ Point out the lens on the eye diagram. Show students that the lens is clear and curved, just like the glass in a hand lens or magnifying glass, or like a pair of glasses. Everybody has one lens in each of their eyes, behind the pupil.

9. ☐ Discuss with students the question, “What could a lens be for?” Tell them to think about glasses, and why people wear glasses.

Students will think about glasses helping us see better. We have a lens in our eye to help us see. The correct expression is that the lens changes the direction of the light when light passes through it, so that the light is focused on the back of the eye.

10. ☐ Pass a hand lens around the class so that students can feel that it is thicker in the middle and thinner on the edges, just like the lens in our eyes.
 - When students look through the hand lens, they can see that it makes close things larger.
 - Explain that the lens helps us see by focusing the light so that it strikes the retina in the back of our eye.
11. ☐ Discuss the last important part of the eye, the retina, with your students. Explain that the retina is a layer of light receptors in the back of our eyes. The light receptors in the retina receive light and pass it onto our brain which allows us to see an image.

12. ☐ Put the images of animal eyes in a location for all students to see. Have students examine the images of animal eyes and guess what type of animal belongs to each type of eye.



13. ☐ Explain to the students that animals don't see things in the same way as we do. Have students roll up a piece of paper into a small tube and peer through it. Ask them to describe how this changes what they can see.

Students will notice that they can see much less of their surroundings. Point out that some animals have limited vision, and some animals are even blind because they always live underground.

14. ☐ Ask the following questions about the eyes of different animals:

- a. Why would a goat need a pupil that is horizontal? Have students hold their hands in front of their eyes with a horizontal slit between them for peeking through and ask them to describe how their view is changed.

Students will only be able to see a horizontal slit of a view, like a horizon. Herbivores are grazers, and need to keep an eye on the wide horizon for predators while they graze.

- b. Why would a cat need pupils that have a vertical slit? Have students hold their hands in front of their eyes with a vertical opening between the hands for peeking through and ask them to describe how their view is changed.

Students will see only a limited amount of light, but will be able to look very specifically at one thing in the center of their vision. This limits the amount of light but aids a predator in concentrating on his victim.

- c. Why would a little bird like a dove or a chick need eyes on the sides of its head?

Students may guess that it is to watch out for predators trying to sneak up on it. It is almost like having 360 degree vision.

- d. Why would an owl need two eyes straight forward like ours are?

Students will guess that it would help the owl spot prey down in the fields as it flies overhead. They see very much like we see, except that they have a special lens that acts like a magnifying glass. It makes the vision of birds of prey sharper than any other type of animal.

- e. What is different about the eyes of a fly?

Accept any answer. Tell them that the insect's eye is actually made up of dozens of lenses. It is called a compound eye.

Teacher Tip: If you have a magnifying glass or bug jar with a magnifying top, or a microscope, catch a fly or bee and display the eyes for students to look at closely.

15. ☐ Have students answer questions 1 and 2 on their student response sheet.

Let's Explore

In this section students explore the properties of human vision and compare them to the properties of how the light sensor “sees”.

16. ☐ Ask your students to describe the properties they see. Once they have described what they see, explain that not all animals “see” with the same properties. Use the following questions to help your students describe what they see.

Q Can you see different shapes?

Q Can you see different colors?

Q Can you see brightness and darkness?

Q Are some things too bright to look at?

17. ☐ Discuss with the students how animals see differently and why vision is important to the survival of animals. Use the following questions as needed:

Q Why is it important for animals to see?

Q Do all animals see the same colors that we, humans, see?

18. ☐ Explain to the students, that many animals see differently than humans see. Some animals do not see the same colors as we do. Some see more colors and some see fewer. Other animals do not see color at all, but rely on brightness (how light or dark something is) to survive. Refer to the table below (Properties of Vision in Animals).

Properties of Vision in Animals

Animal	Color Vision? (Number of primary colors seen)	Binocular Vision? (Good depth perception)	Other
Humans	Yes - trichromatic (three color vision)	Yes	
Apes and chimpanzees	Yes - trichromatic	Yes	
Monkeys	No – dichromatic (see blues and yellows better than greens and reds)	Yes	
Dogs	No - dichromatic	Yes, for the most part	Humans see distant objects better than dogs. Dogs see flickering objects better.
Cats	Yes, and perhaps better seeing blues than reds	Yes, almost as well as humans	See close objects better than far objects.
Birds of Prey	Yes, and can see in the ultraviolet range as well	Yes	The best far vision of all other animals.
Chickens	Yes - trichromatic	No –see with both eyes together but not nearly as well as with one eye at a time	
Fish	Yes, but limited. (closer to dichromatic)	No	
Lizards (Diurnal)	Yes - trichromatic	Yes	
Horses	No – dichromatic	Yes, but also see very well to either side	
Goats	No – dichromatic	Yes, but see better to the sides	

19. ☐ Show the students the light sensor that you have attached to your data collection system that is being projected.

20. ☐ With a digits display of light intensity displayed for all the students to see, point the light sensor toward a bright light. And ask the students, “What is the light sensor reporting?”

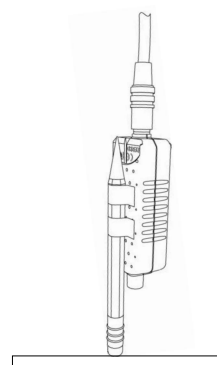
The student should report the number being displayed on the board.

21. ☐ Then move the light sensor to an area with less light and ask the students, “Now what is the light sensor reporting?”

Now the light sensor is reporting lower numbers.

Teacher Tip: You may have to move the light sensor back and forth from bright to dark several times to convince students that the light intensity values are significantly different.

22. ☐ Explain to the students that the light sensor measures light intensity which is a numerical value for the brightness of an object. High numbers mean higher light intensity. Lower numbers mean lower light intensity. Brightness is our perception of light intensity.
23. ☐ Explain that the units of light intensity are lux. Remind students of other units such as kilograms for mass and degrees Celsius for temperature.
24. ☐ Explain to the students that they are going to measure the light intensity of different objects in the room.
25. ☐ Have students select four objects and bring them to their desk. Have them order the objects on their desk from brightest to darkest.
26. ☐ Have students write their ordered prediction in Table 1 under student response question 3.
27. ☐ Guide the students through the process of determining the light intensity of their four objects.
- Start a new experiment on the data collection system.
 - Connect the light sensor to the data collection system.
 - Display the light intensity in a digits display.
 - Have the students hold the light sensor so that the pencil taped to the light sensor is touching the object.
- Teacher Tip:** The pencil is used to standardize the distance the light sensor is from the objects they are measuring.
- Begin data recording.
 - Once the light intensity value has stabilized, stop data recording.
 - Have the students record the light intensity into Table 1 under student response question 3.
 - Have the students repeat the process for their remaining three objects.



28. ☐ Help the students analyze their results to determine if their prediction is correct by asking the following questions:
- Q How do you know which object is the brightest based on the light intensity measured?**
- Q How do you know which object is the darkest based on the light intensity measured?**
- Q Did you rank them in the right order?**
29. ☐ Have the students re-list their objects according to their light intensity in Table 2 under student response question 4.
30. ☐ Ask, “How is the light getting into the sensor? Does the light sensor have a pupil and a lens like we do?”
- Students will notice the hole that looks like a pupil, and inside it they will see a glass bubble that looks like it could be a lens.
31. ☐ Under student response question 5, have the students draw a picture of the light sensor. On their drawing, have the students:
- Label the “eye” of the sensor.
 - Draw an arrow that shows the direction the light sensor is “looking”.

Explain It

Explain the difference between a light source and reflected light. Explain that humans, animals, and light sensors “see” when light enters their eyes, and that light intensity is a numerical measure of the brightness of light.

32. ☐ Review with your students that humans, animals, and light sensors all “see”, but that the properties they see can be different. Some animals, like humans, have very good vision and can see detailed shapes, lots of shapes, objects that are both near and far away, and a variety of colors. Other animals, however, may not be able to see as well, but their sight is good enough for them to survive.
33. ☐ Ask the students to summarize what they learned about what a light sensor “sees” compared to what humans see.
- The students should explain that a light sensor “sees” brightness and gives it a numerical value. Humans can see brightness and attach meaning to it. Humans see so much more than a light sensor and our brains give meaning to all we see.
34. ☐ Ask the students, “How do our eyes interact with light to allow us to see?”
- Light from an object enters our eye through the pupil and is focused onto the retina by the lens. The retina sends an image of the object to our brain which then helps us identify the object we are seeing.

35. ☐ Explain to students that our pupils expand and contract to control the amount of light that enters our eyes. The light sensor, on the other hand, has a fixed opening where light enters. We can control the amount of light entering our eyes, but a light sensor cannot. Therefore, the light sensor measures the actual amount of light in the environment while our pupils adjust the environmental light to meet our needs.

Teacher Tip: Remind students to think about the beginning of this activity when you were looking into your partner's eyes and the pupil changed.

36. ☐ Help students focus on the difference between reflected light and sources of light.

Q Name some things that produce their own light (shine)?

Q Can a lamp that is not plugged in produce light? Explain.

Q Did the objects you measured earlier produce their own light?

37. ☐ Explain to the students that light can enter our eyes directly from objects that emit their own radiant energy such as the sun or a light bulb. These types of objects are called light sources. Most objects, however, do not emit their own light. Instead, light from a light source hits the object and is reflected (bounced off) from the object. This reflected light enters our eyes and allows us to see the object.

38. ☐ Check for student understanding: ask them to tell you if the following items “give off light” or “reflect light.”

- The sun (Gives off light)
- A lake (Reflects light)
- A mirror (Reflects light)
- A flashlight turned on (Gives off light)
- A flashlight not turned off (Reflects light)
- A lamp turned on (Gives off light)

39. ☐ Review the following vocabulary terms with your students.

Iris	The colored part of the eye that controls the pupil size
Pupil	The opening in the center of the iris that lets light into the eye
Lens	Clear oval disc behind the pupil that focuses light on the retina
Retina	A layer at the back of the eye that contains light receptors. The light receptors receive light and pass the light information to the brain.
Reflect	When light bounces off of surfaces
Brightness	Our perception of the amount of light reflected or given off by an object
Light intensity	A numerical measure of brightness

Tell Me More

In this part of the activity, students play a game in which they hunt for an animal (hidden on a piece of paper) using the light sensor as their “eyes”.

One partner will be the “predator” and will hunt for the “prey” that the other partner has drawn on the piece of paper. The predator partner is allowed to see the screen of the data collection, but not the piece of paper with the animal drawn on it. The predator partner uses the light sensor to hunt for the “prey” that is drawn on the paper. The partner who has drawn the “prey” holds the paper screen to block the view of the predator partner. The predator partner will find the hiding animal when the reading on the display drops (the animal drawn in a dark marker reflects less light). The goal is to find the animal, but not necessarily to identify the animal.

40. ☐ Ask students to consider what it would be like if they were an animal whose eyes could only detect brightness (like a light sensor).
41. ☐ Give each student a tissue and ask them to hold the tissue over their eyes and look around. Have them discuss what they can and cannot see.
- Students will get a sense for how limited their vision becomes, and they will only be able to see brightness and dimness.
42. ☐ Give students a sheet of plain white paper and ask them to draw a secret animal somewhere on the paper (not necessarily the center) and fill it completely in with a solid dark color. Tell them to leave the rest of the picture bare. The animal should be at least as big as their fist. Tell them to make sure that their partner does not see their drawing.
43. ☐ Have the students use a second sheet of paper to screen their animal drawing from their partner’s view.

44. ☐ Ask students to predict if they can find the animal by using the light sensor measurement displayed on the data collection system. Ask them how they will know if they find the animal.
- Students will be able to use the light sensor. They will be looking for a change in brightness.
45. ☐ Have one partner place their animal paper on the desk with the paper screen blocking the view from the other partner.
46. ☐ Make sure the students have their data collection system set up to display light intensity in a digits display (to review this process see the Let's Explore section) and that their light sensor still has the pencil taped in the correct position.
47. ☐ Have one student hold the light sensor and "hunt" for the animal by watching the screen on the data collection system and have the other student hold a piece of paper up so that the first student can't see where the animal is.
48. ☐ When the student with the sensor thinks, by looking at the light intensity numbers displayed, that the animal has been located, they can shout, "I found you!" The other student should answer yes or no.
49. ☐ Have the students switch roles until all the students have had the opportunity to "hunt" for an animal.

Sum It Up

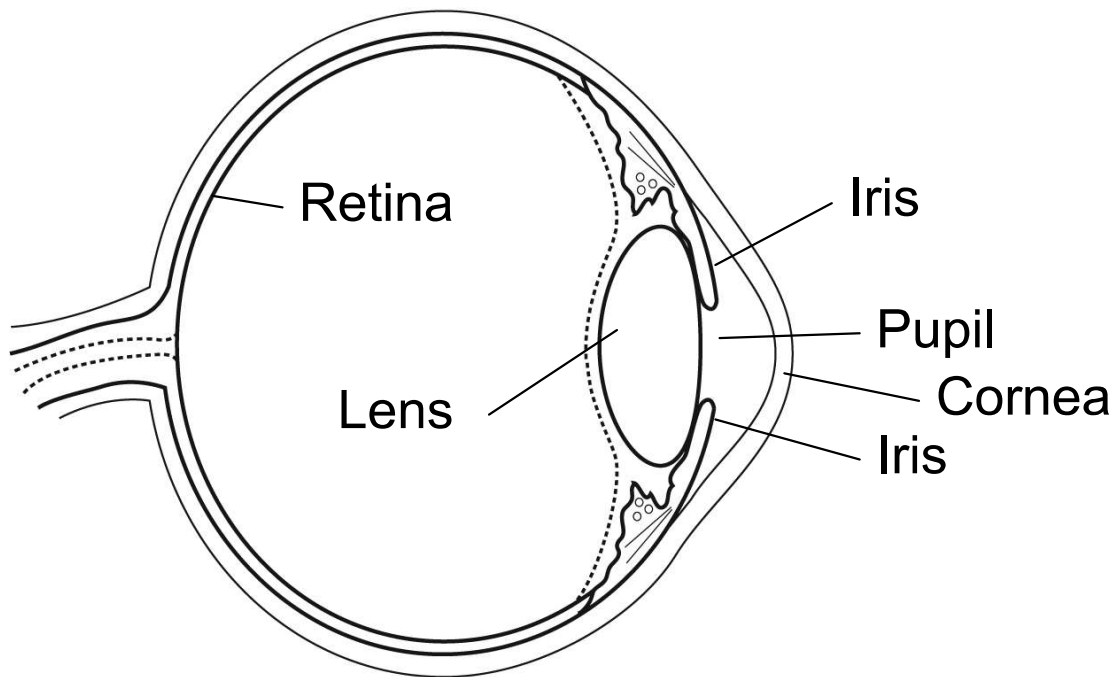
50. ☐ Review the hunting with light game by asking the students the following questions:
- a. How could you tell where the animal was based upon the light sensor measurement?
- Students will say that the brightness of the paper changed, and they saw the light intensity reading decrease.
- b. Did the color of the animal make a difference?
- Students will note that color does not help or hurt their ability to find the animal.
- c. Did the shape or size of the animal make a difference? Explain your answer.
- Shape or size does not make a difference.
- d. If an animal could only see brightness and darkness, would it be able to hunt for food?
- Answers will vary.
51. ☐ Complete the activity by having the student discuss the following questions:
- Q What are the main parts of an eye?**
- Q What is light intensity?**
- Q How do organisms, including humans, see compared to what an electronic light sensor can detect?**

Further Investigations

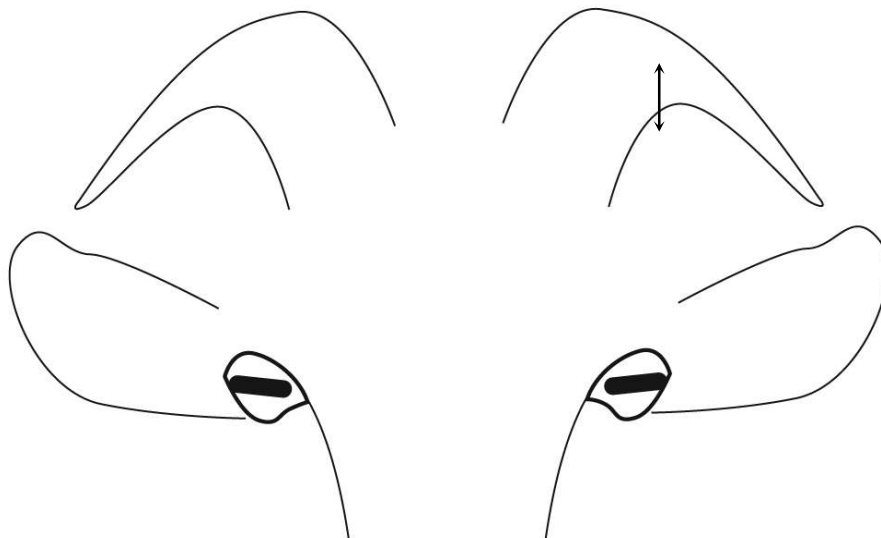
Your students may want to investigate camouflage, and how this tricks the vision of other animals. Have animal books about camouflage available for students. Connect camouflage to this discussion by identifying the predator and prey animals' type of eyes. Discuss if there is a connection between the type of eye and the camouflage strategy.

Teacher Resources

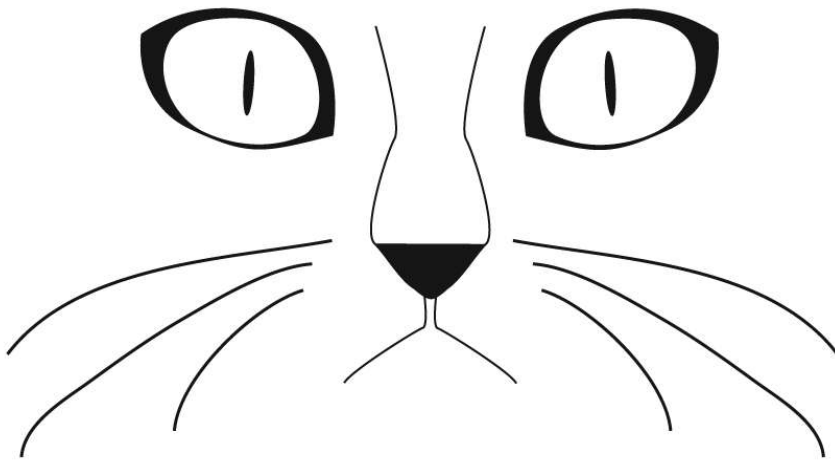
Diagram of the Human Eye



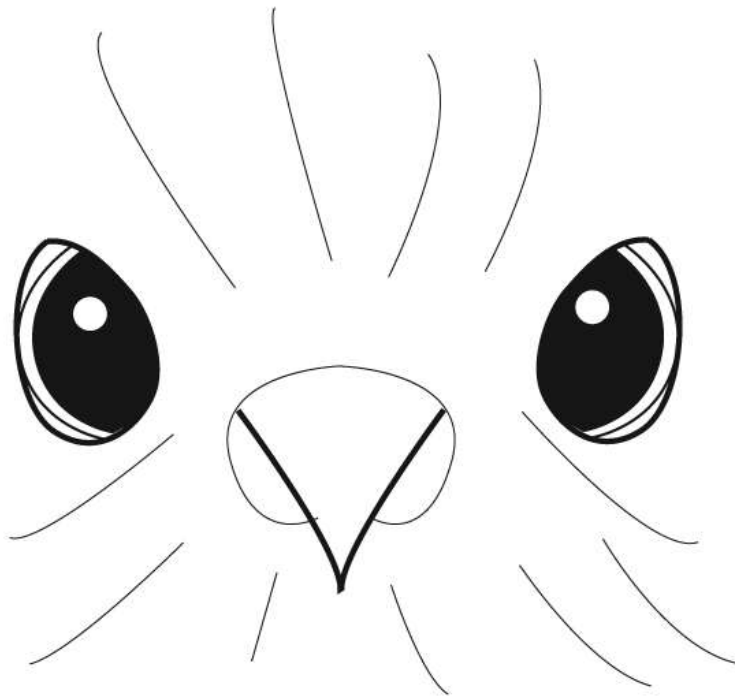
Images of Animal Eyes



Goat



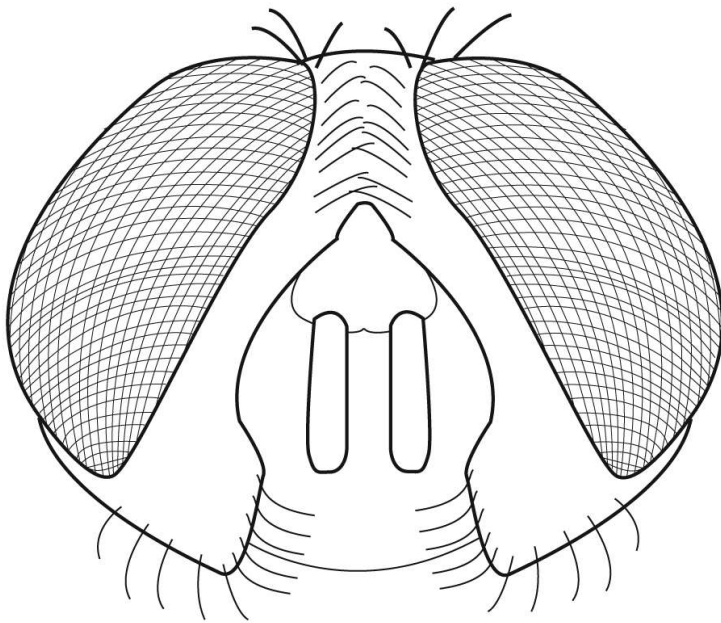
Cat



Chick

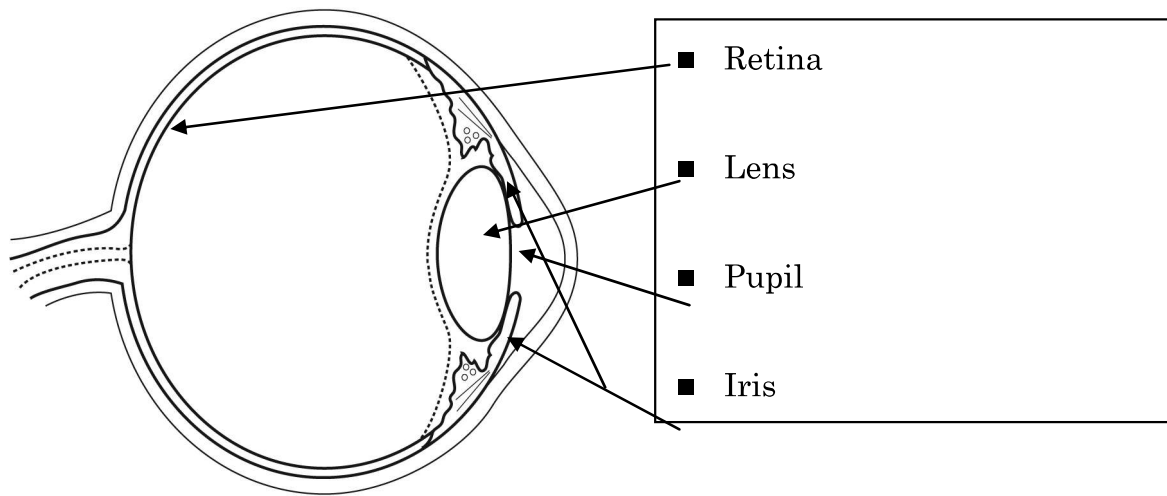


Owl

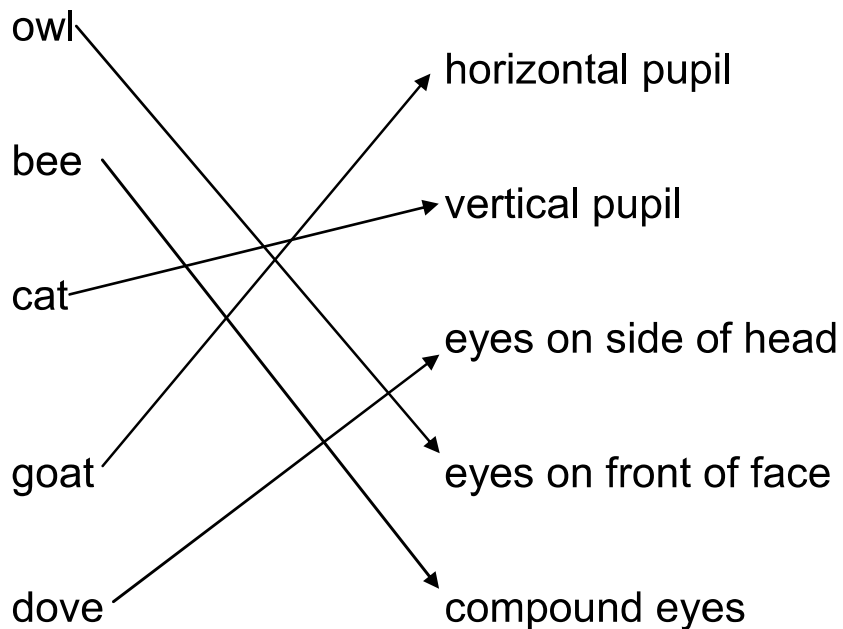


Insect

Draw lines from each word on the right to its location on the eye:



2. Draw a line from the animal to its shape of eye or pupil.



3. List the object you chose in order from brightest to darkest. Then measure the light intensity.

Table 1: Predicting the brightness of objects.

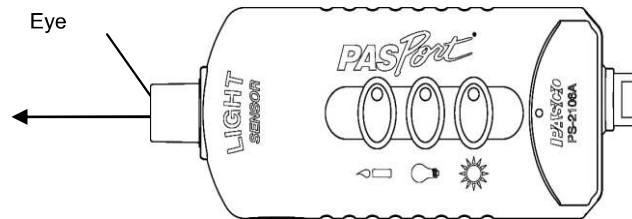
Bright  Dark	Name of Object	Light Intensity (lux)
	book	0.75
	eraser	0.83
	ruler	0.52
	binder paper	1.64

4. Re-list your objects according to their light intensity values. List the object with the most light intensity first.

Table 2: Objects listed according to light intensity.

Most intense  Least Intense	Light Intensity (lux)	Name of Object
	1.64	binder paper
	0.83	eraser
	0.75	book
	0.52	ruler

5. Draw a picture of the light sensor. Label the “eye” of the sensor and draw an arrow to show the direction it is “looking”.



11. Investigating Sound Levels

Recommended Grade Levels: 2 – 3

Objectives

Students recognize that continuous sound is made by vibrating objects, and can be described by its pitch and volume. Students explore different continuous sounds by studying the changing volume.

Procedural Overview

To understand this content, students:

- Describe sound volume using drawings and verbal descriptions
- Hum in a variety of ways near the sound sensor and test the effect of a “megaphone”
- Compare graphs of sound levels and draw conclusions about sound and vibrations

Time Requirement

- | | |
|-----------------------|-----------------|
| ■ Teacher Preparation | 5 – 10 minutes |
| ■ Get Started | 10 - 15 minutes |
| ■ Let's Explore | 10 - 15 minutes |
| ■ Explain It | 15 - 20 minutes |
| ■ Tell Me More | 15 - 20 minutes |
| ■ Sum It Up | 10 - 15 minutes |

Materials

- | | |
|---|--|
| ☐ Data collection system | ☐ Sensor extension cable |
| ☐ Sound level sensor | ☐ Sheet of paper to make a sound tube |

Activity at a Glance

Get Started

- ☐ Students hum while holding fingers over their throats to feel the vibrations of the vocal cords.

Let's Explore

- ☐ Students predict how the graph of a louder hum will differ from that of a quieter hum, and they record this prediction on the student response sheet.
- ☐ Students hum into the sound sensor at two different sound volume levels and compare their graphs.

Explain It

- ☐ Students make a variety of humming sounds into the sound sensor with their mouths closed and then again with mouths open. They compare the graphs of sound level.
- ☐ Review the following vocabulary with the students: vibration, volume, and sound level sensor.
- ☐ Students copy the sound level graphs onto the student response sheet.

Tell Me More

- ☐ Students hum into the sound sensor with a paper sound tube and then without the sound tube the same distance from the sensor. They compare the graphs of sound level.
- ☐ Students illustrate the function of a sound tube and the volume data on the student response sheet.

Sum It Up

- ☐ Guide a class discussion in which students share results and conclusions.

Safety

Add these important safety measures to your normal class procedures:

- Do not make loud noises close to other people's ears. You may damage their eardrum.

Preparation

These are the materials and equipment to set up prior to the activity.

- Prior to the activity, you may want to set up the data collection system to display a graph of Sound Level versus Time:
 1. Start a new experiment on the data collection system.
 2. Connect the force sensor to your data collection system.
 3. Create a graph of Sound Level versus Time.

Note: Sound level is displayed in units of decibels (dBA).

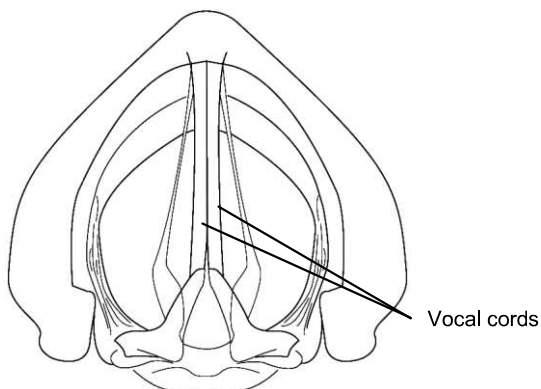
 4. Practice recording runs of data and hiding runs of data.
- If possible, connect the data collection system to the classroom projection system. Even if students will be using data collection systems in smaller groups, it is valuable to have the activity projected for reference with the whole class.

Background

Sound and the Vocal Cords

Vocal cords moving back and forth cause pressure variations in the air. These variations travel through the air and make the eardrum move when they arrive there. Young students may not understand the concept of air pressure. They may also notice that sounds travel through solid things and water. A way to describe it more simply is to say that the vibrations cause

disturbances in the air, or in a solid or water, as the case may be. These disturbances travel through the medium and cause a disturbance when they arrive at something that can vibrate, such as the surface of a drum.



Objects that vibrate within our range of hearing — 30 to 15,000 vibrations per second, or hertz (Hz) — and transmit that vibration to the air make sounds that we can hear.

Students often confuse loudness (amplitude of the vibration) with pitch (frequency of the vibration). Since our voices usually get louder as we raise the pitch, students may confuse these two factors. Be sure to focus the students on the same sound with different sound level intensities.

The Sound Level Sensor and Decibels

The sound level sensor displays measurements in units called decibels, abbreviated as dBA. The “A” in the abbreviation indicates that this is the “A-weighted” scale or system. Decibels are an expression of the relative loudness of sounds in air as perceived by the human ear. In the A-weighted system, a correction is made at low frequencies because the human ear is less sensitive below about 1000 Hz than it is at higher frequencies.

Decibels are defined in terms of power per unit of surface area, on a scale where 0 dB is just at the threshold of human hearing, up to the threshold of pain, which is considered to be between 120-140 dB. For example, the sound level of an average adult conversation is about 60 dB; average home entertainment (television and music) levels are about 85 dB; a loud rock concert is about 110 dB, and standing near a jet engine is about 150 dB.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- How can you make sounds at different volumes?

Get Started

Our throat muscles pull on our vocal cords, much like fingers pulling on a rubber band. The muscles pull less hard on them when we sing a soft note and pull harder when we sing a loud note. The windpipe carries air from our lungs to our mouth.

Students cannot observe their vocal cords directly, but they can feel how their vocal cords vibrate and hear how resulting sounds are made.

Note: Make sure that all of the students locate their vocal cords and feel them vibrating while they hum.

1. ☐ Have students hum softly to themselves while holding their fingers over their throats so they can feel their vocal cords vibrating.
2. ☐ Discuss with students that continuous sounds come from objects that are vibrating, that is, moving back and forth in a regular way. Ask the students if their vocal cords are vibrating when they hum.

Q What do you feel when you hum softly?

3. ☐ Have students hum again while holding their fingers over their throats. Tell them to make their humming louder this time.

Q What do you do to make your voice louder?

Let's Explore

4. ☐ Set up the data collection system to display a graph of Sound Level versus Time:
 - a. Start a new experiment on the data collection system.
 - b. Connect the sound level sensor and sensor extension cable to your data collection system.
 - c. Create a graph of Sound Level versus Time.
 - d. Start data recording.

5. ☐ Have a student volunteer hum softly directly into the sound sensor.

Teacher Tip: Encourage the student volunteer to hum steadily at the same volume for ten seconds.

6. ☐ Stop data recording.
7. ☐ After observing the graph, ask students to predict what the graph will look like when a student volunteer repeats the humming at a louder sound level. Have the students complete the prediction section on the student response sheet for question 1.
8. ☐ Have the students test their predictions using the sound level sensor:
 - a. Start data recording.
 - b. Have a student volunteer hum loudly directly into the sound sensor.

- c. Stop data recording.
9. ☐ Ask students how the graph of the loud hum compares to that of the soft hum.
- Students should observe that the louder they hummed, the greater the sound level they recorded (corresponding to the line higher on the graph).

Explain It

In this part of the activity, students further investigate the effect on sound level of humming with their mouths open and closed.

10. ☐ Explain to students that the next two volunteers will make sounds first with their mouth closed, and then with their mouth open.

Teacher Tip: The important feature for each graph is loudness—the intensity of sound—evident as a value higher on the graph. Prompt the students to appreciate that making louder sounds requires more energy.

11. ☐ Start data recording.
12. ☐ Have students try out the sound sensor for 30 seconds by humming directly into the sound sensor. Tell students, “Make as many different kinds of humming sounds with your voice as you can with your mouth closed.”
13. ☐ Stop data recording.
- Note:** You may choose to hide or keep displayed the run of data just collected.
14. ☐ Start data recording.
15. ☐ Have students try out the sound level sensor for 30 seconds. Now tell the students, “Make as many different kinds of humming sounds with your voice as you can with your mouth open.”
16. ☐ Stop data recording.
17. ☐ Show students the data for the open mouth humming and also for the closed mouth humming.
18. ☐ Have the students copy the Sound Level versus Time graphs they collected on the student response sheet response 2.

19. ☐ Discuss the results with the students by asking the following questions:

Q Was the sound level of the humming from a closed mouth louder than or not as loud as the humming from an open mouth?

Q How can we tell from the graphs where the loudest and quietest humming was?

Investigating Sound Levels

20. ☐ In their investigations of sound levels students learned some new scientific ideas. These ideas have their own scientific terms. It is important to be able to discuss results using these words and terms correctly.

Discuss with the students the meaning of the following terms in their own words, using what they have learned from the activity.

Vibration	Moving back and forth
Volume	The amount of loudness or intensity of sound
Sound level sensor	Tool to measure the loudness of sound

Tell Me More

In this part of the activity students use a sound tube made of a piece of paper. They test the level of different sounds with and without the sound tube. Many of the students will be surprised that the sound tube appears to amplify (make louder) the sound, even though they are further away. Just as the outer ear collects and funnels vibrations into the ear canal, the paper tube directs sound to the sensor instead of allowing it to spread out.

21. ☐ Start data recording.
22. ☐ Have a student volunteer hum directly into the sound sensor for 10 seconds. Ask the student to try changing how loudly he or she hums. Stop data recording.

Q What feature in the graph shows you how loud the sound is?

23. ☐ Start data recording.
24. ☐ Have a student volunteer hum close to the sound sensor, then farther away. Tell the student not to change the loudness of his or her hum.
25. ☐ Stop data recording.
26. ☐ Show students the graph and discuss the way it varied.

Q What changes do you notice in the graph?

27. ☐ Make a tube by rolling up a piece of paper.
28. ☐ Start a new experiment on the data collection system.
29. ☐ Display Sound Level on the y-axis of a graph with Time on the x-axis.
30. ☐ Start data recording.
31. ☐ Put one end of the tube near the sound sensor and have a student volunteer hum into the other end.

Write the result from the graph on the board:

The sound level is 74 dB .

32. ☐ Now take away the tube and ask the same student volunteer to hum with exactly the same loudness and at the same distance from the sound level sensor as with the tube.

Write the result from the graph on the board:

The sound level is 58 dB .

Have the students copy the sound levels from the board onto the student response sheet for question 3.

Sum It Up

33. ☐ Have the students share the results and conclusions from the Tell Me More section with the rest of the class.

34. ☐ Ask the students what they have learned about sound and vibrating objects. Their responses should answer the driving question: How can you make sounds at different volumes?

Sound level increases when an object vibrates with more energy or by using a tube to prevent the air vibrations from spreading out and diminishing.

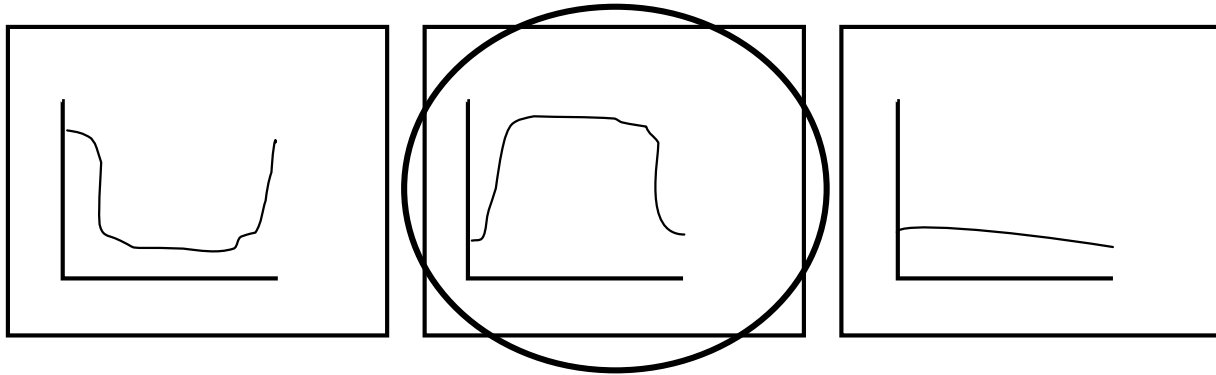
35. ☐ Have students draw a diagram of how they used the sound tube to cause the vibrations from their vocal cords to reach the sound level sensor. Direct students to question 4 on the student response sheet.

Further Investigations

Collect a variety of objects that vibrate. Include some musical instruments of different types, such as a stringed instrument and a drum or tambourine. Include other objects that aren't associated with music, such as paper or plastic bags or a balloon to pop, rocks to bang together, and paper to tear. Use each of the objects to make sounds. Ask students to tell what is vibrating in each case. Students may not realize that the air is being disturbed (is vibrating). Point this out as you demonstrate each object.

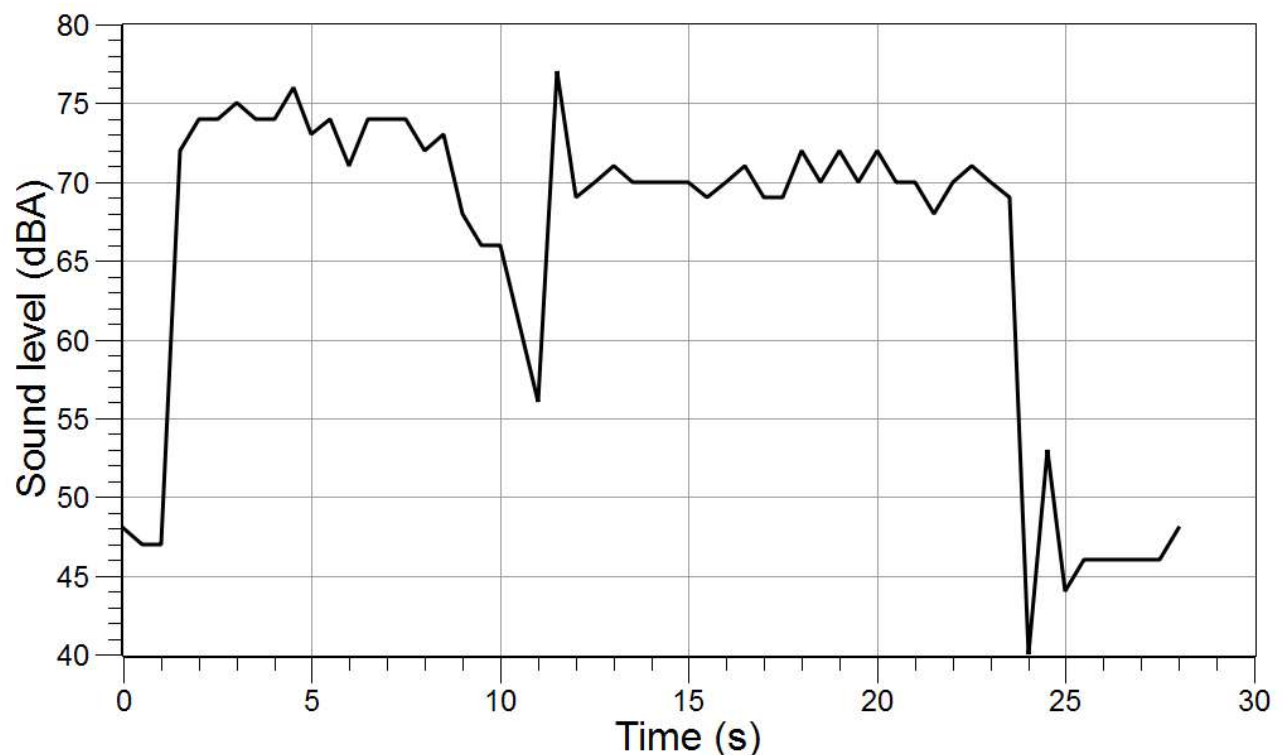
Use the sound level sensor to monitor the noise in the classroom. Project the graph of sound level versus time. Try this at first without telling students the purpose of the graph. See how quiet the class can become based on the graph. You can also ask the class to make a specific type of noise, such as snapping their fingers in unison or whispering a word or vowel sound and watching what happens to the sound level.

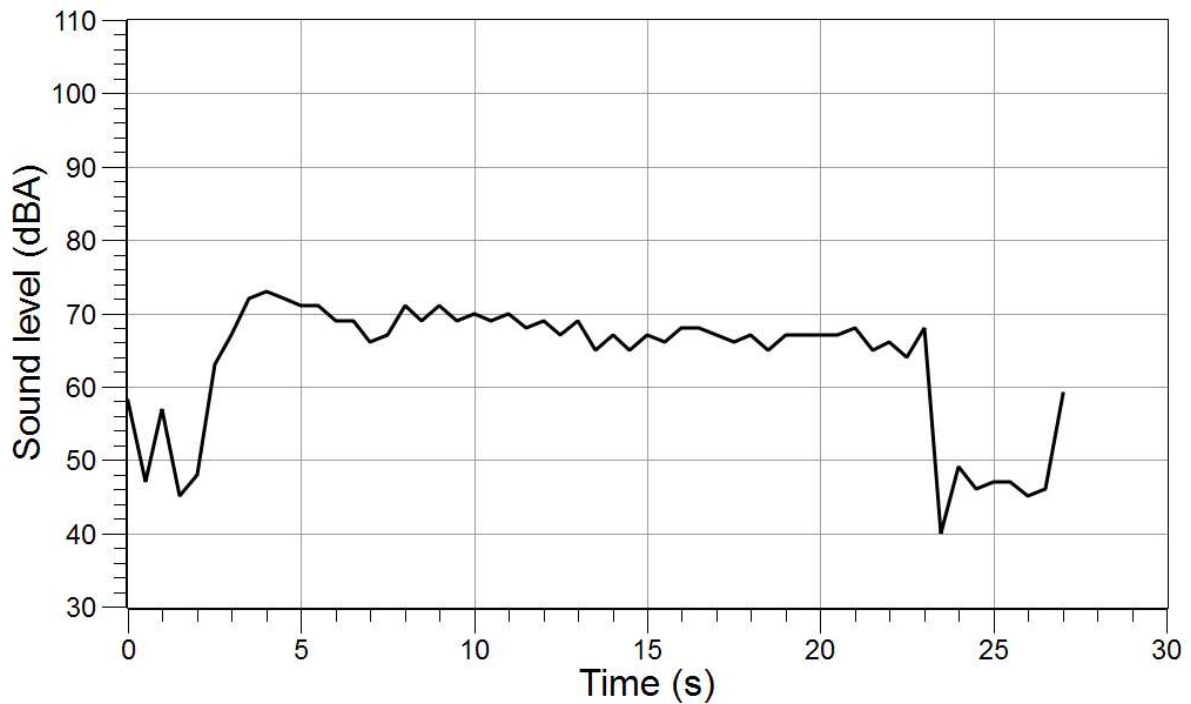
1. Predict: Circle the picture you think best shows what the graph of louder humming will look like compared to softer humming.



2. Draw the graph that shows the results from humming with an open mouth and a closed mouth:

Humming with Mouth Open

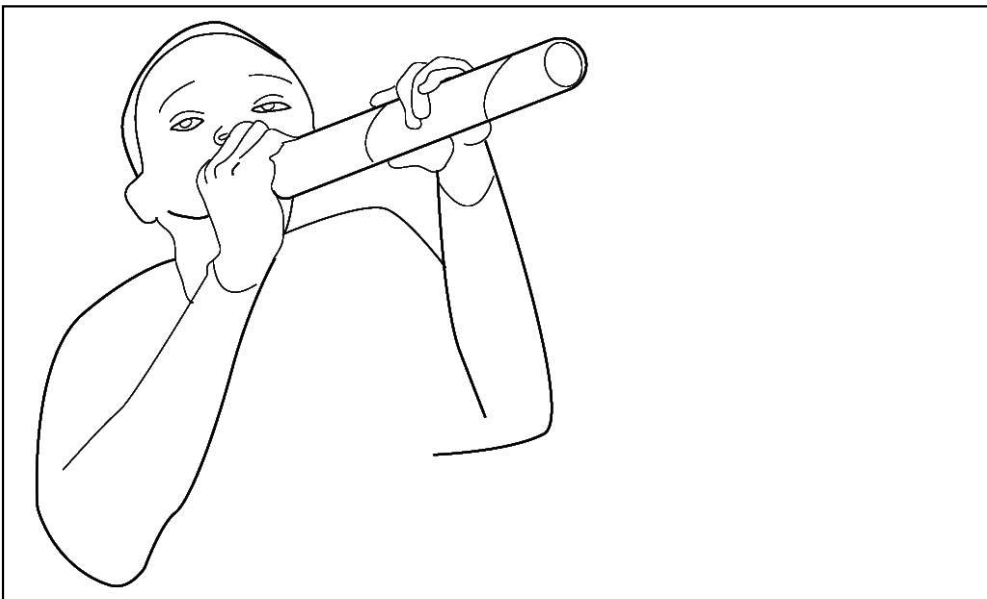


Humming with Mouth Closed

3. Sound level with sound tube: 74 dBA

Sound level without sound tube: 58 dBA

4. Draw a diagram to show how the sound tube works:



12. Feeling and Measuring Temperature

Recommended Grade Levels: 2 – 3

Objectives

Students learn the about the differences between feeling temperature and measuring temperature.

Procedural Overview

- Students compare the feeling of still air and moving air against their bare arm
- Use a temperature sensor to measure the temperature of still air and moving air
- Predict how water and air at the same temperature will feel and test the prediction by measuring the temperature of air and water and then feeling the two samples

Time Requirement

- | | |
|-----------------------|-----------------|
| ■ Teacher Preparation | 10 – 15 minutes |
| ■ Get Started | 15 - 20 minutes |
| ■ Let's Explore | 20 – 30 minutes |
| ■ Explain It | 15 - 20 minutes |
| ■ Tell Me More | 20 – 30 minutes |
| ■ Sum It Up | 10 - 15 minutes |

Materials

For each student or group:

- | | |
|---|--|
| ☐ Data collection system | ☐ Paper or cardboard sheet for fan, 21 cm x 28 cm (8½ in. x 11 in.) |
| ☐ Temperature sensor | ☐ Plastic cup (3), 400 mL or 12 oz |
| ☐ Thermometer, bulb-type | ☐ Water, cool, 100 mL |
| ☐ Metal object ¹ | ☐ Water, warm, 100 mL |
| ☐ Wooden object ¹ | |
| ☐ Projection system (teacher only) | |

¹Any metal and wooden object will work. Ideally use objects that are already in the classroom such as the metal leg of a desk and the wooden surface of a desk.

Activity at a Glance

Get Started

- ☐ Discuss how we use our fingers to sense temperature and compare that with the use of a temperature sensor (or thermometer) to sense temperature.
- ☐ Have the students feel a metal object and a wooden object and then, as a class, project the actual temperature of each object using a temperature sensor and a classroom projection system.

Let's Explore

- ☐ The students use their arm to feel the temperature of still air and moving air.
- ☐ The students measure the temperature of still air and moving air using a temperature sensor.

Explain It

- ☐ The students compare the results of feeling temperature and measuring temperature using the comparison between moving air and still air.
- ☐ Explain to the students that feeling (sense of touch) and measuring are different. Go over the importance of feeling and measuring with your students.
- ☐ Review the following vocabulary with the students: temperature, temperature sensor, feeling, and measurement.

Tell Me More

- ☐ Have the students predict how water and air at the same temperature will feel.
- ☐ Have the students test their prediction by measuring the temperature of the air, creating a cup of water that has the same temperature as the air, and feeling the two samples.
- ☐ Help the students analyze their data and draw a conclusion about the difference between feeling of temperature and measuring temperature.

Sum It Up

- ☐ Have the students discuss what they have learned about feeling and measuring temperature.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not use hot water. It may cause burns.

Preparation

These are the materials and equipment to set up prior to the activity.

Getting Started:

- Set up the data collection system to display a digits display of temperature:
 1. Start a new experiment on the data collection system.
 2. Connect the temperature sensor to your data collection system.

3. Create a digits display of temperature.
 4. Temperature is displayed in units of degrees Celsius. Optionally, change the units to degrees Fahrenheit.
 5. Practice recording a run the temperature of data.
- Practice connecting the data collection system to your classroom projection system and projecting the temperature you collected in front of the class.

Tell Me More:

- Fill one cup with approximately 100 mL of warm water for each student group.
- Fill one cup with approximately 100 mL of cool water for each student group.

Background

Feeling temperature vs. measuring temperature

There are special nerves in the skin that sense hot and cold—different from the nerves that sense pressure or pain. Different parts of the body are more and less sensitive to temperature. To explore this, touch your skin with an ice cube wrapped in plastic. Try your finger, inner and outer arm, forehead, leg, and cheek. There are many situations where the body and the temperature sensor don't give the same results. The reason is that they measure different things. The temperature sensor measures the absolute temperature, but the skin senses the difference between its own temperature and the environment, because that's what matters to our body.

If the surroundings are colder than the skin and the conduction of heat away from the skin is increased, then the skin cools down and the body detects coldness. Examples include moving air (Let's Explore), which carries heat away better than still air and water (Tell Me More), which conducts heat much better than air. Also, the feeling of a room temperature metal surface, which conducts heat away from the skin very quickly and will feel very cold, compared to a room temperature wood surface, which is less of a conductor and will feel warmer. Another example is bare skin, compared to skin insulated with clothes or blankets or dry clothes, compared to wet clothes.

The reverse is also true. If the surroundings are warmer than the skin and conduction is increased, then the skin heats up and the body detects warmth. Examples include hot water which is much more dangerous than hot air, again because water conducts better than air. For this same reason, the air in an oven might be above 100 °C. It will make your hand feel hot, but won't instantly burn it, as boiling water would. Another example is a cloth hot pad that protects your hand from the hot metal handle of a frying pan, which would conduct heat very quickly to your skin and burn it.

Temperature sensor

The temperature sensor detects the absolute temperature, because it is designed to do that. "Temperature" has a specific physical meaning that scientists have agreed upon: the average kinetic energy, or energy of motion, of the molecules. Temperature sensors have been made to measure this in a consistent way, so that scientists working all over the world, in many different experimental situations, can understand and repeat each other's results. The temperature sensor is a very important scientific tool.

Celsius and Fahrenheit

This investigation is written using Celsius ($^{\circ}\text{C}$) temperature units. In the Celsius system, water freezes at 0 degrees C and boils at 100 $^{\circ}\text{C}$. This scale may be difficult for students who are used to the Fahrenheit ($^{\circ}\text{F}$) system, for which water freezes at 32 $^{\circ}\text{F}$ and boils at 212 $^{\circ}\text{F}$. You may spend some time comparing these scales if you wish, but it's not necessary for the investigation, which uses graphs as well as numerical values to display temperature.

Cooling by evaporation vs. cooling by moving air

Cooling by evaporation is different from cooling by moving air. Students have experienced both and probably think they work the same way. Unlike moving air, evaporative cooling affects both the skin and the temperature sensor. When you wave around a wet finger or a wet temperature sensor, the water molecules evaporate into the air, cooling off the surface. It not only feels cooler, it is cooler. In very hot weather, or when we are working hard and our muscles produce a lot of heat inside our bodies, we cool off by sweating: our skin secretes water, which then evaporates and cools us.

Body temperature control and climates

The feeling of hot and cold is essential to survival. All animals face changes in the temperature of their surroundings that are greater than their bodies can tolerate. For instance, the interior of our bodies must stay close to 37 $^{\circ}\text{C}$ for us to stay alive. Animals must be able to detect the surrounding temperature and have strategies for maintaining their proper body temperature. Here are some examples, and students can think of others: Many mammals have hair or fur that creates a thin layer of still air near their skin, which is a better insulator than moving air. Musk oxen and polar bears have heavy fur coats with several layers of fur that keep them warm even in winter in the far north.

When our skin temperature gets too high, we sweat and the evaporating water cools us down. Some fur animals, like rabbits, lose extra heat from their ears.

Whales and seals have layers of fat (blubber) that insulate them from cold arctic waters. Water birds like ducks have oil in their feathers that keep the water away from their skin. Cold-blooded animals, like reptiles and insects, take different approaches from warm-blooded animals, such as mammals. Their body temperatures are not as constant, and their activity level often changes depending on the temperature.

One reason that people can live all over the world, and many animals cannot, is that people can make themselves clothes that protect them from heat, cold, and wet.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- How is feeling and measuring temperature different?

Get Started

In this section, the students are introduced to measuring temperature with the human sense of touch as well as with tools such as a temperature sensor (or thermometer).

1. ☐ Explain to the students that our skin is very sensitive to temperature and that we often use our fingers to feel how hot or cold something is.
2. ☐ Discuss why the ability to feel hot and cold is essential for survival. Use the following questions to guide the discussion:

Q What if you couldn't feel hot or cold?

Q What would happen if you touched a hot stove, but could not sense the heat?

Q What if you were given a cup of hot cup of tea, but could not sense the heat?

Q How does the ability to feel hot and cold help humans survive?

3. ☐ Ask the students if they know of any tools that are used to measure hot and cold?

The students will likely suggest a thermometer or temperature sensor.

4. ☐ Project a digits display of temperature and display room temperature. Show the students both a typical thermometer and a temperature sensor.

Teacher Tip: Since students may have more experience with a bulb-type thermometer, you should demonstrate the conventional thermometer and the electronic sensor side by side, to show they measure the same thing.

5. ☐ Have students discuss how tools (thermometers and temperature sensors) compare to our bodies ability to sense temperature. Through this discussion help the students to understand that tools provide objective numerical temperature readings whereas our sense of feel just give comparative sensations (warm or cold).

Q Which of our five senses do we use to detect temperature?

Q How do you describe the temperature of objects?

Q What does a temperature sensor tell you? Does it state whether an object is hot or cold?

Q Have you and a friend ever disagreed on whether a room is hot or cold?

Q Are there times when your senses cannot be trusted?

6. ☐ Have the students touch a metal object near them with one hand and a wooden object with their other hand. Then ask them how the objects feel and whether or not the two objects have the same temperature.

7. ☐ Use the data collection system that is connected to your classroom projection system to determine the temperature of the two items. Record the results on the board:

Table 1: Temperature of a metal and wooden object

Object	Temperature
Metal	24.8 °C
Wood	24.8 °C

8. ☐ Summarize the activity with the students by explaining that the two objects feel like they are different temperatures, but the temperature data collected from the temperature sensor shows that the two objects have the same temperature (or very similar temperatures).
9. ☐ Tell the students that they are going to experiment with other examples of how feeling and measuring temperatures can produce different results.

Let's Explore

In this section the students will compare the temperature of still air to the temperature of moving air using their sense of touch and using the temperature sensor.

Teacher Tip: It is important to avoid telling students what we think they should discover. Instead, keep asking students what they have observed and what the experiment shows. When there is a conflict between what they believe and what they observe, it is only natural for students to ignore their observations in favor of what they believe. So, while students measure the same temperature for moving air and still air, they will cling to the idea that moving air is cooler. Only through reflection and discussion will they understand why measuring and feeling temperature are different.

10. ☐ Have the students think about how their bare arms feel in still (not moving) air.
11. ☐ Have the students make air move across their arm by waving a piece of paper or cardboard back and forth, like a fan.
12. ☐ Explain to the students that they are using their bare arm to feel how the temperature of still air compares to moving air.
13. ☐ Have the students explain how moving air feels compared to still air when they use their arm to feel the difference. Direct the students to write their observation on the student response sheet under student response 1.
14. ☐ Ask the students how they think the temperature of still air will compare to the temperature of moving air when the temperature of each is measured with a temperature sensor. Have the students make their prediction by answering student response 2.

15. ☐ Have the students measure the temperature of still air by guiding them through the following steps:

Teacher Tip: Depending on the air circulation in your classroom, you may need to have the students find or build an area where they can test still air. Drafts and air circulation systems will cause variation in the data.

- a. Start a new experiment on the data collection system.
 - b. Connect the temperature sensor to the data collection system.
 - c. Display the temperature data in a graph with Temperature on the y -axis and Time on the x -axis.
 - d. Begin data recording.
 - e. Adjust the scale of the graph to clearly see the temperature data.
 - f. After one minute, stop data recording.
16. ☐ On the same graph, have the students collect a second run of temperature data this time measuring the temperature of moving air. Use the following steps to guide them through this process:
- a. Have one student constantly wave a piece of paper or cardboard back and forth, like a fan to create a moving air.
 - b. Have a second student hold the temperature sensor in the moving air.
 - c. Begin data recording.
 - d. After one minute of holding the temperature in the moving air, stop data recording.
17. ☐ Have the students copy both runs of data onto their student response sheet under student response question 3. Have them label each run of data.
18. ☐ Ask the students how the measured temperature of moving air compares to the measured temperature of still air?
- The measured temperature of the moving air is the same as that of still air.
19. ☐ Have the students write their conclusion about how the measured temperature of moving air compares to that of still air under student response question #4.

Explain It

In this section, help your students analyze how the data they collected while feeling was different than the data they collected when measuring. Then explain to the students how feeling and measuring are different.

20. ☐ Discuss with students how the results from feeling the difference between moving air and still air compared to the measuring the difference in temperature between moving air and still air.

Q How did moving air feel compared to still air? (student response 1)

**Q What was the measured temperature of moving air compared to still air?
(student response 4)**

Q Do we sense temperature the same way the temperature sensor does?

21. ☐ Have the students state whether or not feeling and measuring gave the same results by answering question 5 on their student response sheet.
22. ☐ Explain to the students that our senses (in this activity, touch) are different than electronic sensors (temperature sensor). Senses and sensors measure different things. A thermometer measures absolute temperature and our fingers sense the difference between our body and our surroundings. While feeling is great for survival, measuring is better for science.
23. ☐ Discuss with your students why feeling is important for survival, while measuring is better for science by going over the following information:

Table 2: Feeling versus measuring

Feeling (important for survival)	Measuring with a Sensor (important for science)
Sensations may change depending on the setting and previous experience.	A sensor will measure the same value in the same situation, again and again.
It may vary from person to person.	Data collected using a sensor can be displayed on a time graph so that you can watch changes take place and find patterns.
Give sensations like “cool” or “warm”.	Give numerical values.
Can make comparisons like A is warmer than B.	Can express how much warmer or cooler different objects are.
We can process feelings quickly and make immediate decisions.	Sensors can sometimes measure smaller differences than humans can.

24. ☐ Go over the following vocabulary words with your students. Relate each of the vocabulary words to the feeling and measuring air temperature activity that the student just completed.

Table 3: Vocabulary and definitions

Temperature	A measure of hot and cold.
Temperature sensor	An electronic tool that is used to measure temperature.
Feeling	Make an observation by using the sense of touch.
Measurement	To find the value or amount of something with a device or tool that uses standardized units.

Tell Me More

In this section, the students determine how water and air that have the same measured temperature feel relative to each other.

25. ☐ Discuss with your students their predictions about how water and air at the same temperature will feel. Use the following questions as a needed.

Q If you measure the water temperature and the air temperature with a temperature sensor and they are the same, do you think they will feel the same?

Q Will the water feel cooler, feel warmer, or feel the same temperature as the air?

Q What makes you believe this is true?

26. ☐ Have your students record their prediction under student response question 6.
27. ☐ Guide your students through the process of measuring the temperature of the air.
- Start a new experiment on the data collection system.
 - Connect the temperature sensor to the data collection system.
 - Display temperature in a digits display.
 - Hold the temperature sensor in the air, and begin data recording.
 - Allow the temperature to stabilize, then stop data recording.
28. ☐ Have the students copy the air temperature into the table under student response question 7.

Feeling and Measuring Temperature

29. ☐ Provide each student group with a cup of warm water, a cup of cool water, and an empty cup.
30. ☐ Guide the students through the following steps of mixing their warm and cool water until they create water that has the same temperature as the air (within one degree):
- Have one student hold the temperature sensor in the empty cup and start collecting data (in the digits display).
 - Have another student slowly add some warm and cool water into the cup while monitoring the temperature.
 - Once the temperature stabilizes, the students may have to add a little more warm or cool water to adjust the temperature in the cup so that it the same temperature as the air.
 - Once the temperature of the water is the same as the air temperature, have the students stop recording data
 - Have the students copy the water temperature into the table under student response question 7.
31. ☐ Direct the students place one of their fingers into the water and another in the air.
- Q How does the water feel on your finger compared to air?**
- Q Does the water feel cooler, warmer, or the same as the air?**
32. ☐ Have the students record their observations under student response question 8.
33. ☐ Help the students analyze their data and then draw a conclusion about the difference between the feeling of temperature and the measurement of temperature. Direct the students to write their answer under student response question 9.

Sum It Up

Review with the students what they have learned during this activity.

34. ☐ Have the students share what they have learned in this activity with a partner.
35. ☐ Have the students discuss the following questions:
- Q How are human and electronic sensors different?**
- Q How are feeling and measuring different?**
- Q If you were doing a science experiment, which would be better for measuring temperature—using your finger or a temperature sensor? Why?**
- Q What if you touch two objects and it feels like they are at different temperatures. Then, you measure both objects with a temperature sensor and find they are at the same temperature. Which would you believe, your senses or the temperature sensor? Why?**

Further Investigations

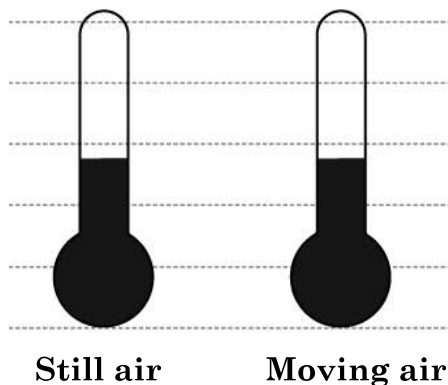
Fool your fingers. Make three pitchers of water—one hot, one cold, and one medium. Put one hand in the hot water and one in the cold. Wait for one minute. Put both hands in the medium water. Does it feel the same to both hands? Measure the three pitchers with the temperature sensor. Can you explain what is going on?

With your finger, touch several materials that have been sitting in the classroom for a while: wood, plastic, metal, glass. Do they all feel the same temperature? Then measure each one with the temperature sensor. Use tape, and not your fingers, to hold the sensor against the material. Do the materials measure the same temperature? What do you think is going on?

1. How does moving air feel compared to still air?

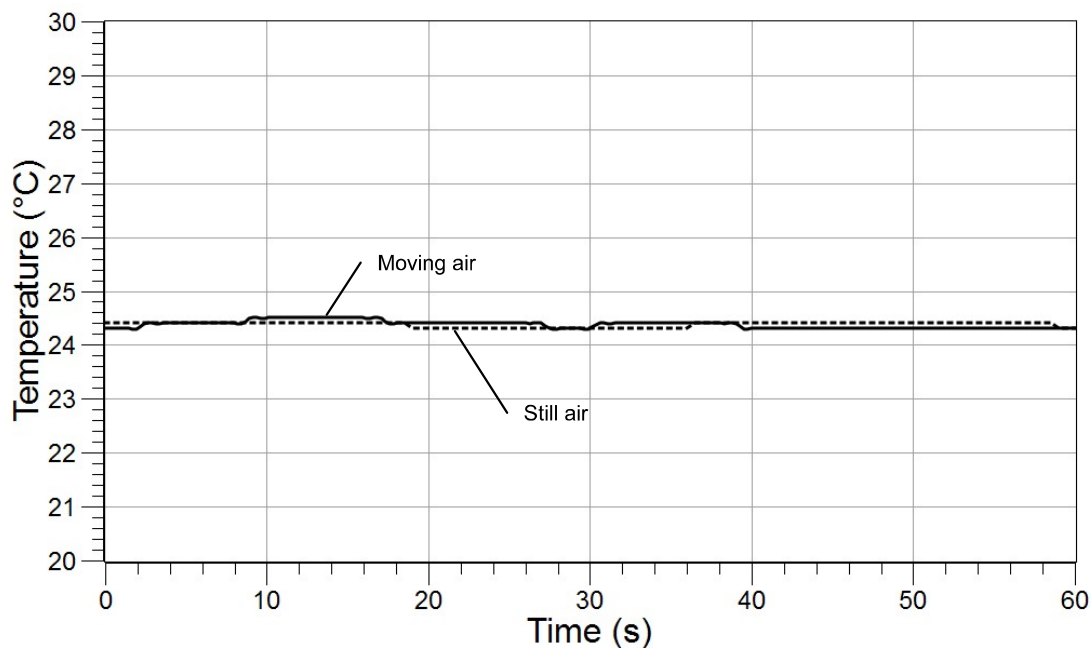
Moving air feels cooler than still air. _____

2. Color in the thermometer to show how you think the measured temperature of still air will compare to moving air.



3. Draw the results from your experiment.

Temperature of Still Air and Moving Air



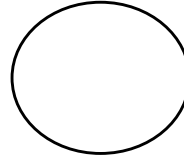
4. Measuring temperature conclusion:

Still air and moving air are the same temperature.

5. Do the results for feeling and measuring temperature for air temperatures agree? Circle the best answer.

YES

NO



6. Water that has the same temperature as the air will feel

the same as the air.
(the same as, warmer than, cooler than)

7. Measured temperatures:

Air temperature is:

23.5° C

Water temperature is:

23.4° C8. How does the water feel on your finger compared to air?

Water feels cooler than air.

9. Is there a difference between the feeling, and the measurement of temperature?

Yes. Even though the temperature of air and water was the same it felt different.

13. Cars and Heat

Recommended Grade Levels: 2 – 3

Objectives

Students determine how the temperature inside a car parked in the sun compares to the temperature of the air outside the car. Through this activity, students

- Realize that when light is absorbed by an object the temperature of that object can increase
- Observe that air movement within an object affects the temperature inside that object
- Learn that some objects reflect light and heat better than other objects

Procedural Overview

To understand this content, students:

- Build a simple model of a car and passenger from a shoe box, black paper, paper cup and other items
- Use a temperature sensor to measure the temperature in their model car when it is placed in the sun and left open, and then when it is covered with plastic food wrap
- Compare the temperature graphs and examine the data to draw conclusions about the temperature inside of parked cars

Time Requirement

■ Teacher Preparation	10 – 15 minutes
■ Get Started	5 - 10 minutes
■ Let's Explore	20 - 30 minutes
■ Explain It	15 - 20 minutes
■ Tell Me More	20 - 30 minutes
■ Sum It Up	10 - 15 minutes

Materials

For teacher guided discussion in the Get Started section of the activity:

- | | |
|--|---|
| ☐ Mobile data collection system | ☐ Projection system |
| ☐ Temperature sensor | ☐ Shoe box model car, assembled ¹ |

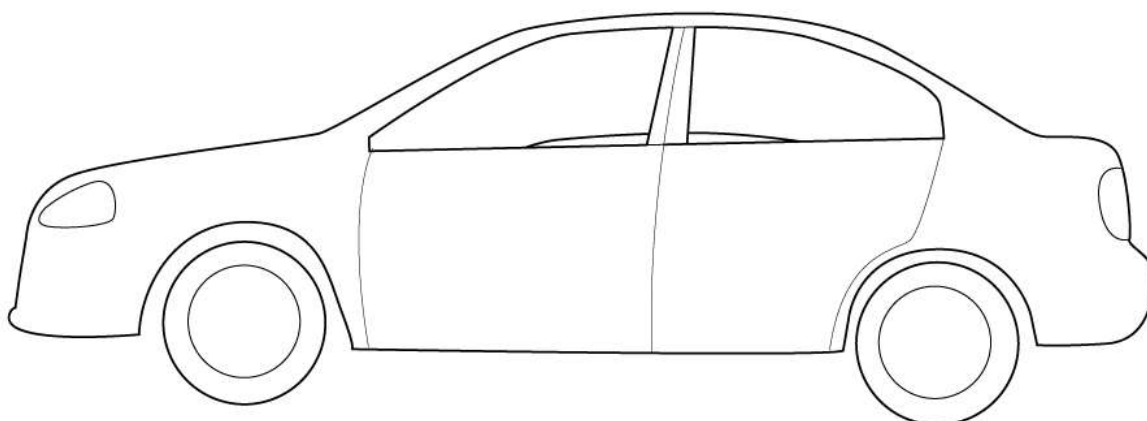
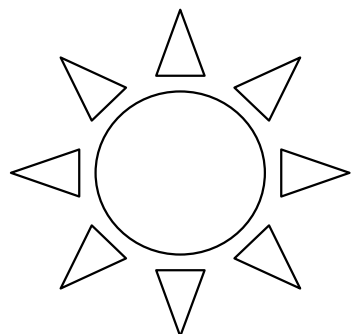
¹The materials needed to assemble the shoe box model are the same as the materials listed for each student group below. Refer to the Preparation section for instructions on how to build the model car.

For each student group:

- | | |
|--|---|
| ☐ Mobile data collection system | ☐ Paper cup ¹ |
| ☐ Temperature sensor | ☐ Yarn, cotton balls, other craft supplies |
| ☐ Shoe box ¹ | ☐ Markers |
| ☐ Black paper ² | ☐ Glue stick |
| ☐ Plastic food wrap to cover shoe box | ☐ Tape, ~30 cm |

¹Exact size does not matter; the modified cup must be able to fit entirely into the shoe box.

²Enough black paper is needed to line all 5 inside surfaces of the shoe box.



Activity at a Glance

Get Started

- ☐ Lead the students in a discussion about how sunlight contributes to the overall temperature on earth.
- ☐ Use a temperature sensor to measure the temperature outside and project it for all the students to see.
- ☐ Students predict how the temperature inside a parked car will compare to the temperature of the air outside the car.

Let's Explore

- ☐ Students build a model of a car and passenger with a shoe box, black paper, and a paper cup.
- ☐ Students draw and label their model of a car on student response sheet.
- ☐ Students measure the temperature inside their model for five minutes as it sits in the sun.

Explain It

- ☐ Help the students analyze the data they recorded to determine the temperature in the model car after it had been in the sun for five minutes.
- ☐ Have the students brainstorm why the temperature is hotter in a parked car than outside and what people do to keep a parked car cool on a warm, sunny day.
- ☐ Review the following vocabulary with the students: temperature, temperature sensor, absorb, reflect, light, and heat.

Tell Me More

- ☐ Students predict whether a car with open, partially open, or closed windows gets the hottest when it is parked in the sun.
- ☐ Students test their predictions by measuring the temperature in their covered model car as it sits in the sun for five minutes.
- ☐ Students copy the graph of temperature data they collected onto their student response sheet.

Sum It Up

- ☐ Help the students analyze their data to determine whether the temperature became hotter in the open model car or the closed model car.
- ☐ Have the students review what they have learned by doing this activity.

Safety

Follow all standard classroom practices.

Preparation

These are the materials and equipment to set up prior to the activity.

Get Started

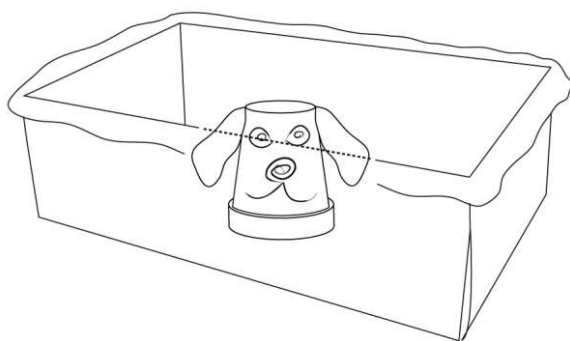
In this section the class is working together rather than individually. The teacher projects the data and leads the class in discussion.

1. Set up the data collection system to display a digits display of temperature:
 - a. Start a new experiment on the data collection system.
 - b. Connect the temperature sensor to your data collection system.
 - c. Create a digits display of temperature.
 - d. Temperature is displayed in units of degrees Celsius. Optionally, change the units to degrees Fahrenheit.
 - e. Practice recording a run the temperature of data.
2. Practice connecting the data collection system to your classroom projection system and projecting the temperature you collected in front of the class.

Let's Explore

In this section, the students make a shoe box model car and paper cup passenger. The students place the model in the sun and measure the temperature for 5 minutes. Prepare a sample shoe box model car and paper cup passenger to show the students.

1. Line all five of the inside surfaces of a shoe box with black paper. Use glue or tape to secure the paper in place.
2. Make a passenger by decorating an inverted paper cup. Draw a face on the cup and embellish it as you wish to make it look more realistic.
3. Place the paper cup passenger in the middle of the lined shoe box.



Background

The Sun's Radiation and Your Car

Energy from the sun arrives at Earth's surface in the form of electromagnetic radiation. We perceive some of the wavelengths of this radiation as light, while other wavelengths we perceive as heat.

Solar radiation can be absorbed, reflected or scattered. Cars can act like a greenhouse because they have the ability to do all of these things. Glass lets some of the light from the sun go through it, and reflects some. In particular, infrared "light" (which you cannot see) will not go through the opaque exterior of a car. Light is absorbed by the exterior of the car and heats up the interior regardless of whether the windows are closed or open. If the windows are shut, heat is basically trapped in the car where temperatures can rise to over 90 degrees Celsius (200 degrees Fahrenheit) possibly causing the windows in the car to blow-out as the air expands within the car due to heating. Additionally, this can pose danger for animals and infants if left in cars without adequate ventilation and water.

Albedo and Surface Reflection

Scientists use the term albedo to define the percentage of solar energy reflected back by a surface. Albedo can be thought of as the "reflectivity" of a surface. Sunlight falling on a white shiny surface is strongly reflected back into space; such a surface is said to have high albedo. This results in very little heating of the surface. Sunlight falling on a dark matte surface is strongly absorbed; this type of surface has low albedo. This results in a large amount of heating of the surface.

If you cover the inside of your windshield with a sunshade, your car will be cooler. The surface reflects light and does not scatter it much. So it reflects the light right back through the window

without converting much of the light to infrared light. The best sunshade is metallic (high albedo), as a nonmetallic (low albedo) sunshade tends to absorb some of the light and heat up your car. A white sunshade will produce less infrared light, and your car will be cooler. A glossy surface on the sunshade will reflect some of the light and scatter less, and make your car cooler.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful place a check mark in the box after you complete that step.

Driving Questions

This activity investigates the following questions:

- How does the temperature inside a parked car compare to the temperature of the air outside the car?
- Do you think the temperature inside the car will be greater if the car windows are open or closed?

Get Started

In this section the class is working together rather than individually. The teacher projects the data and leads the class in a discussion about the impact of sunlight on the earth.

1. ☐ Have the students think about how heat from sunlight generally contributes to the overall temperature on earth and changes in seasons. Start by asking the following questions:
 - Q How is the temperature different in the summer and the winter? Why?**
 - Q How does the temperature in the morning compare to the temperature in the afternoon? Why?**
 - Q Does sunlight heat all surfaces equally? On a hot summer day would you rather stand barefoot on blacktop or grass? Why?**
2. ☐ Ask the students what instrument could be used to measure the current temperature outside.

An electronic temperature sensor or thermometer could be used to measure the temperature outside.
3. ☐ Show the students the temperature sensor that is connected to the mobile data collection system. Take the data collection system to the door and have a student volunteer hold the temperature sensor in the air outside while you record the temperature.
4. ☐ Project a digits display of the outside temperature for all the students to see and have the students record today's temperature on the student response sheet under student response number 1.
5. ☐ Ask the students to think about how the temperature outside compares to the temperature inside a parked car.

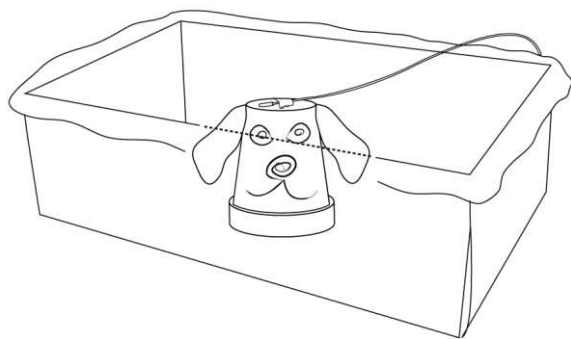
Q How will the temperature inside a parked car compare to the temperature of the air outside the car?

6. ☐ Have students record their prediction on the student response sheet by circling their best choice under student response number 2.
7. ☐ Tell the students that during the summer months of the year we often hear how important it is never to leave our pets or children in a parked car. Have the students think about whether or not this warning could be due to a change in temperature inside the car.
8. ☐ Explain to the students that they will test their predictions by building a model car and measuring the temperature inside the car when it is placed in the sun.

Let's Explore

In this section, the students make a shoe box model car and paper cup passenger. The students place the model in the sun and measure the temperature for 5 minutes.

9. ☐ Show the students a sample shoe box model car and paper cup passenger. Explain to the students that they will be making their own model car and passenger.
10. ☐ Direct students to line all five of the inside surfaces of a shoe box with black paper. Have the students secure the paper in place using glue or tape.
11. ☐ Have the students make a paper cup passenger using an inverted paper cup, yarn, cotton balls, markers, and other craft supplies. Let the students decide if the passenger in their model car is a child or a pet.
12. ☐ Have the students place the paper cup passenger in the middle of the paper-lined shoe box and tape the tip of the temperature sensor to the top of their passenger, as shown in the graphic below.



13. ☐ Tell the students that this is their model of a car with a pet or child riding inside. Ask the students the following questions:

Q Which part of the model represents the car?

Q Which part of the model represents the pet or child?

14. ☐ Have students draw a picture of their model and label the car, the passenger, and the temperature sensor, on the student response sheet under student response number 3.
15. ☐ Explain to the students that they will use their model of a car with a passenger to determine if their prediction, about how the temperature inside a parked car compares to the temperature of the air outside the car, is correct.
16. ☐ Have each students place their shoe box model with passenger and temperature sensor outside in the sun (or indoor where sunlight shines through a window).
17. ☐ Guide the students through the following steps to record a run of temperature data:
 - a. Start a new experiment on the data collection system.
 - b. Connect the temperature sensor to the data collection system.
 - c. Display the temperature data in a graph with Temperature on the y -axis and Time on the x -axis.
 - d. Begin data recording.
 - e. Adjust the scale of the graph to clearly see the temperature data.
 - f. After five minutes, stop data recording.
18. ☐ Have the students move their data collection system and model car back inside. The model car needs to cool back to room temperature before it is used again in the Tell Me More section.

Explain It

In this section, help your students analyze the data they have recorded.

19. ☐ Have the students look at their graphs of Temperature versus Time that they just recorded. Ask the following questions to help the students understand their graphs.
 - Q What happened to the temperature over the five minutes of data collection?**
 - Q After five minutes, how did the temperature inside the car model compare to today's temperature outside the car?**
20. ☐ Have the students determine the temperature in their model car after it had been in the sun for five minutes. Direct the students to write this temperature down in student response number 4.
21. ☐ Have the students write what they learned by doing this activity as their conclusion in student response number 5.
22. ☐ Have students brainstorm why the temperature inside a car is hotter when it sits in the sun. Make a list on the board of the students' reasons.

Students should suggest that the light and heat from the sun warm the inside of the car. Students may suggest that when a car is parked, no breeze is able to blow through the windows, so the heat is

trapped inside the car even if the windows are partially rolled down. Students may also suggest that dark colored cars or cars with dark colored interiors get even hotter than light colored cars.

23. ☐ Ask students to describe and list some things people do to help keep a parked car cool on a warm, sunny day. Make a list on the board of the students' ideas.

Students may suggest any of the following: park in the shade, put up sunshades in the windshield, leave the windows open, tint the windows, cover the seats with a cloth to keep the sunlight off them, or turn on the air conditioning.

24. ☐ Go over the following vocabulary words with your students. Relate each of the vocabulary words to the model car activity the students just completed.

Temperature	A measure of hot and cold
Temperature sensor	An electronic tool that is used to measure temperature
Absorb	To take in light and heat energy and trap or keep it; the opposite of reflect
Reflect	To let light energy bounce off a surface; the opposite of absorb
Light	Energy from the sun that we can see as brightness
Heat	Energy from the sun that we feel as warmth

Tell Me More

In this part of the activity students predict what will happen if their model car is covered with plastic food wrap, to model a car with closed windows, and then left in the sun for five minutes. They then test their prediction.

25. ☐ Ask the students to think about whether a car with open, partially open, or closed windows gets hottest when it is parked in the sun.
26. ☐ Have students record their predictions on the student response sheet by circling their best choice under student response number 6.
27. ☐ Ask the students whether the first set of data they recorded in their model car represented the windows of the car being open or closed?

The students should explain that the first set of data represented a car with the windows open. This is because air was able to easily flow in and out of their model car.

28. ☐ Discuss with the students how they could change their model car to represent a car with its windows closed. Make sure that the students understand that windows prevent air from moving into and out of the car, but still allow sunlight to come in. In this activity, the students will cover their model cars with food wrap to represent a car with closed window.

- 29. ☐ Direct the students cover the top of the shoe box car model with plastic food wrap. If necessary, have the students tape the plastic wrap to hold it in place.
- 30. ☐ Have each student place their covered shoe box model with passenger and temperature sensor outside in the sun (or indoor where sunlight shines through a window).
- 31. ☐ Have the students record a run of temperature data for the covered model car on the same graph that they recorded their temperature data with the open model car.
 - a. Have the students make sure that their graph is still displayed on the data collection system.
 - b. Have the students begin data recording.
 - c. After five minutes, stop data recording.
- 32. ☐ Have the students copy both runs of Temperature versus Time data that they recorded on the student response sheet under student response number 7.

Sum It Up

In this section, help your students analyze the data they recorded and draw conclusions about what they have learned in this activity.

- 33. ☐ Have the students look at their graphs of Temperature versus Time that they just recorded. Ask the following questions to help the students understand their graphs.
 - Q What happened to the temperature inside the covered model car as it sat in the sun for five minutes?**
 - Q Did it get hotter in the covered model car or in the open model car? How do you know?**
- 34. ☐ Give the students some time to analyze their own results and establish a conclusion. Have the students record their conclusion on the student response sheet under student response number 8.
- 35. ☐ Have students brainstorm why the temperature inside the closed model car became hotter than the temperature in the open model car.

Students should suggest that the light and heat from the sun warm the inside of both model cars, however the heated air is allowed to move out of the open model car, but is trapped inside the closed model car.
- 36. ☐ Review what the students have learned by having them answer the following questions:
 - Q How does the temperature inside a parked car compare to the temperature of the air outside the car?**
 - Q Do you think the temperature inside the car will be greater if the car windows are open or closed?**

Further Investigations

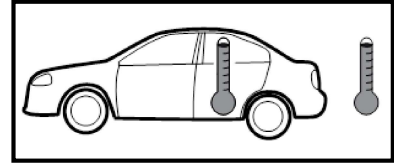
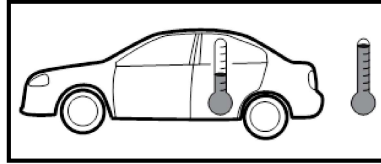
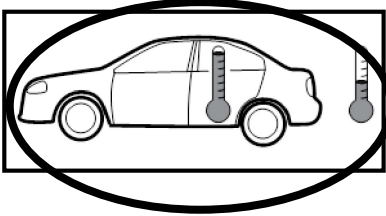
Put a mobile data collection system into your car with the windows closed on a sunny day. Record the change in temperature over one or two hours. Retrieve the system and project the results for students to see, discuss, and interpret in a class discussion.

Compare the temperature changes inside two similar cars at the same time, one car with the windows open and the other with the windows closed. Ask student to identify other variables they might test experimentally, such as cars of different colors, sizes, or with tinting on the windows. Carry out as many investigations as time and access permit.

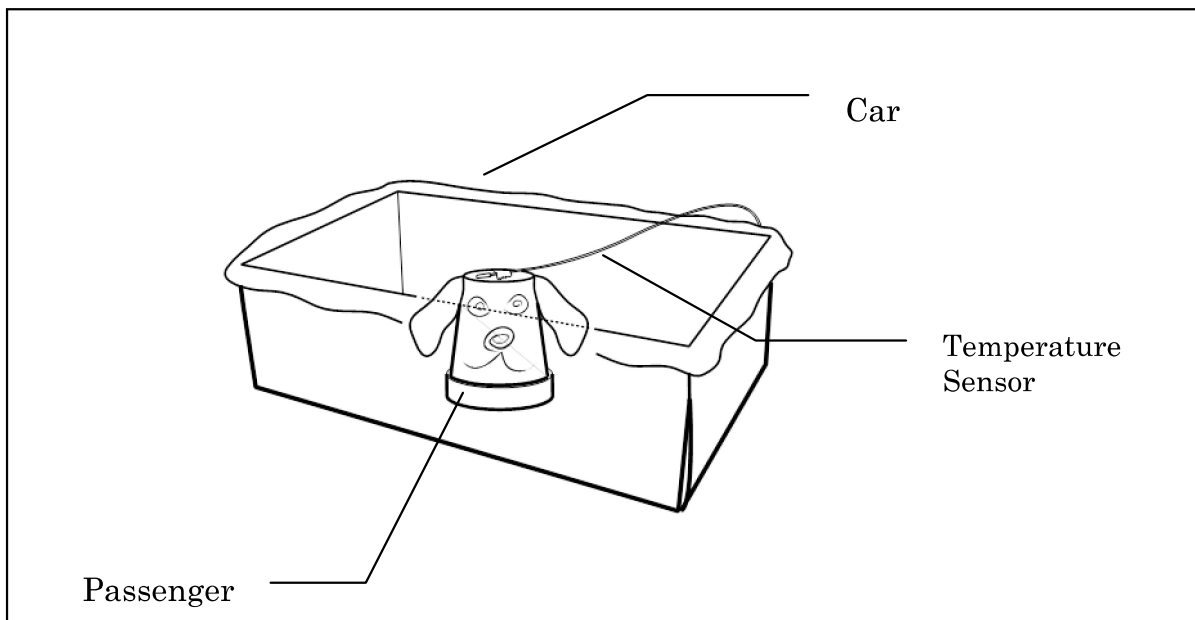
1. What is today's temperature?__

25° C

2. Circle the picture that you think best shows how much hotter it will get inside a car than outside on a sunny day.



3. Draw your model car and passenger. Label the parts.



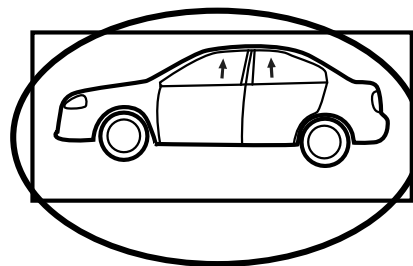
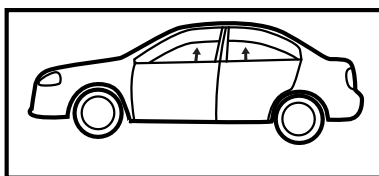
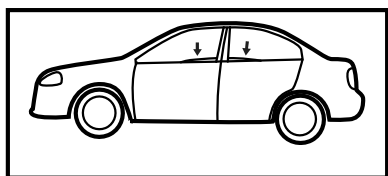
4. What is the temperature inside the model car after it had been in the sun for five minutes?

36° C

5. Conclusion:

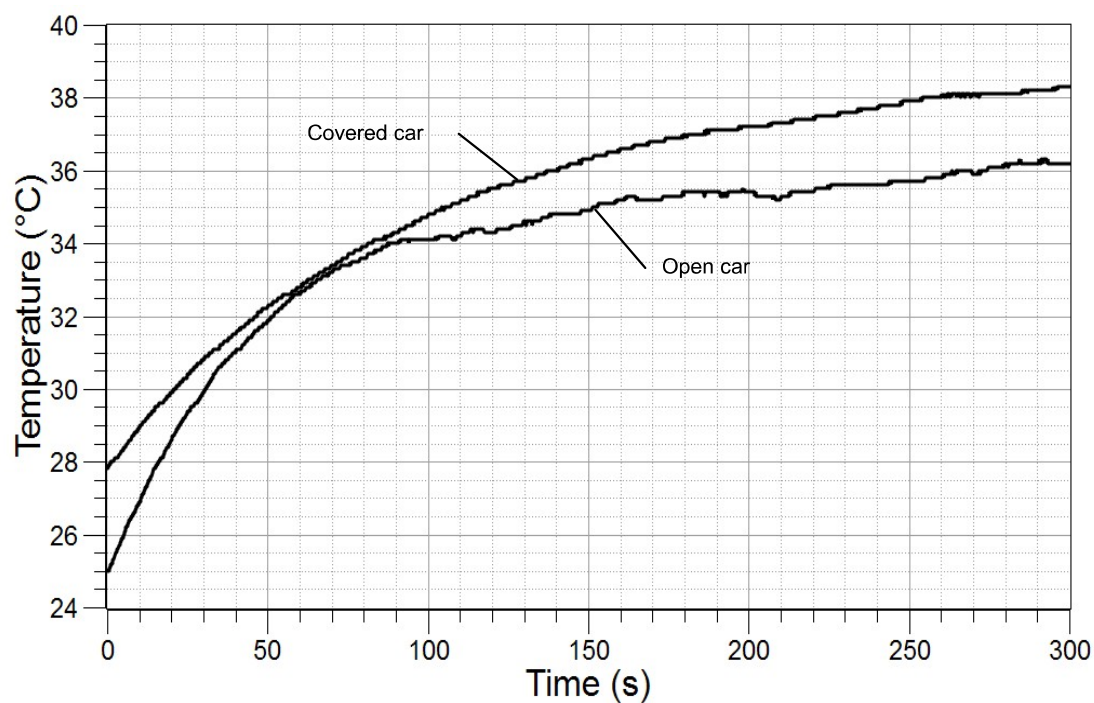
The temperature inside a car is hotter than outside a car.

6. Circle the picture that you think best shows which car will get hottest on a sunny day.



7. Draw the results from your experiment.

Model Cars in the Sun



8. Conclusions:

A car with the windows closed gets hotter than a car with the windows open.

14. Observing Clouds

Recommended Grade Levels: 2 - 3

Objectives

Students learn that clouds in the sky have properties that can be observed and described. They associate cloud formation with specific weather conditions such as temperature and humidity.

Procedural Overview

To understand this content, students:

- Identify types of clouds in the sky using standard pictures of clouds
- Use a compass and learn direction
- Monitor temperature and humidity for three days
- Relate changes in weather to the formation of clouds

Time Requirement

■ Teacher Preparation	15 – 20 minutes
■ Get Started	30 – 40 minutes
■ Let's Explore	30 minutes
■ Explain It	30 minutes
■ Tell Me More	15 – 20 minutes per day for three days
■ Sum It Up	15 minutes

Materials

For teacher demonstration:

- | | |
|--|---|
| ☐ Mobile data collection system | ☐ Sponge |
| ☐ Weather sensor | ☐ Plastic wrap and rubber band |
| ☐ Glass canning jar, 1-quart | ☐ Wooden stick matches |
| ☐ Posters or pictures of cloud types, in color ¹ | ☐ Ice, 50 mL |
| ☐ Turkey baster | ☐ Hot water, 20 mL |

¹ Alternatively, print out a large copy of the Cloud Types graphic included in the Background section.

For each student or group:

- | | |
|--|---|
| ☐ Mobile data collection system | ☐ Paper fastener (brad) |
| ☐ Weather sensor | ☐ Weather Journal handout ¹ |

Observing Clouds

- | | |
|--|--|
| ☐ Cloud Types handout ¹ | ☐ Tagboard or card stock, 14 cm x 14 cm |
| ☐ PASCO Cloud Finder handout ¹ | ☐ Compass |
| ☐ Scissors | ☐ Ribbon, 12-15 cm long |
| ☐ Glue | |

¹Refer to the Preparation section for assembling these handouts

Activity at a Glance

Get Started

- ☐ Make a cloud in a bottle.
- ☐ Raise questions about clouds and observe the conditions that made the cloud form in the bottle.
- ☐ Using the glass with ice water and the glass with room temperature water, introduce the concepts of condensation and evaporation.

Let's Explore

- ☐ Discuss the different types of clouds and the characteristics of clouds.
- ☐ Have students construct a "Cloud Finder" and take them outside so they can use it to help identify cloud types in the sky.
- ☐ Have students learn to illustrate the amount of the sky covered by clouds.
- ☐ Help students use a ribbon to determine the direction of the wind and compare it to the movement of the clouds.

Explain It

- ☐ Have students describe the weather for the day and the types of clouds visible.
- ☐ Students predict the weather conditions that would bring clouds.
- ☐ Review the following vocabulary with the students: water vapor, condensation, evaporation, humidity, relative humidity, precipitation, stratus, cumulus, cirrus, altostratus, nimbostratus, cumulonimbus.

Tell Me More

- ☐ Demonstrate the concepts of humidity and relative humidity.
- ☐ Have students examine the parts of the weather sensor and discuss the features it measures.
- ☐ Students measure and record the temperature and humidity of the air for three days. They also record the sky conditions and the cloud types for the same period.
- ☐ Have students examine their data to see if it supports their predictions.

Sum It Up

- ☐ Students analyze their data to see how their weather conditions support the formation of clouds.
- ☐ Students complete the student response sheet.

Safety

Add these important safety measures to your normal classroom procedures:

- Do not look at the sun at any time. Permanent eye damage can result.
- Use caution working with scissors.
- Do not go outside to log clouds or make entries in the Weather Journal in extreme weather conditions.

Preparation

These are the materials and equipment to set up prior to the activity.

- Prepare copies of the following handouts for each student or group of students. There are several Student response sheets needed in this lab. Be sure to prepare copies of the following:
 - Cloud Types
 - Multiple choice
- Make a large print of the diagram entitled Cloud Types to display on the wall, or project it using any system you may have in place. Alternatively, you may use any cloud poster you already have at hand. A large color illustration of cloud types will be useful in all of your discussions during this activity.
- Before beginning the activity, place two clear glasses on your desk top. Fill the first glass with ice and top it off with cold water. Fill the second glass with room temperature or tepid water (and no ice).
- For the humidity demonstration in the Let's Explore section, determine the amount of water that should be in the turkey baster to saturate the sponge. (If any more water is added to the sponge, the sponge won't be able to absorb it and water will start dripping from the sponge.)
- Prepare your data collection system in advance to model its use for students when carrying out the Tell Me More section:
 1. Start a new experiment on the data collection system.
 2. Connect the weather sensor.
 3. Display temperature in a digits display and relative humidity in a digits display.
 4. Temperature is displayed in units of degrees Celsius. Optionally, change the units to degrees Fahrenheit.
 5. You can change the precision of the digits display if you want to remove the tenths (decimal) place.

Note: Set up as many data collection systems as you have groups of students who will be going outside together to gather weather data.

Background

Why Clouds Form

Depending on the temperature of the air, Earth's atmosphere can hold water in all its phases (gas, liquid, and solid). As a gas, water molecules have the most energy and form a vapor. When air pressure decreases or the air temperature reaches the dew point, the air becomes saturated and water vapor will condense into tiny, liquid water droplets and form clouds. If the droplets get large enough to form precipitation, the air temperature determines if it comes down as rain, snow, sleet or hail.

Water changes from a gas—water vapor—to a liquid through the process of condensation. To "condense" means to go from the gaseous phase to the liquid phase. Water vapor in the air condenses into droplets of water on the surface of a cold window. Water gets into the air through the process of evaporation. In this case, water molecules are energized by heat when sunlight shines on surfaces of lakes or wet fields. The energized water molecules break free of the surface and become airborne. Water molecules in clouds can also evaporate into the air.

Air at different temperatures can hold different amounts of water vapor. Warm air can hold more water vapor than cold air. The amount of water vapor in the air is called humidity. If air at a certain temperature is holding as much water as it can possibly hold, we say that it is "saturated." "Relative humidity" indicates how saturated the air is at that temperature: 50% relative humidity means that the air is only half full of the total amount of water vapor that it could hold. One hundred percent humidity means that the air is completely full of water vapor, so if the temperature should drop, it would rain!

Clouds form when the relative humidity goes up and the temperature drops, usually as a result of pressure changes. In this activity, we will leave the pressure changes out of the picture.

The first step to cloud formation is to saturate the air, that is, to get the air to hold as many water molecules as it can possibly hold at that temperature. If the temperature drops so the air can no longer hold as much water, the water vapor will condense on any solid particulate material floating in the air and form clouds. Air temperature can drop when it is lifted to higher elevations, but the most common cause for air temperature to drop is a change in air pressure. As air expands and pressure decreases, the air cools. This causes an adiabatic temperature change (heat does not enter or leave the system) and clouds will form if the air is moist enough.

To determine if clouds will form, air can be monitored for temperature and humidity. Falling temperature, rising humidity, or a change in wind could lead to the formation of clouds.

Naming Cloud Types

Clouds form at any elevation in the sky, but certain types of clouds tend to form at particular elevations. Clouds generally form from 2,000 meters to 20,000 meters, but can form all the way to the ground in the case of fog.

There are three main types of clouds, so named for their general shape. Sheet-like clouds are called "stratus." They form a blanket that covers the sky and exist at low elevations. Cumulus clouds look like the puffy white clouds of storybooks, and form at low to medium elevations. The term "cumulus" is applied to any cloud that is densely packed and fairly finite in shape. The third cloud type is the "cirrus" cloud, a thin, wispy-looking cloud that resembles horses' tails blowing in the wind. Cirrus clouds form only at the highest elevations. Some cumulus clouds build vertically to surprising heights; these dangerous clouds are full of static electricity and are associated with lightning, rain, hail, and tornadoes.

Certain prefixes are used to describe cloud types. The prefix "alto-" means that the cloud forms at a middle elevation, around 4,000 meters. The prefix "nimbo-" means that the cloud has enough water vapor to form precipitation. A "nimbostratus" cloud is a low, sky-covering rain cloud. An "altostratus" cloud is a mid-elevation sky-covering stratus cloud. A "cumulonimbus" cloud is a towering cumulus cloud that brings rain. Cloud names are also combined, as in "altocumulus," "stratocumulus" or "cirrostratus." The second part of the name describes the basic cloud form; the first part indicates the approximate elevation.

Cumulonimbus clouds are huge; they start at 2,000 meters and rise to 6,000 meters or more. Since their tops are high enough to be caught in high-elevation wind bands, the tops of these clouds usually stream out in one direction, forming an anvil-shaped top. The bottoms of these clouds are very dark, and rain and lightning are associated with them. They are the most dangerous clouds.

Observing Clouds

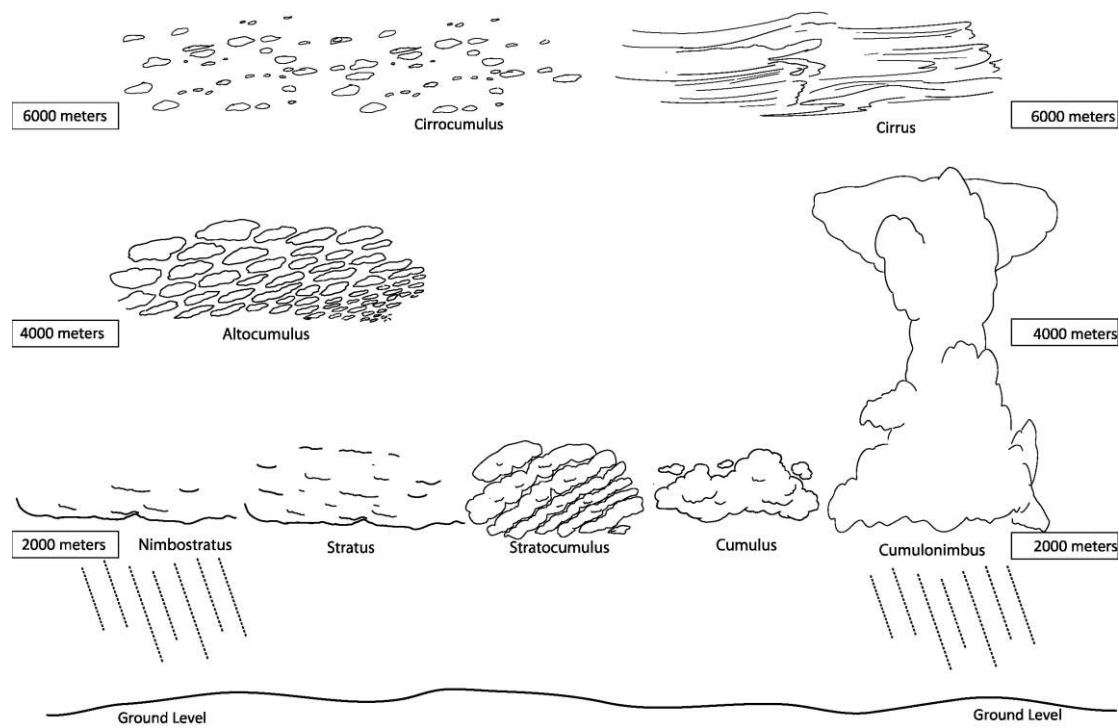
In this investigation, students initially observe and describe the making of a cloud in a bottle to observe the conditions that cause clouds to form. Students next observe the changing patterns of clouds. Finally, students record in their weather journals daily observable weather conditions: the type of clouds, the wind direction, and the air temperature, for three days (not necessarily consecutive days).

When students are looking at clouds, direct them to use the following characteristics in their descriptions:

- **Shape:** There are two different shapes or forms of clouds. They are either "heaped" (cumulus) or "sheeted" (stratus). The dense, huge masses of varying heights are called cumulus clouds. The low, horizontal sheets of layered, lifted fog are called stratus clouds. Clouds that are both heaped and spread out in layers are called stratocumulus clouds because they are like both stratus and cumulus clouds.
- **Color:** When the color changes from a fluffy white to a dark cloud, the word nimbus is added to the beginning or ending of the cloud form. For example, a dark cumulus cloud with a dark base that is threatening to rain or hail is called a cumulonimbus cloud. A dark gray horizontal stratus cloud that is threatening to snow, rain, or drizzle is called a nimbostratus cloud.
- **Height:** The altitude above the ground can also describe clouds. Usually clouds are classified as low, medium, or high. Towering layered clouds that may extend to over 20,000 meters in height form a separate category called vertical clouds. Vertical clouds that have strong updrafts of air are associated with sometimes dangerous precipitation, winds, storms, and even tornadoes. There can be very strong rain and hail from these clouds.
- **Low:** Clouds that range in height from 0 to 2000 meters are classified as low clouds. Fog is a cloud that forms at ground level. Stratus clouds are usually low clouds. Cumulus clouds and stratocumulus clouds can also be low.
- **Medium:** Clouds that range in height from 2000 to 5000 meters are classified as medium height clouds. Often the prefix "alto-" is used to indicate a specific medium height cloud. Altocumulus and altostratus are two examples.
- **High:** Clouds whose bases are above 5000 meters are classified as high clouds. Cirrus clouds are high level clouds that develop in filaments (strands) or wispy patches at extremely high elevation. Often the prefix "cirro-" is used to indicate a high cloud. Cirrocumulus clouds have a spotty appearance created by the many small patches. These clouds are so high and the air so cold that when water vapor condenses, it forms tiny ice crystals instead of water droplets.

Observing Clouds

- “Contrails” are clouds created by water vapor condensing into ice crystals on the small particles from the exhaust of planes that fly at high altitudes.



Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful, place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- Why do clouds form?

Get Started

1. ☐ Ask for a volunteer to draw a picture of a cloud. Discuss with the class if this agrees with how they each picture clouds in their imagination.
2. ☐ Ask students to list all the questions they have about clouds. Record these questions so they are available to refer to while conducting the investigation.

3. ☐ Ask students in what kinds of weather they have seen clouds form.

Students will notice kinds of weather in which the air has some water vapor in it.

4. ☐ Ask students if they have seen clouds form at different times of day or in different seasons of the year?

Students may answer that there are clouds at any time of day, in all seasons. Students can describe how clouds vary throughout the seasons.

Condensation and Evaporation

5. ☐ Introduce the concept of condensation. By now the glass you set on your desk at the start of this lab has produced moisture on the outside of the glass and is “sweating”.
6. ☐ Ask students, “What has formed on the outside of the glass of ice water?”

Drops of water formed on the outside of the glass. The moisture may be a thin film of tiny water droplets, or there may even be drops large enough to collect and roll down to the bottom of the glass.

7. ☐ Tell students that this is called condensation. Ask them where they think the water came from.

Students may think it came from inside the glass, and that somehow it “leaked” through the glass. But if you have them think about all the glasses they ever filled and drank from, they will quickly realize that glasses don’t really leak. The water had to have come from somewhere else. Explain that it came out of the air. This process of water vapor in the air becoming water droplets on the glass is called “condensation.”

8. ☐ Have students think about temperature. Which was colder, the ice water in the glass or the air in the room?

Observing Clouds

Students will know that the ice water in the glass was colder than the air in the room. Emphasize that there is a big difference in the coldness of the glass and the warmth of the air.

9. ☐ Ask students, “Did the other glass ‘sweat’?”

Students should notice that the glass with room temperature water did not “sweat”.

10. ☐ Tell students to think about temperature. Is there a big difference or a small difference between the temperature of the glass with no condensation and the air temperature?

The glass with the room temperature water feels about as warm as the air feels. Invite students to feel and compare the temperature of the two glasses.

Teacher Tip: If your class is familiar and comfortable using their data collection systems, you could measure the air temperature and then measure the water temperatures, but a qualitative comparison is enough for this demonstration.

11. ☐ Ask students, “Would the condensation happen if the water in the glass is warm and the air is also warm? Why or why not?”

Lead students to understand that temperature is the major factor affecting the amount of invisible moisture air can hold at any given time. Cooler air cannot hold as much water in the gaseous form as warmer air. The ice water in the glass lowers the temperature of the air around the glass, making the water vapor in that air come out of the air and condense on the sides of the glass.

12. ☐ To sum this up, ask students, “Tell me where the water on the outside of the glass came from and what made it condense on the cold glass.”

Students need to state that the *water came out of the air* when the *cold glass cooled the air*.

Make a Cloud in a Bottle

13. ☐ To focus on this process and address some of the students' questions that have been raised, demonstrate the formation of a cloud in a bottle. In this demonstration, you

- Place hot water (40 °C to 80 °C) in a small glass bottle.
- Light a match and blow it out near the top of the container, allowing the smoke to drift into the container.
- Cap the container with a clear plastic sheet and a rubber band.
- Put an ice cube on top. (See the illustration.)



14. ☐ Students will see the formation of a cloud in the bottle. Ask them to discuss the conditions that cause the cloud to form.

If they need help, guide students to name the following conditions: the hot water, the smoke, and the ice to cool the air.

15. ☐ Ask students the following:

- Why is the hot water important?

Hot water puts water vapor into the air. If they don't realize this, remind them of the steam they see above a hot tub or spa, or from a warm pool on a very cold day, or even above their bath water or a hot cup of coffee. This process of a liquid transforming into a gas is called *evaporation*.

- Why is the smoke important?

The smoke puts particles into the air; the particles provide a surface for the water vapor to condense on. This is also a hard concept, but have them recall that the cold glass provided the surface for the water in the air. Condensation always has to happen on a surface. Smoke particles are extremely small, but still they provide a surface on which the water can collect.

- Why is the ice important?

The ice chills the air in the top of the jar. Point out that there has to be a temperature drop in the air for condensation to happen.

16. ☐ To clarify the concepts of evaporation and condensation, ask students, “How does the warm water get into the air?”

Warm water has more energy than cold water, and will evaporate more quickly than cold water. The water on the surface of the warm water *evaporates* into the air, like steam rising from a hot tub of water (visible because the warm water condenses in the cooler air above).

17. ☐ To find out if the warm water warms the air above it,

- a. Replace the water in the jar with hot water and place a temperature sensor into the bottle above the water.
- b. Display the data on a graph, and record the temperature of the air as it warms.

Teacher Tip: Display the data on a computer projection system. If this is not possible, help all students to watch the display as the temperature increases.

18. ☐ Have your students think about what happens to warm air inside a house, and what happens to smoke from a fire.

Warm air, like warm smoke from a fire, rises and cold air sinks. Similarly, the warm air rises inside the bottle and the colder air up at the top sinks. In this way the air circulates inside the bottle.

19. ☐ Ask students what they think the ice cube does to the air inside the bottle.

The ice cools the air at the top of the bottle.

Teacher Tip: Let students know that this process of air circulation is happening all the time in the atmosphere around us. Air picks up moisture from the earth's surface—oceans, lakes, streams and other sources of moisture. Warmer air carrying this water goes to higher altitudes where it becomes cooler. The water can condense out of the air to form a cloud.

20. ☐ Have students predict the weather conditions necessary for clouds to form. Keep a record of these predictions to compare with the weather observations they will make.

Let's Explore

21. ☐ Have students complete the "Cloud Types" section of the student response sheet. Display any posters or photos of clouds you may have.

Cloud Types

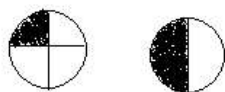
22. ☐ Ask students to describe features of the clouds on the Cloud Types picture (see Background section) or on any of your cloud-types posters or pictures you have assembled. Listen for them to use the terms "shape," "color," and "height." They should use these characteristics to describe clouds.
- **Shape:** point out that the shape of the cloud helps us to name it.
 - **Color:** the darker the cloud, the more likely it is that precipitation will fall from it.
 - **Height:** discuss the relative heights of clouds. Compare their heights to familiar things, such as helicopter height (low clouds) and passenger jet heights (high clouds).
23. ☐ Have students fill out the Cloud Types portion of the student response sheet in class or as a homework assignment. The questions provide students with a place to practice the vocabulary for naming clouds.
24. ☐ Have students create a "Cloud Finder" to help them recognize cloud types. The Cloud Finder gives them a tool for observing clouds in the sky. Make materials available for the class.
- Materials for the Cloud Finder are as follows: PASCO Cloud Finder handout, brass brad, scissors, card stock, glue.

Direct students to do the following:

- a. Cut out the two circles that make up the Cloud Finder.
- b. Cut out the two windows on the top part.
- c. Glue the bottom part to a piece of card stock for rigidity.
- d. Trim around the circle.
- e. Attach the top circle to the bottom circle with the brass brad.

Sky Cover

25. ☐ Point out that clouds can cover the whole visible sky, or just parts of the sky.
26. ☐ Discuss and agree on how much of the sky is covered by clouds. You may use relative terms such as "barely covered" or "mostly covered," or you can use fractions or percents. Another way to model sky coverage is to draw a small circle and color in the circle to represent the amount of the sky covered by clouds. The first image below shows a sky that is $\frac{1}{4}$ covered by clouds, or 25%. The other shows a sky half covered by clouds, or 50%.



27. ☐ Take the class outside and have them stand with their backs to the sun. Use the Cloud Finder to identify current cloud types.

Note: Caution students never to look directly at the sun.

28. ☐ At the same time, have students notice if there is a wind, if there is a wetness to the air, and if the clouds are moving fast or slow.

Q In what direction are these clouds moving?

Wind Direction

29. ☐ To determine wind direction, make sure students are familiar with the use of a compass.
30. ☐ While holding a ribbon in one hand, students should hold a compass in the palm of their other hand.
31. ☐ Students should turn their bodies to face north, the same direction as the compass needle is pointing.
32. ☐ Students can match the direction the ribbon is blowing with the compass. For example, they might notice that their ribbon is blowing toward the east.
33. ☐ Explain to students that wind is blowing “from” a direction instead of “toward” a direction. If the ribbon is pointing toward the east, then that is a west wind. It is blowing “from” the west.

Explain It

34. ☐ Back in the classroom, review the conditions that were necessary for the cloud to form in the bottle:
- a. Water vapor in the air: there must be some water vapor in the air to begin with.
 - b. Particles in the atmosphere: there must be dust or smoke or exhaust in the air for the water vapor to condense on.
 - c. Cooling temperature: the ice cube cooled the warm air inside the bottle. Cool air holds less water vapor than warm air.
35. ☐ Review condensation and evaporation. Evaporation is how water changes from a liquid to a gas. Condensation is how water changes from a gas into a liquid. Model them as opposites.

Humidity

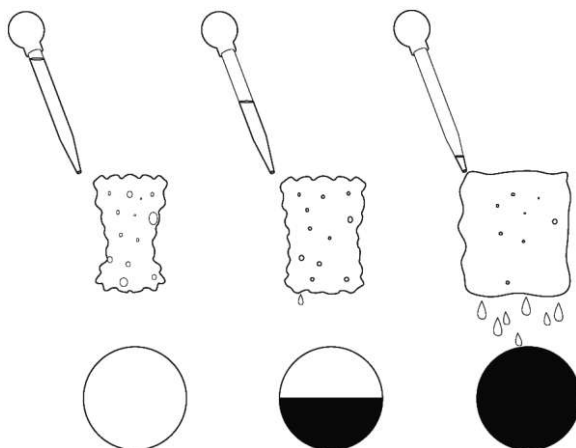
36. ☐ Evaporation adds water vapor to the air. The amount of water vapor in the air is called “humidity.” Relative humidity is the percentage of water vapor in the air compared to how much water vapor the air can hold at that temperature.

Teacher Tip: Humidity can be compared to a gas tank. If the tank is half full, it is 50% full. If it is three-quarters full, it is 75% full. A full tank of gas is 100% full. Relative humidity is measured similarly. If the

air is half full of water vapor, the relative humidity is 50%. The higher the relative humidity, the more likely clouds will form. The closer relative humidity gets to 100%, the more likely rain will come out of the clouds.

37. ☐ Another way to demonstrate percent humidity and precipitation is to use a sponge. In this comparison, think of the sponge as representing the air. The turkey baster is holding 100% of the water that the sponge could possibly hold. When the turkey baster is empty, the sponge is 100% full and is saturated.

Add water to the sponge with the turkey baster, a little at a time. After each addition, lift up the sponge to show that it is not yet dripping because it is not yet full.



- When the turkey baster is half empty and the sponge is half full, compare the situation to the air being at 50% humidity.
 - When the turkey baster is nearly empty and the sponge is just about to start dripping, compare to the air being at 100% humidity.
 - If the sponge is squeezed, or if you continue to add more water, the sponge will start dripping. This is like the air being cooled and starting to rain.
38. ☐ In your investigations of properties of clouds, cloud formations, and weather conditions, students learned some new scientific ideas and terms. It is important to be able to discuss results using these words and terms correctly.

Take this opportunity to discuss with the students the meaning of the following terms in their own words using what they have learned from the activity.

➤ Vocabulary table with definitions for the teacher

Water vapor	Water in its gaseous state
Condensation	Energy reduction phase change of water from gas to liquid
Evaporation	Energy increase phase change of water from liquid to gas
Humidity	The amount of water vapor in the air
Relative humidity	Comparison of current air humidity to saturated air humidity
Precipitation	Water droplets that have grown large enough to fall to Earth as rain, hail, or snow
Stratus	Wide, low, sky-covering sheets of clouds
Cumulus	Dense mounded lumpy clouds at varying elevation
Cirrus	Thin, high, wispy clouds made of ice crystals
Altostratus	Stratus clouds occurring at medium elevation
Nimbostratus	Low stratus clouds from which rain is falling
Cumulonimbus	Towering cumulus clouds, unstable; associated with rain, hail, lightning

Tell Me More

This part of the lab can be done as a teacher demonstration or by groups of students. Students will need their Cloud Finders, their Weather Journal, their mobile data collection systems, and a pencil.

39. ☐ With students grouped, give each group of students their data collection systems with the weather sensor attached, and a digits display of temperature and relative humidity. (These should already be set up, as directed in the Preparation section.) Point out the slotted top of the weather sensor, and the tips of the probes visible inside. These are the sensor tips that measure the temperature and humidity of the air.
40. ☐ Allow students some time to practice starting and stopping runs of data, and moving around the room to determine where the warmest or coolest locations are located. This will ensure that they are familiar with the device before you go outside.
41. ☐ Help students choose two times during the day to observe the sky and record the temperature and relative humidity. Students will collect data twice a day for three days. Suggestions for collecting this data include:
 - Students may be grouped and this data collected in a center with the supervision of a parent helper, aide, or older student helper.
 - This data may be collected as a whole class instruction.

Note: Remember that students must be supervised when they leave the classroom to record this data and make observations.

Teacher Tip: The observation days do not have to be consecutive. Recording data twice a day allows students to see how the weather conditions change during the day and how those changes can produce clouds. Recording data three times a day could help reveal this relationship more quickly.

- 42. ☐ Have students gather their Cloud Finder, pen, Weather Journal, and data collection system to take outside for each monitoring session.
- 43. ☐ Once the students are outside, direct them to start collecting data.
- 44. ☐ When the data stabilizes, have them stop recording data.
- 45. ☐ Students record the temperature and relative humidity in their journals.
- 46. ☐ Students use their Cloud Finder to name the types of clouds, describe their shape, color and relative height. They draw a symbol showing the amount of sky cover, and comment on any precipitation.

➤ Weather Journal

Condition	Day 1: A.M.	Day 1: P.M.	Day 2: A.M.	Day 2: P.M.	Day 3: A.M.	Day 3: P.M.
Time of day	9:00 AM	2:30 PM	9:00 AM	2:30 PM	9:00 AM	2:30 PM
Temperature	78 °F	Answers vary throughout				
Relative humidity	56%					
Sky cover						
Wind direction	from the west					
Precipitation	None					
Cloud Description						
Shape	thin and wispy					
Color	white					
Height	very high					
Cloud type	cirrus					

Sum It Up

47. ☐ Restate the driving question, “Why do clouds form?” Explain that clues to the answer lie in the collected data.

48. ☐ First consider temperature. Ask these questions:

- Was the temperature increasing or decreasing throughout the day?
- Where the clouds were forming, what was the temperature probably doing?

If the temperature was increasing, warm air was probably rising in the afternoon, moving water vapor up into higher elevations. If temperature was decreasing, clouds may have been blowing into the area and conditions for clouds would be present even at low elevations. Students should know that the temperature must have been decreasing at the elevation of the clouds.

49. ☐ Next, consider relative humidity. Ask these questions:

- How was the relative humidity changing?
- How do our observations support our predictions about how clouds form?

If relative humidity is low, clouds are less likely to be seen. As it increases, clouds form and could lead to precipitation. Students should list the increases in humidity, the changes in temperature, and the height of clouds where the temperature is probably decreasing. Students should know that clouds form at the places in the sky where water vapor is condensing to microscopically small water droplets and that water will condense when the air is cooled.

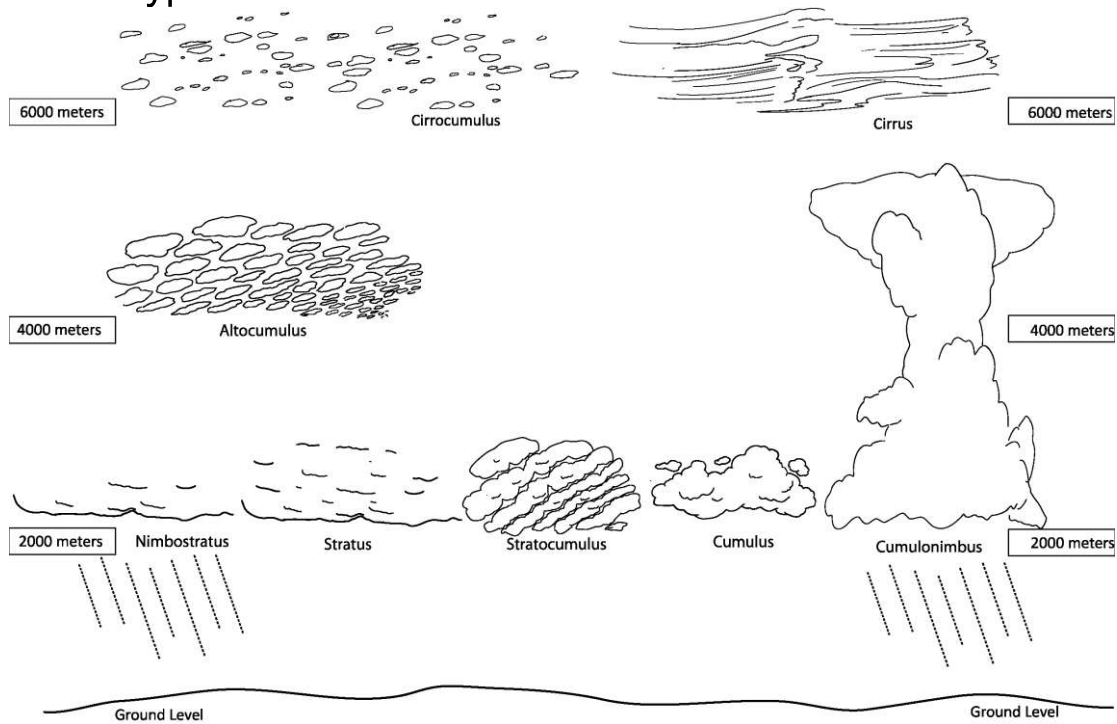
50. ☐ Have students complete the Multiple choice and Cloud Identifications sections of the Student response sheet.

Further Investigations

Have students revisit their Weather Journals in different seasons. Design a weather journal booklet that is large, strong, and permanently located in the classroom with a dedicated data collection device. Encourage students to gather data on any day and at any time. This could become such a popular activity that you may need to set up a rotation system for gathering the daily weather data.

After a period of a month, graph the data. You can have students graph just the highest and the lowest data for the month, or they can average the data and graph the average for the month. This will get more and more interesting as the seasons change.

Cloud types



Use the pictures above to answer the following questions:

1. Stratus clouds look like

a wide flat blanket.

2. Cumulus clouds look like

fluffy white and gray cotton balls, sometimes stacked or piled up.

3. Cirrus clouds look like

thin wispy streaks very high, maybe even like horses' tails blowing in the wind.

4. What word part means "rain"?

"Nimbus" or "nimbo-" means rain.

5. What word part means "middle height"?

"Alto-" means middle height.

Multiple Choice (darken the circle of the correct answer)

1. Clouds form when the temperature of the air]

- ☒ **A Gets colder**
- ☐ B Gets warmer
- ☐ C Stays the same

2. If the clouds are 100% full of water,

- ☐ A It will not rain
- ☒ **B Rain is likely**
- ☐ C Rain will occur with or without clouds

3. Clouds form because of

- ☐ A Evaporation
- ☒ **B Condensation**
- ☐ C Precipitation

4. The air also contains

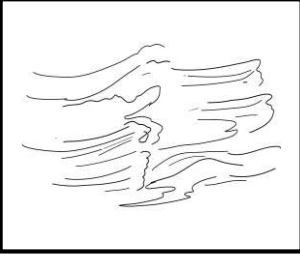
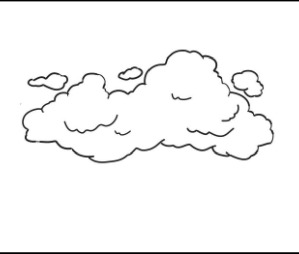
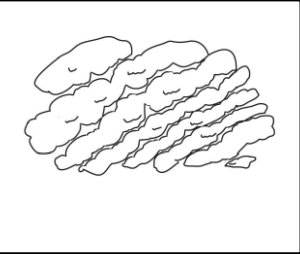
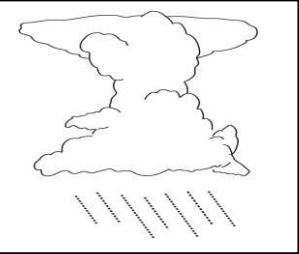
- ☐ A Water vapor
- ☐ B Dust
- ☒ **C Both water vapor and dust**

5. Clouds are made of

- ☐ A Cotton balls
- ☐ B Water vapor
- ☒ **C Tiny water droplets**

Identify the types of clouds below.

Word Bank: Altocumulus, cirrus, cumulonimbus, cumulus, nimbostratus, stratocumulus

			
Cirrus	Cumulus	Stratus	Cumulonimbus

15. Can Plants Survive without Light and Water?

Recommended Grade Levels: 2 - 3

Objectives

Students determine that plants need both light and water to survive. They also learn that plants have adaptations to help them survive.

Procedural Overview

To understand this content, students:

- Compare the characteristics of animals and plants that make them alive
- Identify the basic needs of plants that will enable them to survive
- Recognize adaptations of plant leaves and roots that help plants acquire sunlight and water
- Identify sunlight as the source of energy for plants to photosynthesize
- Design and carry out an experiment to test if plants need both water and sunlight to survive

Time Requirement

■ Teacher Preparation	30 minutes to ½ day
■ Get Started	15 minutes
■ Let's Explore	20 minutes
■ Explain It	15 minutes
■ Tell Me More	15-20 minutes per day for 5 days
■ Sum It Up	15 minutes

Materials

For teacher demonstration:

- | | |
|--|---|
| ☐ Data collection system | ☐ Leaves of plants, a variety ³ |
| ☐ Light sensor | ☐ Growing light (optional) ⁴ |
| ☐ Potted plants (8), young plants, all the same kind ¹ | ☐ Markers |
| ☐ Roots of plants, a variety ² | ☐ Ruler |

¹ Herbs such as mint, or flower plants such as impatiens work well for this because they are non-toxic. Check with Poison Control websites for a list of non-toxic plants.

² Uproot some weeds and bring in some root vegetables with stems and leaves attached, such as carrot and beet.

³ Collect a variety of leaves from plants with different textures: hairy, waxy, succulent, needle and broadleaf.

⁴ A fluorescent light works best, but any light will do.

Can Plants Survive without Light and Water?

For each student group:

- ☐ Data collection system
- ☐ Ruler
- ☐ Light sensor

Activity at a Glance

Get Started

- ☐ Engage students by talking about the things they can do that make them alive. These are the characteristics of all living things.
- ☐ Help students to differentiate between animals and plants.

Let's Explore

- ☐ Students compare the different kinds of roots and discuss their purpose.
- ☐ Students compare the different kinds of leaves and discuss their purpose.
- ☐ Show students the light sensor and demonstrate its use.

Explain It

- ☐ Link the needs of plants (nutrients, water, sunlight, air) to plants' structural parts.
- ☐ Guide students to plan the set up of their investigation.
- ☐ Review the following vocabulary with the students: characteristic, adaptation, chlorophyll, photosynthesis, and light.

Tell Me More

- ☐ Guide students to determine how they will conduct the experiment.
- ☐ Determine how students will water the plants, measure the plants, and move through the stations.
- ☐ Run the test over several days to see the effect of the test on the condition of the plants.

Sum It Up

- ☐ Determine the best growing conditions for plants from this test.
- ☐ Propose a follow-up experiment to answer any further question concerning how much light and water plants need.

Safety

Add these important safety measures to your normal class procedures:

- Always wash your hands with soap and water after handling plants or soil.

Preparation

These are the materials and equipment to set up prior to the activity.

- This lab should be conducted while you have a good amount of daily sunshine coming in your classroom window. If you need to conduct the lab during the cloudy months, you will have to change the goals and directions of the activity.

- Carefully uproot one small plant of any type (a weed will do) and rinse the roots clean of soil. Try to keep the roots intact. Wrap the roots in a wet paper towel to keep them from drying out. Obtain one carrot and one beet with its leaves intact so students can see the whole plant. Any other root plant or tuber like potato or iris corms would be good to include if you want to talk about tubers.
- Collect a large variety of leaves from different kinds of plants. Find leaves of light green and dark green, needles and broadleaves, hairy, waxy, fuzzy, ribbed, thickened and smooth.
- Prepare a location on your windowsill for four plants. Provide a power strip or extension cord if a power source is far away. If you do not have a windowsill in your room, you will want to set up an artificial light above a table. Obtain a growing light from a garden store and mount it on a rack to shine down on the table surface. Make sure it is located high enough from the plants to keep them from burning. Alternatively, a shop light will also work.
- Students will keep a Journal (#7 in the student response sheet) for a period of 5 days to monitor the effect of light and water on the growth of plants.
- A word about measurement: in this lab students need to measure their plants to “quantify” how the light is affecting their growth. If your students are not ready to use a ruler, you can use Unifix® cubes or graph paper. Cut strips of graph paper and glue them onto a piece of tag board. Students count how many squares high their plants are and estimate to the nearest whole square.
- Set up the data collection system to display for the Let’s Explore portion of the activity.
 1. Start a new experiment on your data collection system.
 2. Connect the light sensor to the data collection system.
 3. Display the data in a digits display.

Background

Plants need nutrients, water, air and sunlight to grow. Plants derive their nutritional needs from minerals in the soil or the water they live in. In kindergarten, students learn about the basic needs of plants. Roots take up water and nutrients from the soil; special xylem cells transport the nutrients and water to the leaves, where, in the presence of sunlight and chlorophyll, the plant makes simple sugars which are then transported to the rest of the plant by phloem cells. In this activity, students investigate the necessity of light and water for the survival of the plant.

Adaptations

Since plants are found in almost every type of environment on this planet, the basic needs of plants are met in a huge variety of ways, and plants have developed a wide range of adaptations to allow them to fully utilize light and water resources wherever they grow. Thickened leaves, lack of leaves, silvered leaves, thickened bark, waxy coatings on leaves, and hairy leaves are all adaptations that plants have evolved to moderate the amount of light they receive or to conserve water. Thickened roots, taproots and fibrous roots, tubers and corms are all adaptations of plants to maximize water absorption and conservation.

Growing Toward the Light

Hormones in the apical meristem, or growing tip, of seedlings cause the seedling to grow toward a light source. Experiments have been done to place seedlings in a variety of dark locations and watch the plant grow around corners or under barriers to reach the light source. A simple example of this is when house plants become unbalanced if they are not rotated in their position, so that all sides of the plant get sunny exposure every few days.

Lack of Sunlight and Water

Plants need sunlight and water to conduct photosynthesis, which provides the plant with the energy that it needs to grow and fruit. Visible signs of insufficient light include paleness of color, especially in the leaves, even whitening of the plant; weakening and thinning of plant tissues; and elongation of young stems so that the plant cannot maintain its upright structure. Visible signs of insufficient water include withering, brown dry edges on leaves, and lack of strength in the stems.

Activity with Answer Key and Teacher Tips

There is a box (☐) next to each step. If you find it helpful place a check mark in the box after you complete that step.

Driving Question

This activity investigates the following question:

- What do plants require to stay alive?

Get Started

In this part of the activity, students review the characteristics of living things and their needs for survival. Then they become acquainted with plant adaptations.

1. ☐ Have a discussion with your students about how we know if something is alive.

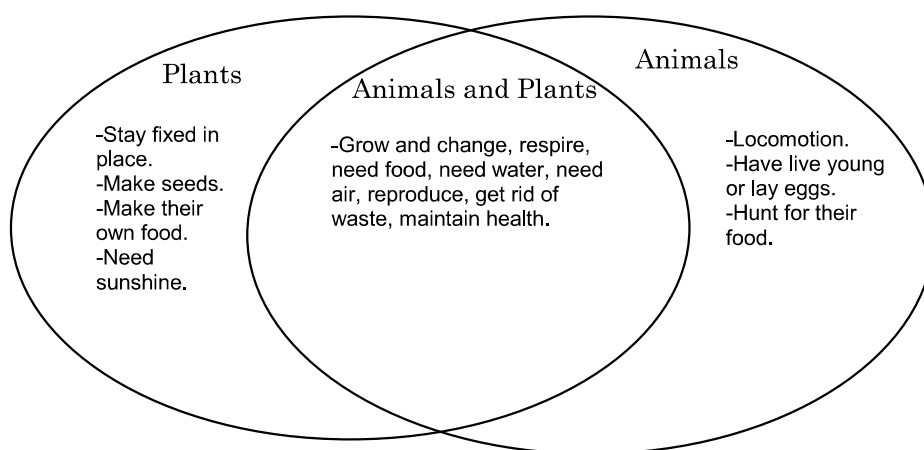
Q Tell me as many things about yourself as you can that would prove to me that you are alive.

Q Are these things also true of plants?

2. ☐ Make a list of proof-of-living things that plants and animals share in common.

Characteristics known to 2nd and 3rd graders include these: living things need food, water and air; living things grow and change; living things make more of themselves (reproduce), eliminate wastes, and need to rest.

3. ☐ Explain to students that these features that are common to all living things are called characteristics.
4. ☐ Draw a Venn diagram on the board and discuss what characteristics plants and animals have in common, and what characteristics they have separately.



5. ☐ Direct students to response 1 on their student response sheet.

Let's Explore

6. ☐ Focus on the needs of plants only. Break off a stem from one of your plants and let students examine inside the stem to see that it is wet.

Q Where did the water come from?

Q If the plant did not get this water, what would happen to it?

7. ☐ Show the uprooted plant's roots. Show how small and delicate they are in a young plant.
- Discuss how the roots anchor plants to the ground.
 - Discuss the main purpose of roots—to draw water and nutrients out of the soil.
8. ☐ Discuss how a carrot and a potato are adaptations of plant roots. Show the whole carrot plant.
9. ☐ Show students the eight test plants. Use one of your sample plants to explain how plants make food in this way:

Q Do you see the parts of the plant that are green, even the stem?

Q Do you know that the green coloration in the plant is called chlorophyll?

Q What part of a plant is not green?

Q Only the green part of the plant can make food, which is a simple sugar. Do you know the name of the process for a plant to make sugar? (photosynthesis)

Can Plants Survive without Light and Water?

10. ☐ Name plants that we eat that taste sort of sweet. This will help students think of the sugar that the plant makes and stores inside its tissues.

Teacher Tip: If students name sweet foods such as apples and oranges, help them see that the sugar made in the green leaves is transported to all other parts of the plant, especially the fruit, but also the roots (carrots are sweet).

Students may think of celery, lettuce, and other fruits and vegetables.

11. ☐ Compare the leaves of the example plants.

Students will observe differences in thickness of leaves, width of leaves, and texture of leaves.

12. ☐ Discuss the purpose of all these adaptations:

Q Why would a plant have a waxy leaf?

Q What would a thickened leaf do for the plant?

Q What would a plant want with a hairy leaf?

13. ☐ Discuss what part of the plants take in air.

Students may not know this, but the underside of a leaf contains the stoma, or breathing cells, for plants.

14. ☐ Ask students why, when leaves are so important for plants, some plants have very skinny leaves and other plants like cactus have spines instead of leaves?

Students may suggest that plants have different needs, depending on where they live and how they grow. Needle type leaves are an adaptation, as are broadleaved plants. In some cases, the shape and structure of the leaf prevents the plant from drying out.

15. ☐ Identify sunlight as the source of the sun's energy that helps plants produce food and grow.

16. ☐ Introduce the light sensor as a tool to measure how much sunlight plants are receiving, and demonstrate its use.

- a. The light sensor should already be connected to your data collection system and the measurement should be displayed in digits.
- b. Start data recording.
- c. Show students how the measurement is greater when the sensor is pointed toward light sources and less when it is pointed away from light sources.
- d. Pass the data collection system and sensor to students and encourage them to point the sensor in different directions so that they can become familiar with how it is measuring the brightness of light.
- e. Explain that the brightness of light is measured in units called "lux," just as their weight is measured in units called pounds or kilograms and time is measured in seconds or hours.

17. ☐ Direct students to responses 2 and 3 on their student response sheet.

Explain It

In this part of the activity, students focus on the basic needs of plants and determine ways to test those basic needs, particularly light.

18. ☐ Write the four basic needs of plants on the board (water, sunlight, nutrients, air).

19. ☐ Begin a discussion of each of the four basic needs of plants.

Q How do we know if plants really need sunlight to survive?

Q How do we know if plants need water?

Q Why do plants need nutrients? (Relate this to students' own need for proteins, calcium from milk or other sources, and vitamins.)

Q Why do plants need air? (Relate this to their need for air.)

20. ☐ Lead students through a simple discussion of how they could set up a test to see if plants really need these things to survive.

- Explain that a test needs to have two groups of plants: one that gets the normal condition and one that gets the test condition.

21. ☐ Explain to students that since both light and water are critical for the plant to make food, we will focus our test on these two needs only.

22. ☐ Even though we need to test two possible plant requirements, we should still test one requirement at a time. Here is an arrangement to share with your students:

	Sunlight	No Sunlight
Water	Plant in sunlight and given normal water	Plant in darkness and given normal water
No Water	Plant in sunlight but not given water	Plant in darkness but not given water

23. ☐ Explain to students that they will have to measure the amount of light and water the plants get. They can use the light sensor to measure the amount of light the plants get, and a tablespoon or 50-mL beaker to measure the amount of water they give the plants.

24. ☐ Ask students to name two locations for the test plants:

Q Where can we put the plants that we want to get sunlight?

Q Where can we put plants that we want to remove from sunlight? Remember that they still must have the same amount of air as the plants in the sunlight.

Can Plants Survive without Light and Water?

25. ☐ Review the following vocabulary words with your students.

➤ Vocabulary and definitions

Characteristic	A feature of a living thing that describes a basic quality
Adaptation	A change in structure that allows a living thing to survive better in its habitat
Photosynthesis	The process within plants that enables them to make sugar from carbon dioxide and water in the presence of sunlight
Chlorophyll	The green pigment in plant tissues that absorbs light to aide photosynthesis
Light	Energy from the sun for plants to photosynthesize

26. ☐ Have students complete responses 4 and 5 on their student response sheet.

Tell Me More

In this part of the activity, students will conduct an experiment to determine if plants need both light and water to survive.

27. ☐ Explain to students that there will be four groups of plants as described above:
- There will be two locations, one in the light and one not in the light.
 - At each location there will be two groups of plants: one gets water and the other gets no water.
 - There will be two plants in each group, in case one of the plants should break or die due to some unforeseen disaster.
28. ☐ To develop the students' understanding of how they will conduct the experiment, ask students:
- Q How much water will we give all the watered plants? Record that amount (2 tablespoons or 20 mL per day) on the student response sheet.**
- Q How can we label the plants that will get water and the plants that won't get water?**
- Q What is the best way to measure if a plant is getting the necessary sunlight it needs to survive?**
- Q What other observations can we make about the overall health of the plants?**
29. ☐ Demonstrate how to measure the height of the plant. Point out that students should not touch the plants while measuring their height. Their ruler or measuring stick will have

to touch the surface of the soil, but they don't have to pull on the plant. That could break the stem.

30. ☐ Have students predict how much growth they will see in the four different groups of plants, and which group will do the best and the worst. Direct students to write their predictions on student response sheet under response 6.
31. ☐ Set out the plants in the predetermined locations. Label each plant for ease in identifying them.
- a. Of the four plants that are in the light, two of them will have water also, and two of them will have no water. Label them clearly.
 - b. Of the four plants in the darkness, two of them will have water and two of them will have no water. Label them clearly.
32. ☐ Determine a system for students to measure each plant and record their data in their Journal (response 7 on the student response sheet).
- a. Plants can be measured any time during the day, but only measured once per day.
 - b. Each student should be consistent in the time he or she chooses to measure, and try to choose the same time each day.
 - c. Each group should measure the amount of light at a consistent time each day.

Teacher Tip: See the Preparation section for information on creating a Journal for each of the student groups.

33. ☐ Discuss with students why it is important to be consistent when they measure the light and the height of the plant.
- Choose the same time of day to gather data for the sake of consistency. Scientists want to eliminate unintended effects by keeping all variables consistent.
34. ☐ Determine a system for students to take turns watering the plants each day. Post a schedule for this in a visible place.
35. ☐ Guide student groups through the process of using their data collection system and light sensor to gather data in a digits display:
- a. Start a new experiment on the data collection system.
 - b. Connect the light sensor to the data collection system.
 - c. Display the data in a digits display.

Note: The light sensor has three buttons for selecting the range of light depending on the conditions. Students may need to choose the sunlight setting for the window and then switch to the light bulb or candle setting for the darker location.

36. ☐ Allow time for students to move to each of the two locations to measure the amount of light that is available. Guide them through steps to record a run of data.

Can Plants Survive without Light and Water?

37. ☐ Students will want to toggle back and forth to see their previous run of data. Guide them to select the run they want to look at.
38. ☐ This experiment can continue for several days or until your students see enough of a difference to draw a conclusion.
- a. Continue to have students measure, water, monitor the light, and record their data in their Journals each day.
 - b. Encourage students to make good qualitative observations. Model some of your own, observations such as, “The edges of these plants are curling and turning brown.”
39. ☐ Students complete their Journals (response 7 in the student response sheets) each day the experiment is in progress.

Note: The student response sheet Journal is set up to record 5 days’ worth of data. If you would like the experiment to run longer, please print out more of these pages for your students.

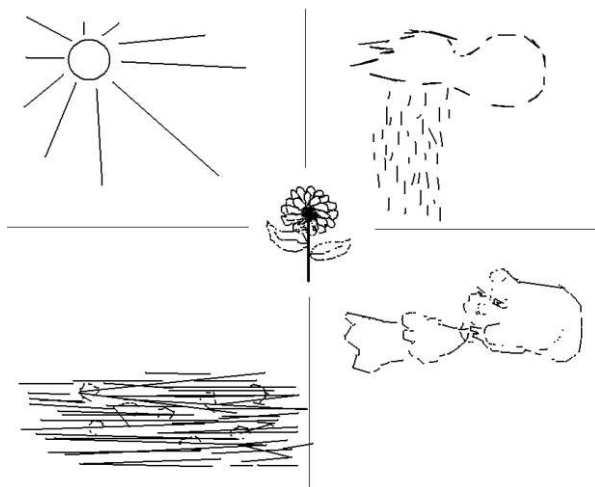
Sum It Up

40. ☐ Guide students to compare their data:
- Q Are your light measurements consistent with other groups’ light measurements?**
 - Q Are the heights you measured consistent with others’ measurements?**
 - Q Which group of plants had the tallest growth?**
 - Q Which group of plants looks the greenest?**
 - Q Which group of plants looks the worst?**
 - Q Did your results match your predictions? Please explain.**
 - Q If we continued this experiment for 5 more days, what would we find?**
 - Q Do plants need both water and light to survive, or can they get by without one or the other?**
 - Q What do plants require to stay alive?**
41. ☐ Ask students to answer response 8 on their student response sheet.

Further Investigations

The best way to extend this investigation is to let students redesign the experiment. They will have other places to put their plants, and other parameters to control. Some students will want to find a different source of light to investigate, or use light with an intensity between sunshine and darkness. Other students may want to vary the amount of water or have plants grow in water only with no soil.

To cement the idea that plants have four basic needs for survival, you can ask students to illustrate the four needs on a sheet of paper as a homework assignment. Tell them to fold a paper into quarters. In each of the four corners, illustrate and label the four basic needs of plants: light, air (wind), soil (for nutrients), and water (rain or a hose). They can remember this by the acronym **LAWN** (light, air, water, nutrients).



1. What characteristics tell me that plants are alive?

Plants can grow and change, can make their own food, can take in water and need air, can reproduce and eliminate waste, and can maintain their strength and health.

Plants need rest too.

2. Describe how you will use the light sensor.

I will use the light sensor to find out how much light the plants are getting. I will point it at the window where the plants are sitting and take a run of data in a digits display.

Then I will point it into the space of darkness where the other plants are sitting and take another run of data. Then I will record the data and turn my light sensor off.

3. What are the units of measurement called for light?

LUX

4. What are the four basic needs of all plants?

a. <u>water</u>	b. <u>sunlight</u>
c. <u>soil for nutrients</u>	d. <u>air for carbon dioxide</u>

5. Draw lines from each vocabulary word to its description.

Photosynthesis	Changes in the plant that help it to survive better, like waxy leaves or thicker roots
Chlorophyll	The process for a plant to make sugar
Adaptation	Main features of living things, like breathing and eating
Characteristic	Green pigment in plants that aid them in making sugar

6. Predict:

a. Which group of plants do you think will grow the best?

The group that gets both water and sunlight.

b. Which group of plants will grow the least?

The group that gets neither water nor sunlight.

c. How much growth do you predict you will see in the four groups?

Condition	Prediction
Plants in sun and water (#1,2)	<u>Possible answer: These will grow 6 in.</u>
Plants in sun but no water (#3,4)	<u>Possible answer: These will grow 2 in.</u>
Plants in darkness with water (#5,6)	<u>Possible answer: These will grow 4 in.</u>
Plants in darkness with no water (#7,8)	<u>Possible answer: These will not grow at all</u>

7. Gather Data (Journal)

Date: _____			Time: _____
Plant	Height (cm)	Light (lx)	Observations
1	4 cm	529	plant looks healthy and strong
2	5 cm	529	plant looks healthy and strong
3	3 cm	529	plant looks healthy and strong
4	4 cm	529	plant looks healthy and strong
5	4 cm	10	plant looks healthy and strong
6	5 cm	10	plant looks healthy and strong
7	3 cm	10	plant looks healthy and strong
8	4 cm	10	plant looks healthy and strong

Teacher Note: Make five copies of #7 from the Student Response Sheet for each student group.

8. Can plants survive without water or sunlight?

No, not for long