Elementary School

Teacher Guide

PASCO®

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Elementary School

Introductory Science Experiments

Teacher Guide

21st Century Science

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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

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 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

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

12	Feeling and Measuring Temperature Use a temperature sensor to compare the results of measuring temperature to how the temperature feels.	Data Collection System	1
		PASPORT Temperature Sensor	1
		Thermometer. digital	1
		Thermometer, bulb-type	1
		Plastic cup, 400-mL or 12-oz	1
		Water, cool	~100 mL
		Water, warm	~100 mL
		Paper or cardboard sheet for fan (21-cm × 28-cm or 8.5-in. × 11-in.)	1
13	Cars and Heat Use a temperature sensor to determine how the temperature inside a car parked in the sun compares to the temperature of the air outside the car.	Mobile Data Collection System	
		PASPORT Temperature Sensor	
		Shoe box model car, assembled	1
		Shoe box	1
		Black paper	Enough to line the shoe box
		Plastic food wrap to cover the shoe box	1
		Paper cup, modified to fit within the shoe box	1
		Yarn, cotton balls, other craft supplies	A variety
		Markers, a variety of colors	1
		Glue stick	1
		Tape	~30 cm
	Teacher Demonstration	Mobile Data Collection System	1
		PASPORT Temperature Sensor	1
		Projection system	1
		Shoe box model car, assembled	1
14	Observing Clouds Use a weather sensor to show that clouds in the sky have properties that can be observed and described, and that students associate cloud formation with specific weather conditions such as temperature and humidity.	Mobile Data Collection System	1
		PASPORT Weather Sensor	1
		Cloud Types handout	1
		PASCO Cloud Finder handout	1
		Scissors	1
		Glue	1
		Paper fastener (brad)	1
		Weather Journal handout	1
		Tagboard or card stock, 14-cm × 14-cm	1
		Compass	1
		Ribbon, 12–15 cm long	1
	Teacher Demonstration	Mobile Data Collection System	1
		PASPORT Weather Sensor	1
		Glass canning jar, 1-quart	1
		Plastic wrap and rubber band	1
		Posters or pictures of cloud types, in color	1
		Sponge	1
		Turkey baster	1
		Water, hot	20 mL
		Water, ice	50 mL
		Wooden stick matches	1

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.	Data Collection System PASPORT Light Sensor Ruler	1 1 1
	Teacher Demonstration	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 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.	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	1 1 1 1 Several 3 300 mL 200 mL 200 mL 1 3 200 mL 100 mL 300 mL
	Teacher Demonstration	Data Collection System PASPORT Temperature Sensor Wooden block Ice cube, 0.5 g or less Tape, ~3 in. piece Balance Projection system	1 1 1 2 1 1 1
	Preparation	Bucket to hold ice water Thermos® Balance	1 1 1

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

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 ~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 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 PASPORT Temperature Sensor Construction paper, skin-tone (8 cm × 12 cm) (3 in. × 5 in.) 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 Meteorology records on the Internet Meter stick Petri dish or small shallow dish or jar lid Scissors Table or stool to clamp lamp Utility lamp with clip, 75 W, 100 W, or sunlamp Water, room temperature World map or globe	1 1 1 40 mL to 50 mL A variety 1 2 1 1 1 40 mL to 50 mL 1

24	Chemical Reactions	Data Collection System	1
	Use a temperature sensor to	PASPORT Temperature Sensor	1
	measure the change in	Sugar cube	1
	temperature as two	Beaker half full of water	1
	substances chemically react.	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 each2	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
	Teacher Demonstration	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

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
29	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 K-1

1. Heavy and Heavier

Recommended Grade Levels: K – 1

Objectives

Students learn that objects have a property called weight that can be measured, and that an object's weight is not necessarily related to its size.

Procedural Overview

To understand this content, students:

- Observe properties of matter such as size, weight, and shape
- Classify objects as heavy and heavier

Time Requirement

■ Teacher Preparation	10 – 15 minutes
■ Activity	20 – 30 minutes
■ Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Force sensor with hook installed
- ☐ Container (bucket or basket) to attach to the force sensor hook[1]
- ☐ 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] A recycled butter tub or other container with 2 or 3 holes for string works well.

Safety

Follow all standard classroom practices.

Preparation

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

- Inflate a balloon large enough to fit in your bucket and tie the end.
- Set up your data collection system to measure force.

1. Start a new activity on the data collection system.

2. Connect the force sensor to the data collection system.

3. Display Force, pull positive on the y-axis of a graph with Time on the x-axis.

4. Adjust the scale of the graph to best represent the range of forces you will measure.

Background

Heaviness: Mass versus Weight

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."

Force Sensor Explained

The "heaviness-measuring tool," or force sensor, measures the strength of pushes and pulls. It measures force in newtons.

In this activity, where the force sensor 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 has less mass than the Earth, and therefore has less gravitational pull on objects. 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.

The Relationship between Size and Heaviness

An object's heaviness is not necessarily related to its size. For example, a large piece of foam may weigh much less than a piece of wood half its size. Size and heaviness are two different properties of matter. Size can also be referred to as volume, or the amount of space an object takes up. Heaviness, on the other hand, refers to an object's weight. Although these are different properties, their relationship is an important concept in science known as density. Density is the ratio between the mass and volume of an object. This can be written as a word equation: density equals mass divided by volume.

Heaviness, Mass, Volume, and Density

Students will ultimately have to know the various terms for describing the size and composition of an object, but we recommend for this activity that you use the term "weight" only. Weight can be described as "related" to the amount of matter in an object. One of the secondary goals of the activity is to show that there is not a direct relationship between size (volume) and weight, in an effort to prepare students for later discussions of mass and density.

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

How do you know if an object is heavy or heavier?

Get Started

1. ☐ Set out the following objects in students' view: the large piece of polystyrene, the large and small fruits or vegetables, the toy vehicle, and the inflated balloon.

   Note: Any objects may be used, but they need to be between 1 and 50 newtons in weight (0.1 to 4 kg in mass), and should vary enough so that no two objects are similar in mass. Experiment to find out which objects work best.

2. ☐ Pick up the inflated balloon and take it for a walk around the room as if it were very heavy. Exaggerate all of your movements.

3. ☐ Follow up on students' reactions to your behavior with such questions as:

   Q Do you think this balloon is heavy?

   Q What makes you think this balloon is heavy?

4. ☐ Have students point to one of the objects they think is not heavy. Ask them to tell why they think it is not very heavy.

   Answers will vary and may center on previous experience with an object.

5. ☐ As you listen to their answers and comments, discuss their ideas about the size of the objects and the materials the objects are made of.

6. ☐ Help students understand that the word "light" can be used to mean "not heavy."

7. ☐ Next have students point to one of the objects they think is heavy. Guide a similar discussion about why they think the object is heavy. Ask questions such as:

   Q Is it heavy because it is big?

   Q Is it heavy because it is made of wood (or metal, or other material)?

Let's Explore

8. ☐ Have students take turns picking up and holding each of the objects.

9. ☐ Ask students to sort the objects into two group: heavy and heavier.

Explain It

10. ☐ Ask students, "How do you know if something is heavy?"

    Pick it up and compare how difficult it is to lift versus other objects.

11. ☐ Ask, "Which object would make a louder thud if you dropped it on the table from here?" (Have the object at a height of ½ inch above the table.)

    Q Is it heavier because it is larger?

    Q Is it heavier because it is shinier?

    Q Is it heavier because there are no holes in it?

    Q Is there one of these objects that you would rather not have dropped on your bare foot?

Tell Me More

12. ☐ Ask, "What tool can be used to measure heaviness?"

    Students may be familiar with a bathroom scale or food scale at the market.

13. ☐ Have students examine the parts of the force sensor.

14. ☐ Once the bucket is hanging from the hook, zero the force sensor and then start recording a run of force data.

    Teacher Tip: If students are curious about the zeroing operation, it may be instructive to tell them the bucket has weight, but we are interested in the weight of the objects we put in the bucket. If your students want to know more, begin collecting data before adding the bucket, and then add the bucket and press the zero button.

15. ☐ Measure the heaviness of the bucket as more objects are added to it.

16. ☐ Help students observe that the heavier the bucket is, the higher the graph goes.

Sum It Up

17. ☐ Have students look at the graph of heaviness (force) data. Ask students

    How the graph helps show us when heavier objects are put into the bucket?

    Students should be able to look at the graph and point to places where the line is higher and relate the higher points to heavier items in the bucket. They should be able to point to lower points on the graph and relate these to less heavy items in the bucket, or an empty bucket altogether.

18. ☐ How do you know if an object is heavy or heavier?

Students may say they need to have two objects to compare in order to determine if an object is heavy or heavier.

19. ☐ Have students complete the student response sheet.

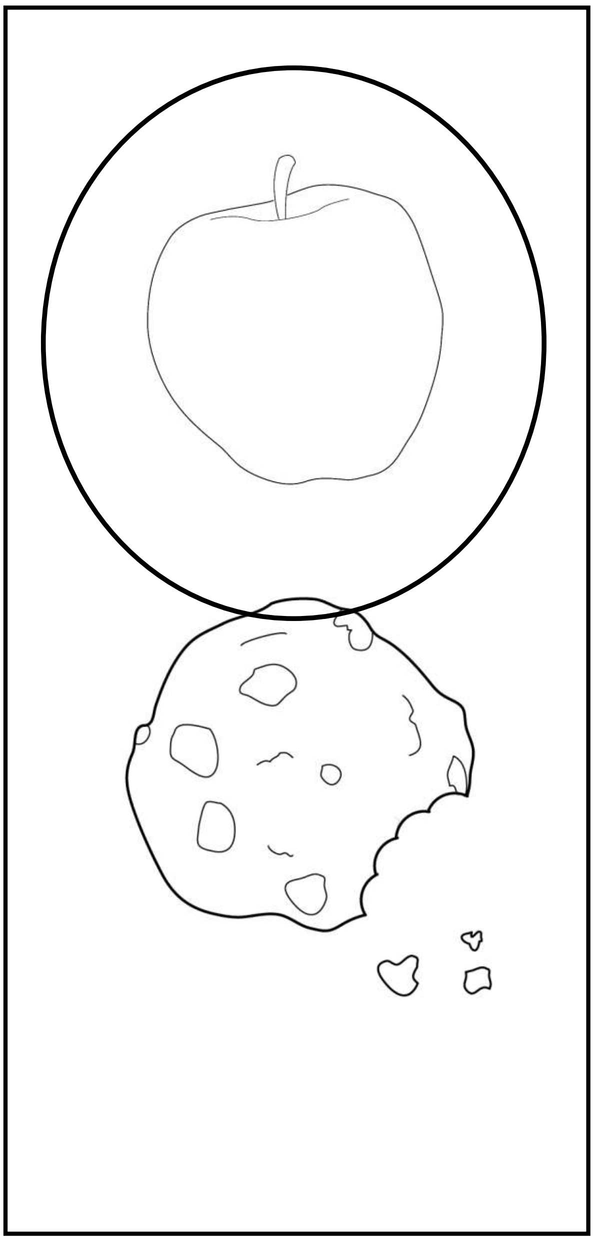
Further Investigations

Provide your students with three identical opaque closed containers, each with a different material inside with a significantly different density. Have your students guess what the material inside the container might be based on the weight of the container

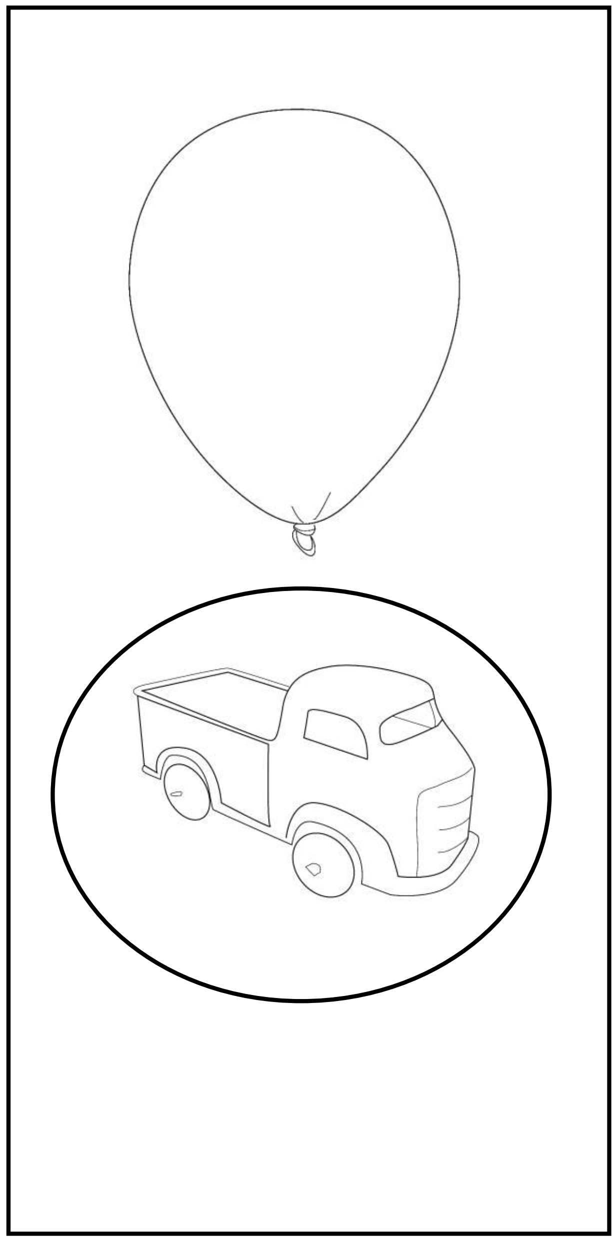
If something has more weight, we say it is:

heavier

Which one is heavier? (circle one)



Which one is heavier? (circle one)



2. Near and Far

Recommended Grade Levels: K – 1

Objectives

Students learn to describe the position of an object as being near or far from another object and they recognize that an object in motion changes its position.

Procedural Overview

To understand this content, students:

- Observe the movement of objects and classmates.
- Describe the location of objects and classmates relative to other objects, such as a reference point or the motion sensor.

Time Requirement

■ Teacher Preparation	10 – 15 minutes
■ Activity	20 – 30 minutes
■ Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Motion sensor
- ☐ Large playground ball
- ☐ Meter stick

Safety

Follow all standard classroom practices.

Preparation

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

- Clear a space at least 2 meters in front of the motion sensor for student safety and to ensure that no other object is reflecting the signal of the motion sensor.
- Set up your data collection system for motion detection.

    1. Start a new activity on the data collection system.
    2. Connect the motion sensor to the data collection system.
    3. Display Position on the y-axis of a graph with Time on the x-axis.

4. Adjust the scale of the graph to best show the range of positions you will measure.

Background

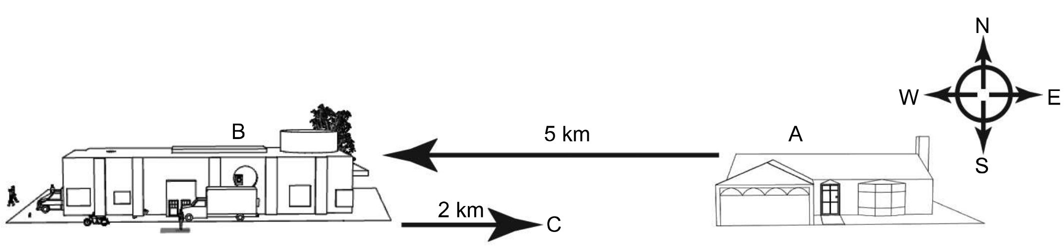
The terms "distance," "position," and "distance traveled" are often used interchangeably in everyday language. This can cause confusion when students begin their study of motion because these terms have different meanings.

"Motion" is defined as a change in position relative to an object or the background. We can visualize the motion of an object by creating a "trace" of the object's change in position over time. A position includes both direction and distance from an object or specified part of the background. It is good practice with young students to get them in the habit of describing position this way.

For example, when using the motion sensor you might describe your position as, "I am 1 meter in front of the motion sensor." If your students are not ready for units of measure like meters, you might try something more concrete such as, "I am two steps in front of the motion sensor." Students may, in fact, notice that one person's steps are longer than another person's steps, or people taking the same number of steps end up at different positions. This is an opportunity to show them a meter stick and let them know that this is why a scale is used for measuring. If everyone uses the same scale, we can more readily describe what we mean when we say, "near" or "far."

Distance versus Position versus Distance Travelled

If you tell someone the distance to your house, you might say "five kilometers" (5 km). However, if you tell someone the position of your house (point A), you might say, "5 kilometers east of the mall" (point B).



In this picture, the distance is 5 km, the direction is east, and you are measuring distance relative to the mall. "Distance traveled" is the total distance required to get from one position to another.

Assuming that you travel on a straight road to the mall, the distance traveled is 5 km and your position is 5 km west of your home. Now imagine that you turn around and travel from this position toward your house, going a distance of 2 km (point C). The total distance traveled is then 7 km (5 km plus 2 km), but your position is 3 km (5 km minus 2 km) west of your house. In this example, your final position is a distance of 3 km, the direction is west, and you are measuring relative to your house.

Near and far are relative terms, so you may need to take extra time to review examples that are familiar to your students. For example, the door to your classroom may be far from you relative to the distance of a student standing next to you, but the door may be near to you relative to the distance to the principal's office.

How the Motion Sensor Works

The motion sensor measures the time it takes for an ultrasonic pulse to travel to an object and back to the sensor. Using the speed of sound, it can determine the distance to the object. This is a rough approximation of the way dolphins and bats use echo location to determine the distance to 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 Question

How do you know if something is near or far?

Get Started

1. ☐ Hold a large playground ball on your hands at arm's-length.

2. ☐ Slowly and steadily draw the ball in closer to your face until it is just touching your nose.

3. ☐ Repeat this two or three times.

4. ☐ Ask students to tell you when the ball is near your nose and when the ball is far from your nose.

5. ☐ Place the ball near a student's nose and ask the class:

   Q Whose nose is the ball near now?

   Q Is the ball far from my nose or near to my nose?

6. ☐ Move the ball back to touch your nose and ask students:

   Q Is the ball near [student's name] nose or far from his or her nose?

7. ☐ Follow up on students' reactions with such questions as:

   Q Was the ball near because it is round?

   Q Was the ball near because it is bouncy?

   Q Was the ball far because it is [color]?

   Q Was the ball far because it is bigger than a pumpkin?

Let's Explore

8. ☐ Choose an object in the room to use as a reference point for near and far. An object such as the door, your desk, or other large, obvious classroom landmark in the students' line of sight works well.

9. ☐ Ask pairs of students to stand near and far from the reference point object. Tell which student to stand near and which student to stand far, but let each student decide where to stand.

Explain It

10. ☐ As pairs of students take their places, ask the class: Who is standing near the object? Who is standing far from the object?

    Students should be able to point to the students who are near and far.

11. ☐ Ask students, "How do you know if someone is near or far?"

    Student answers will vary. Some students may focus on the fact that we are using our eyes to see the difference, but try to direct students to the fact that they are comparing the relative positions of two things.

12. ☐ Help students develop their understanding of near and far with the following questions.

    Q Is he near because he is a boy? Is she near because she is a girl?

    Q Is she far because her name is [student's name]?

    Q Is he near because we are inside the classroom?

    Q Where would you like to stand if there was something really stinky on the [reference object]?

Tell Me More

13. ☐ What tools can be used to measure near and far?

    Students may be familiar with rulers or tape measures. Add "motion sensor" to the list.

14. ☐ Have students examine the parts of the motion sensor. Call attention to the round metal screen which is the reference point.

    Note: Students do not need to know this, but you should be aware that the metal screen is on the front of the motion sensor. The motion sensor cannot detect where they are if the metal screen is not pointing at them.

15. ☐ Begin recording a data run of position versus time data (motion).

16. ☐ Measure your position to show you are standing 15 cm (6 in.) in front of the motion sensor.

17. ☐ Continue measuring your position as you back away from the motion sensor and then walk toward it and stop.

18. ☐ Stop data recording.

19. ☐ For this activity, it is best to show only one run of data at a time, so if necessary, hide the data runs before beginning the next one.

20. ☐ Help a student volunteer walk close to and move away from the front of the motion sensor. It may be necessary to walk with the student to make sure he or she does not step outside of the motion sensor's beam.

21. ☐ Show students that the motion sensor measures "near" and "far." "Far" is higher on the graph than "near" is.

Sum It Up

22. ☐ Display the position versus time graph of the student volunteer. Have the class look at the motion graph of near and far (position) data. Ask:

    - How did the graph help show us whether someone is near or far?

      Students should be able to look at the graph and point to places where the line is higher and lower and relate the higher points to the student being far from the sensor. They should be able to point to lower points on the graph and relate these to the student being near the sensor.

22. ☐ Identify for your students the part of the graph where the student volunteer was changing position.

23. ☐ As a class, have your students describe in words the parts of the graph of Position versus Time.

    For example: [Student name] was near the front of the motion sensor and then changed position by walking away from the motion sensor until he or she was far from the front of motion sensor.

24. ☐ Have students complete the student response sheet.

Further Investigations

Introduce a distance scale:

1. ☐ To further your students' understanding of measuring, place the meter stick on the ground in front of the motion sensor.

2. ☐ Explain, "Instead of measuring the distance to the sensor as steps, I want to use a scale that people have agreed to."

3. ☐ Stand one meter away from the motion sensor and say, "I am one meter way from the motion sensor."

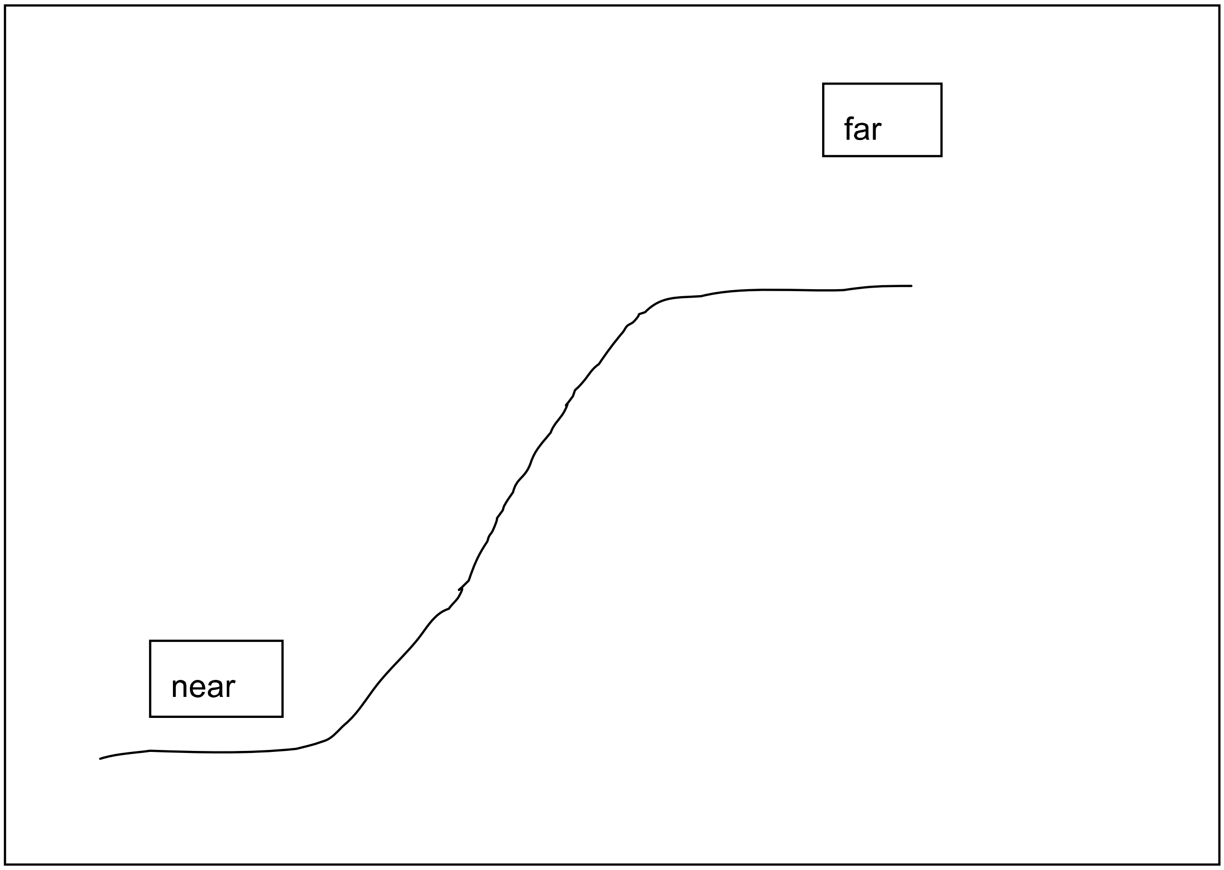
4. ☐ Pick up the meter stick and hold it up next to the y-axis of your graph.

5. ☐ Tell students, "We use a scale like a meter stick so we can all measure the same way."

6. ☐ With the meter stick on the floor, let your students take turns moving back and forth in front of the motion sensor.

   Note: Remember the motion sensor has a minimum distance that it can measure of 15 centimeters.

Draw the graph of position in the box. Label the graph using the words NEAR and FAR



Name something that is near to you.

desk

Name something that is far from you.

door

3. Mixing Water

Recommended Grade Levels: K – 1

Objectives

Students understand that mixing hot and cold water results in a new temperature that is between the hot and cold.

Procedural Overview

To understand this content, students:

- Identify the temperature of different objects
- Recognize that the position of the line on a graph relates to the hot or cold temperature of the object
- Predict the resulting temperature of mixing hot and cold water

Time Requirement

Teacher Preparation	10 – 15 minutes
Activity	15 - 20 minutes
Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Small paper cups (2)
- ☐ Large paper or plastic cup
- ☐ Ice water, approximately 5 ˚C, 200 mL
- ☐ Warm water, approximately 40 ˚C, 200 mL
- ☐ Towels

Safety

Follow all standard classroom practices.

Preparation

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

- Fill one small paper cup with hot water and one with ice water.
- Set up your data collection system for measuring the temperature of the hot and cold water.
    1. Start a new activity on the data collection system.

2. Connect the temperature sensor to the data collection system.

3. Display Temperature on the y-axis of a graph with Time on the x-axis.

4. Set the data collection systems to the temperature scale that is most familiar to your students.

5. Adjust the scale of the graph to best represent the range of temperatures you will measure.

Background

Most students will only be familiar with one temperature scale. Use the scale that is most familiar to your students for the activity.

Temperature: A Measure of Internal Energy

All objects in the universe have some internal energy. This internal energy is due to the energy of the random motion of an object's particles (atoms or molecules). Energy associated with motion is called kinetic energy, while energy associated with position is called potential energy. Temperature is a measure of the average kinetic energy of the particles in a substance.

Temperature Scales

In the United States, temperature is most commonly measured using the Fahrenheit scale. On this scale, the freezing point of water at sea level is 32 degrees and the boiling point of water is 212 degrees. Elsewhere the metric or Celsius scale is used to measure temperature. This is also the temperature scale used frequently in science. This scale is sometimes referred to as the centigrade scale because there are 100 degrees between the freezing point and the boiling point of water at sea level. In the Celsius scale, 0 degrees is defined to be the freezing point of water, with the boiling point at 100 degrees.

Scientists also use the Kelvin scale to measure temperature. On this scale, water freezes at 273 Kelvin, so 273 Kelvin refers to the same temperature as 0 degrees Celsius. A difference in temperature of 1 degree is the same in the Kelvin and Celsius scales, but 1.8 times the difference of 1 degree Fahrenheit.

How Cold Can It Go?

Zero on the Kelvin scale (–273 degrees Celsius) is known as absolute zero. It is a theoretical point at which molecules and atoms have zero kinetic energy and has never been reached in laboratory experiments. Scientists can currently achieve low temperatures of about one-billionth of a degree above absolute zero.

Energy Flows from Warmer to Cooler

Energy is transferred between objects as heat. This energy is transferred because one object is at a higher temperature than the other. If two objects at different temperatures are in contact with one another, the energy will be transferred from the warmer object to the colder object until both reach the same temperature. The point at which each object is the same temperature is referred to as the "point of equilibrium."

When a pie comes out of the over and is placed on a counter to cool, the hot pie transfers heat to the air and counter that come into contact with the pie until they all reach the same temperature. When we mix hot and cold water, heat energy is transferred from the hot water to the cold water until both are at the same temperature. This is similar to the way we change the temperature of a room by mixing warm and cool air.

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

What happens when you mix a hot thing and a cold thing together?

Get Started

1. ☐ Set out two small paper cups filled with hot and cold water.

2. ☐ Ask the students the following questions:

   Q Which one of the cups has COLD water in it?

   Q How do you know the water in that cup is cold?

   Q Which one of the cups has HOT water in it?

   Q How do you know the water in that container is hot?

   Q If you saw a pot full of water on the stove in the kitchen, can you tell by looking at it if the water is hot or cold?

   Q When you take a bath, how do you make sure the water is not too hot or too cold?

Let's Explore

3. ☐ Have students take turns putting their fingers in the ice water and into the warm water.

   - Encourage students to have one finger in the cold water and one finger from the other hand in the warm water at the same time, so they can feel the difference.

   - Keep towels handy to help students dry their hands.

Explain It

4. ☐ Ask students:

   - What things are cold? What things are hot?

     Student answers will vary. Cold things may include ice, snow, refrigerator, or air from an air conditioner. Hot items might include stoves, fire, cocoa, or the sun.

- How do you know if something is hot or cold?

  Student answers will vary. We primarily sense hot and cold by touch, but we can see steam coming off hot water.

- How do you think you can you make something warm?

  Student answers will vary. They may suggest placing the object in contact with something warmer, or placing the object close to something that radiates heat, such as a heater or camp fire.

Tell Me More

5. ☐ Ask, "What tools can be used to measure hot or cold?"

   Thermometers or temperature sensors

6. ☐ Have students examine the temperature sensor.

7. ☐ Start recording a run of temperature data.

8 ☐ Insert the temperature sensor in the ice water in the cup to measure the temperature. Allow the temperature graph to go as low as it will go (20-40 seconds).

9. ☐ Move the temperature sensor to the cup of hot water. Measure the temperature of the hot water. Allow the temperature graph to go as high as it will go.

10. ☐ Help students observe that "hot" is higher on the graph than "cold" is.

11. ☐ Mix the hot water and the cold water together in the large cup. Ask students to predict what the water will feel like.

12. ☐ Ask students to predict where the line on the graph will show up when the temperature sensor is placed in the mixed water cup.

13. ☐ Place the temperature sensor in the large cup containing the mixed water. Allow the temperature graph to reach a stable temperature.

14. ☐ Stop data recording.

Sum It Up

15. ☐ Have students look at the graph of hot, cold, and warm temperature data. Ask them, "How did the graph help show us whether something is hot or cold or in between?"

    Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the hotter water. They should be able to indicate lower points on the graph and relate these to the cold water.

16. ☐ Ask students, "What happens when you mix a hot thing and a cold thing together?"

    The resulting temperature is somewhere between the two starting temperatures.

17. ☐ Have students complete the student response sheet, copying the graph of temperature and adding the words "hot," "cold," and "mild" at the correct places.

Further Investigations

Continue the activity by developing the idea of a temperature scale.

1. ☐ Start recording a run of temperature data.

2. ☐ Remove the temperature sensor from the mixed water, dry it quickly, and let it measure the room temperature.

3. ☐ Stop data recording.

4. ☐ Note the difference between the temperature of the mixed water and the room temperature, and identify the room temperature as "mild" (not too hot and not to cold).

5. ☐ Ask the following questions:

   - What do we call something that is hotter than the room but not hot?

     Warm

   - What do we call something that is colder than the room but not quite cold?

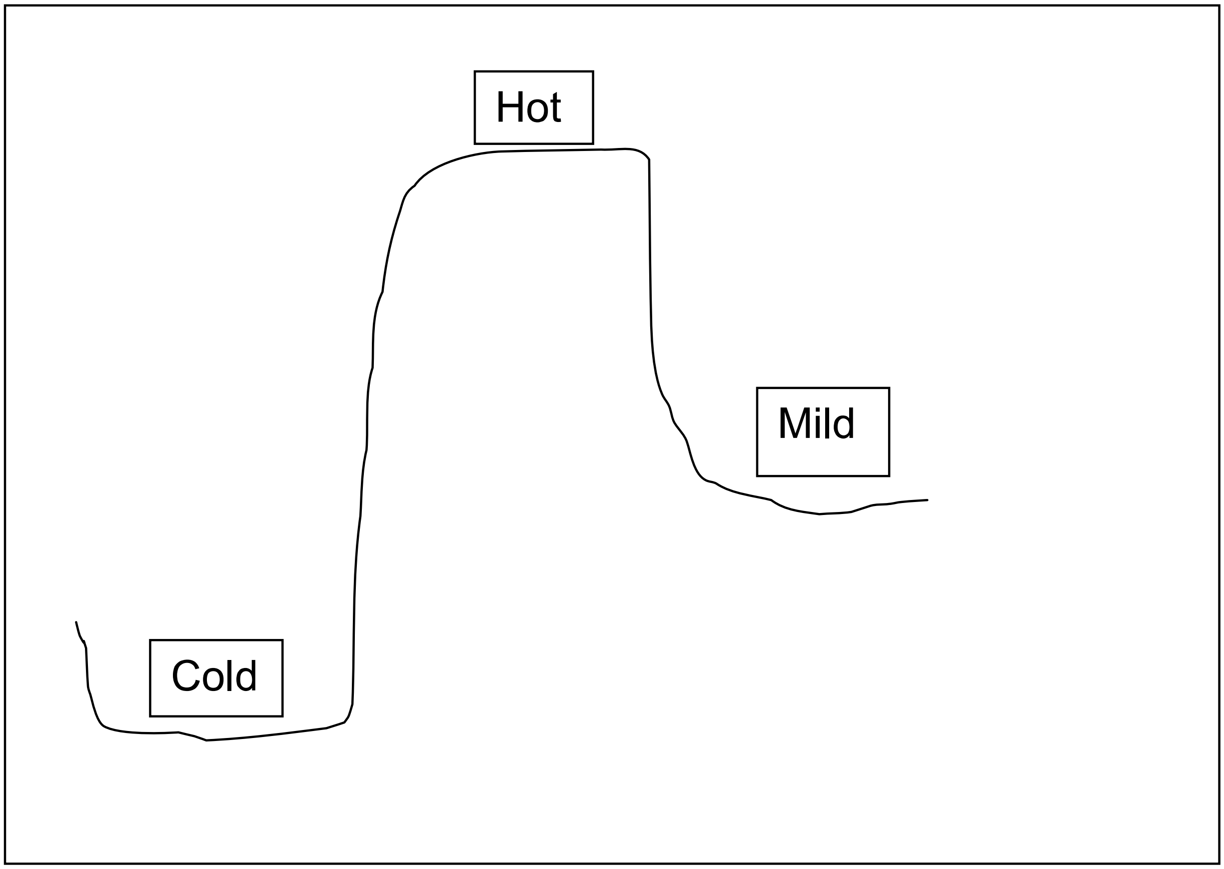
     Cool

6. ☐ Explain that they have created their own temperature scale.

7. ☐ Draw a thermometer and add the new scale starting on the bottom with "cold," and working your way up the thermometer with "cool," "mild," "warm," and "hot."

8. ☐ Have your students identify items in the room that would be in each temperature range and add them to your drawing.

Draw the graph of temperature to show cold, hot, and mild.



Write hot, cold, and mild on the graph of temperature.

What do you get when you mix hot and cold?

mild

4. Light and Dark

Recommended Grade Levels: K – 1

Objectives

Students determine how light is related to what they see.

Procedural Overview

To understand this content, students:

- Observe how the presence and absence of light affects what they see
- Observe the level of light from a light source versus the light reflected from a surface

Time Requirement

■ Teacher Preparation	10 – 15 minutes
■ Activity	20 – 30 minutes
■ Student Response Sheet	5 – 10 minutes

Materials

- ☐ Data collection system
- ☐ Light sensor
- ☐ Sensor extension cable
- ☐ Strips of construction paper, 2.5 cm x 8 cm (1 in. x 3 in.) different colors, 1 per student[1]

[1] Each student should be given one strip of construction paper so that there are a variety of colors within the class. Colored wooden craft sticks may also be used.

Safety

Follow all standard classroom practices.

Preparation

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

- Set up your data collection system for measuring light.

    1. Start a new activity on the data collection system.

    2. Connect the light sensor to the data collection system.

    3. Display Light Intensity on the y-axis of a graph with Time on the x-axis.

Background

Light – Part of the Electromagnetic Spectrum

The electromagnetic spectrum represents the range of waves that can travel through empty space at the speed of light (approximately 300,000 kilometers/second). Electromagnetic waves, as they are called, carry energy and can behave as waves while they travel but are emitted and absorbed as particles. The spectrum, or variety, of waves includes radio waves, microwaves, infrared waves, visible light, ultraviolet light, X rays, and gamma rays. The lower the frequency of an electromagnetic wave, the longer its wavelength becomes. Each color of visible light has a unique wavelength. The color with the longest wavelength is red while the shortest wavelength belongs to violet.

Sunlight is a form of electromagnetic wave. It consists of several types of waves that our eyes and bodies can distinguish. We see visible light, we feel the warmth of infrared light on our skin, and we try to avoid the damage our skin may experience from ultraviolet light.

Light Sensor Explained

The “light-and-dark measuring tool,” or light sensor, measures light intensity as perceived by our eyes. Light intensity is measured in units called lux (abbreviated “lx”). The light sensor has a small aperture, or opening, surrounded by a short black tube. Light rays must shine through this opening in order for their intensity to be measured. This structure is analogous to the iris in our eyes because it admits light.

The Light Sensor Is Like Our Eyes

Both the light sensor and our eyes must have light enter them in order to “see.” If the opening of the light sensor is covered over with a finger, for example, it “sees” no light. A graph of light intensity will show zero intensity until the finger is removed from the opening. Likewise our eyes cannot perceive form or color without some amount of light entering through the iris and striking the retina at the back of the eye.

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

How is light related to what we see?

Get Started

1. ☐ Darken the room or go into a closet. In the dark, hand each student a colored strip of paper or a colored craft stick.

   Note: Be sure not to let students see the paper or craft sticks before they are in the dark.

   Teacher Tip: For best results, this part of the activity needs to be carried out in a very dark environment. Explain to students ahead of time how the room will be darkened or that they will be going into a dark room such as a coat room or closet. You may even want to practice being in the dark so that when you do the activity, students' attention can be focused on looking for the color of their paper, rather than on the novelty of being in the dark.

2. ☐ Ask students to tell what color their paper strip or craft stick is.

Let's Explore

3. ☐ After turning on the light, ask students again what color their paper strip or craft stick is.

   Students should discover the color of their paper or stick.

4. ☐ Follow up on students' reactions to their experience:

   Q What color did you say your paper or stick was when we were in the dark?

   Q What color did you say it was when the lights were on again?

   Q Do you think your paper (or craft stick) changed color or was it the same color the whole time?

   Q Could you tell what color it really was when it was dark?

5. ☐ Encourage students to compare their color results in the dark to their results in the light.

Explain It

6. ☐ Collect the paper strips if you will be saving them for another class.

7. ☐ Affirm that the presence of light made it possible to see the color clearly, and ask students:

Q Where does light come from?

Q Where does light go?

Q Can light go through things?

Q Is it easier to see things in the light or in the dark?

8. ☐ Ask students to think of examples of when someone in their family has had difficulty seeing something in the dark.

9. ☐ Ask students where it would be easier to find a lost toy:

Q Under your bed or in the middle of the room?

Q Outside in the day or outside at night?

Q In the dark with a flashlight or without a flashlight?

10. ☐ Ask students, "When you shine a flashlight on something the light travels straight out from the flashlight, so how does the light get back to your eye so you can see the object?"

A portion of the light is reflected back to your eye.

Tell Me More

11. ☐ Ask students, "What tool can be used to measure light and dark?"

A light sensor can be used to measure the intensity of the light.

12. ☐ Have students examine the parts of the light-and-dark measuring tool (light sensor).

13. ☐ Show students the "eye" of the light and dark measuring tool and explain that it can "see" light and dark. When light gets into the tool's "eye," it can see. Light is higher on the graph, and dark is lower on the graph.

Note: If you are using a Temperature/Sound Level/Light MultiMeasure® sensor, point out to students that the black plastic tube is where the "eye" is located.

14. ☐ Start recording a data run of light intensity versus time. Have a student volunteer use his or her hand or finger to cover and uncover the "eye" of the light-and-dark measuring tool.

15. ☐ Adjust the scale of your graph to clearly see the range of intensities in your room.

16. ☐ Ask the class to tell when the tool's "eye" is "open" and when it is "closed" as the volunteer covers and uncovers the light sensor.

17. ☐ Ask students,

- If we cover up the light sensor (close the eye), how much light is getting into it?

None of the light is getting into the sensor. Point to the graph to affirm that no light is being measured.

- So when we say something is dark, what does this mean?

  No light is present.

18. ☐ Point the light sensor directly at a room light.

19. ☐ Remind your students that the light is going directly from the room light to the light sensor.

20. ☐ Point the light sensor at a surface in the room, and ask the following questions:

- Is the light from the surface more or less than the light coming from the room light?

  The light intensity will be much less. Help your students understand that higher on the graph means more light.

- Where does the light coming from the surface originally come from?

  The light is reflected from the room light.

21. ☐ Stop recording data.

Sum It Up

22. ☐ Have students look at the graph of light and dark data and ask,

- How did the graph help show us when the “eye” was open and closed? How did the graph help us know when it was light and dark?

  Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the “eye” being open and seeing light. They should be able to point to lower points on the graph and relate these to the “eye” being closed and not seeing any light, or dark.

23. ☐ Ask students, "How is light related to what we see?"

Light is needed in order to see. What we see is the light reflected from an object that reaches our eyes. If there is no light, we can't see.

24. ☐ Have students complete the student response sheet.

Further Investigations

Help your students better understand the usefulness of sensors and "sensing" in doing scientific investigations with the following questions:

Q How can the light sensor be used to see into places where we cannot reach?

Q How might this be helpful to us?

Q Can we use the light sensor to find out if the light goes off in a refrigerator when the door is closed?

Another activity that might help students understand how light is reflected is to bring a playground ball and a flashlight into the dark room. Hold up the ball and have a student shine the light from the side so that half of the ball is illuminated. Remind them how the moon looks in the sky at night. Have the student with the flashlight slowly move around the ball. The light from the sun (the flashlight) strikes the moon and is reflected back to us, so we only see the parts that are reflecting the sunlight.

What do we need to see things?

light

What is it like when there is no light?

dark

What do we use to see light?

our eye

5. Exploring Temperatures

Recommended Grade Levels: K – 1

Objectives

Students understand that all matter has the observable property of temperature, and that temperature is a measure of how hot or cold something is compared to a standard scale.

Procedural Overview

To understand that temperature is a measurable property of matter, students:

- Explore temperature changes by the use of graphs and meters for measuring temperature
- Guess which places in the classroom and around the school will be warm and which places will be cool
- Check guesses with a temperature sensor
- Compare the range of warm and cool places inside and outside

Time Requirement

■ Teacher Preparation	15 minutes
■ Activity	30 minutes
■ Student response sheet	15 minutes

Materials

For teacher demonstration:

- ☐ Mobile data collection system
- ☐ Temperature sensor
- ☐ Bag of clothing[1]
- ☐ Large outdoor thermometer
- ☐ Paper meter [2]
- ☐ Paper thermometer scale (can be written on)
- ☐ Thermometer, oral

[1]Clothing should include both hot and cold weather clothing.

[2]Refer to the Preparation section for the simple construction of the meter.

For student groups:

- ☐ Mobile data collection system[1]
- ☐ Temperature sensor[1]

[1]The number of mobile data collection systems and temperature sensors depends on the size of the groups. If you lead the whole class, 1 set is required, otherwise have 1 set per group leader (aide or other class assistant).

Safety

Add this important safety measure to your normal classroom procedures:

- Care should be taken not to disturb the environment.

Preparation

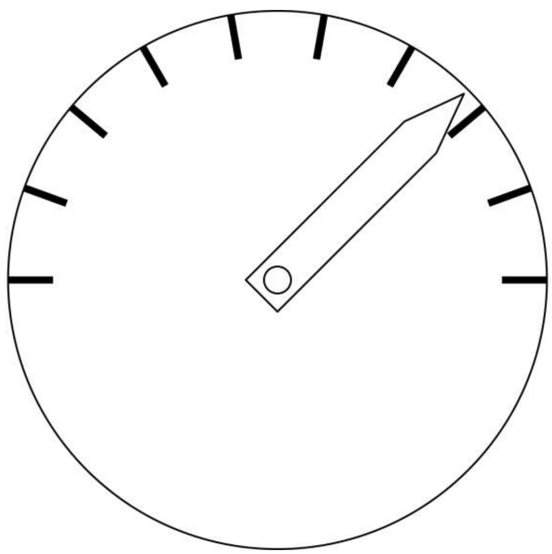
These are the materials and equipment to set up prior to the activity.

- Paper meter construction

  Use construction paper or paper plates and a brad to construct the meter shown below.

- For kindergarten, leave the numbers off, but put marks at evenly spaced points around the meter.

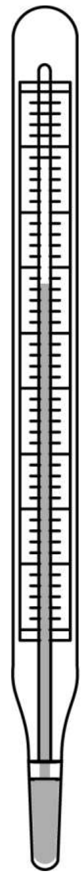
- For first grade, use the Fahrenheit scale, writing whole numbers in the range of 0 °F to 100 °F, counting by tens.



- Paper thermometer construction

- Use construction paper or butcher paper to construct the thermometer shown below.

- Numbers are not necessary; this is just to give a qualitative context to high and low temperature.



- Set up the data collection system for displaying the temperatures of ice water and warm water during the "Tell Me More" portion of the activity:

1. Start a new activity on the data collection system.

2. Connect the temperature sensor to the data collection system.

3. Display Temperature in a meter display.

4. Display Temperature on the y-axis of a graph with Time on the x-axis.

5. Adjust the scale of the graph to best represent the range of temperatures you will measure.

6. Set the data collection system displays to the temperature scale that is most familiar to your students.

7. Set the sampling rate to 1 Hz.

8. If your classroom has a projection system and you want to display the graph and meter to the whole class at once, follow your usual classroom procedure to connect your data collection system to the projection system. You will need the correct software on your computer for your data collection system.

Background

Very young children can distinguish between "cooler" and "warmer." If your students are unfamiliar with the term "temperature," you can start a discussion with comparisons between how they feel when they stand in the shade versus standing in the sunshine, and how they feel when they get hot while playing on the playground or when lying on a cool floor.

Students often think that a coat generates heat when they go outside in the cold. In reality, the coat provides a buffer between the heat given off by their body and the varying temperature of the air outside. This activity focuses on measuring the air temperature in different locations

Air is a gas and has all of the properties of matter attributed to solids and liquids. The property focused on in this activity is temperature. Air temperature is a measure of the amount of thermal energy in the air. Thermal energy is added to the air directly by the sun and indirectly by the re-radiation of thermal energy from the Earth's surface, once it has been warmed by the sun. Heat energy in the local air is reduced when a lower temperature air mass mixes into it.

As heat always flows from a warmer to a cooler object, when a cool air mass mixes with a warm air mass, the warm air mass cools and the temperature is lowered. (Wind is the cause of air masses mixing.)

Raising or Lowering Temperature

Work is done to raise or lower the temperature of a room. Indoors, furnaces add hot air to the classroom and the warmth of peoples' bodies also adds heat energy. Heat energy is reduced in the classroom air by the addition of cold air from the air conditioner and the drawing of warm air out of the room through open windows.

Measure Temperature, Not Heat

The temperature sensor does not directly measure heat energy; the sensor measures how hot or cold the air is with respect to a standard. The temperature will change on the thermometer or sensor until the air and the sensor reach "thermal equilibrium". At this point, heat energy stops being transferred between the sensor and the matter being measured. The sensor displays the temperature at the point of equilibrium.

Be careful to distinguish between heat and temperature. When a thermometer is used to measure your body temperature or the air temperature, it is measuring thermal equilibrium. For young students, guide them to say they are measuring temperature, not heat.

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

Does the air have a temperature?

Is the temperature of the air different in different places?

Get Started

1. ☐ Ask students to explain how they feel on a hot day, and what kinds of activities they like to do on a hot day. Have the same conversation about a cold day.

2. ☐ Use questions like the following to introduce the words "warm" and "cool," and then order "cold," "cool," "warm," and "hot" for students

   Q Do you sometimes feel sort of hot but not too hot? This feeling is called "warm."

   Q Where have you felt warm but not too hot?

   Q Would you rather feel warm or hot?

   Q Do you sometimes feel not too cold but only a little cold? This feeling is called "cool."

   Q Where have you felt cool but not cold?

   Q Would you rather feel cool or cold?

3. ☐ Have a grocery bag containing various pieces of clothing appropriate for cold days and hot days. Items can include a bathing suit, a rain coat, a hat and scarf, mittens, sunhat, tank top, shorts, sweat pants.

4. ☐ Pull the pieces of clothing out of the bag one by one and display them for the class.

   As you pull out each item, ask students to tell you if they would wear the item on a cold day or on a hot day.

   Q If it were a hot day outside, would you feel cool or warm?

   Q If it were a cold day outside, would you feel cool or warm?

5. ☐ Next, ask students to think about the air inside the classroom.

   Q Is the air in the classroom cold or hot?

   Q What is it in the classroom that makes it feel cold or hot?

   Teacher Tip: Guide students' comments to the fact that the air in the classroom is not in direct sunlight, so it stays cooler. Students may want to talk about furnaces and air conditioners here.

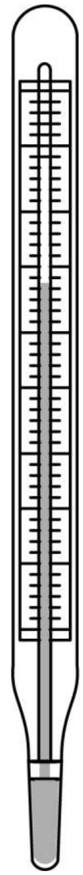
6. ☐ Begin a discussion about ways to measure temperature

   Ask students if they have been sick, and felt too hot or too cold.

   Ask if a parent has ever had to take their temperature. Have students describe how their parents take their temperature.

7. ☐ Show them an oral thermometer and describe the way the red liquid (alcohol) inside the thermometer moves higher on the scale if they have a high temperature.

8. ☐ Show students a large paper thermometer, like the drawing below, and show them how the red liquid could go higher or lower.



9. ☐ Explain to students that temperature is how we measure the hotness or coldness of objects, or of the air.

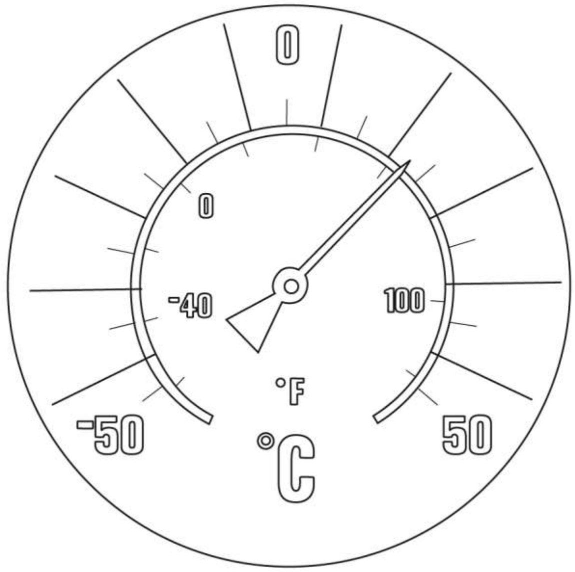
10. ☐ Explain that we can measure the temperature of lots of things to find out how hot or cold they are. Use questions like the following to remind students of temperature measurements in their lives:

    Q Does your parent measure the temperature of a turkey in the oven? (Use any appropriate familiar situation.)

    Q Do you have a thermometer outside in your yard to measure the temperature of the air outside?

    Note: Some students will be unfamiliar with any of these measuring tools, but some will be very familiar with such experiences. Allow them to share their experiences for the benefit of all.

11. ☐ Show students a large outdoor thermometer (the kind with the circular face). Also, have the paper meter you can manipulate.



12. ☐ Using the thermometer and the meter, ask students to demonstrate how high the red liquid would go or where the needle would point if it were a cold day or a hot day.

a. For kindergarten, this is just a lower–higher comparison.

b. For first grade, elicit the idea that 30 °F is a day for coats, scarves and mittens, and 100 °F would be a day for bathing suits and swimming.

Let's Explore

13. ☐ Demonstrate how the sensor records temperature with a line on the graph and a pointer on the meter.

a. Start recording data.

b. Moisten the tip of the temperature sensor, then swing the sensor in the air and show the students how the line on the graph drops lower and the meter's arrow moves to the left.

c. Warm the sensor in the palm of your hand and show how the line on the graph goes up and levels off, and how the meter pointer moves to the right.

d. Repeat this process several times, asking the students to explain to you how the sensor is measuring the temperature.

The sensor measures how hot or cold the air is with respect to a standard. The temperature will change on the thermometer or sensor until the air and the sensor reach "thermal equilibrium".

e. Ask where on the graph the temperature is colder, and where it is warmer. Ask the same questions for the meter.

Students should understand that if the line goes lower on the graph, the temperature is measuring something cooler. They should also know that the needle moving to the left on a meter means cooler.

f. Stop recording data.

14. ☐ Compare temperatures around your classroom together.

a. Start recording temperature data.

b. As a group, predict where the temperature in the classroom will be warmer (or cooler).

c. After each prediction, walk to that location and hold the temperature sensor in place for a few seconds.

d. Show the results to the students and let them decide if their prediction was supported by the data or not supported.

e. Stop recording data.

15. ☐ Have your students break into their smaller groups and ensure each group leader has a mobile data collection system and a temperature sensor.

    a. Encourage each student group to think about locations that can be paired with another location for comparison. For example, take temperature readings of the floor and ceiling of a room.

    b. Have each student group start recording data.

    c. Send each student group to the locations they have chosen to measure.

    d. After students have returned, have them stop data collection.

16. ☐ Give each student group a moment to determine from their data which location was the warmest and which place was the coolest.

17. ☐ Have each group share their results in turn by asking the following questions.

    Q What is the warmest temperature you found?

    Q Why do you think it was so warm?

    Q What was the coolest temperature?

    Q Why was it cooler?

Explain It

18. ☐ Come back together as a class for discussion. Was there a big difference between your warmest spot and your coolest spot, or was there a little difference?

    Students will likely notice that there was only a little difference between the warmest and the coolest places in the classroom, because the air temperature in a classroom is controlled.

19. ☐ What makes the air temperature warm?

    Answers may vary. Students will say being under covers, or in sunshine through a window, or by a hot air duct, it will be warmer.

20. ☐ What makes the air temperature cool?

Answers may vary. Students will say that being indoors is cooler than being in the sun; they will point to the air conditioning or the fan, or mention the cool floor if it is not carpeted. They may also point to an open window.

21. ☐ How do you think outside temperatures will compare to inside temperatures?

Kindergarten students can describe the differences as hotter or colder. First graders can predict a value in degrees Fahrenheit.

Tell Me More

22. ☐ Have your group leaders prepare the mobile data collection system by hiding any previous runs of data.

23. ☐ Ask students, "How can we measure warm and cool temperatures outside?"

Encourage students to explain how they will take their temperature sensor outside and explore air temperature in different locations, just as they did inside. Listen for the use of action words and simple ordering of steps.

24. ☐ To elicit a good procedure, ask students:

Q What will you do first?

Q When will you push the start button?

Note: The goal is to help students to plan what they will do before they do it and explain in words what they will do.

25. ☐ Ask students to predict where they think the temperature of the air will be the warmest? The coolest?

Q Where do you want to take the temperature?

Teacher Tip: Limit each student group to measuring the temperature at only two or three locations.

Q How hot or cool do you think it will be?

Q What will make it warmer or cooler?

26. ☐ Group students again with a classroom helper or aide as group leader, and have each group plan the locations they will go to outside to measure the temperature.

a. Have each group start recording temperature data.

b. Send the groups off to their first location.

c. Group leaders should allow the sensor to adjust to the temperature in each location before moving to the next.

d. Have the groups go to each location where they chose to measure the temperature.

e. Stop recording data and return to the classroom.

27. ☐ Each group should look at the line on their graph to discuss the following.

Q Where did the temperature go up by a large amount?

Q What made the temperature go up in these places?

Q Where did the temperature go down by a large amount?

Q What made the temperature go down in these places?

28. ☐ Come back together as a class and let each group share their data.

Sum It Up

29. ☐ Ask students to compare the outside temperatures with the inside temperatures.

Q For kindergarten: Did the outside temperatures change a lot or a little?

Q For first grade: What was your highest outside temperature? What was your lowest outside temperature?

30. ☐ Determine the hottest places outside and the coolest places outside and sum up with the students what makes these places hot and cold.

31. ☐ Review what the line on the graph did when the temperature was really hot.

The line goes higher on the graph when the temperature was hot.

32. ☐ Discuss what the line on the graph did when the temperature was the coolest.

The line goes lower on the graph when the temperature is measuring something cooler.

33. ☐ Compare locations from different groups and try to find the warmest and coolest locations overall. Can the class see any patterns to the values? What made certain areas warmer or cooler?

34. ☐ Ask students:

Q Does the air have a temperature?

Q Is the temperature of the air different in different places?

35. ☐ Have students complete the student response sheet.

Further Investigations

Ask your students what the coldest thing they can think of is. Answers will vary, but direct them toward blizzard-like temperatures outside or a freezer in their home, whichever is more appropriate. Ask them what happens when we put water in these conditions. Try the following:

1. ☐ Set your data collection system to collect one sample per minute.

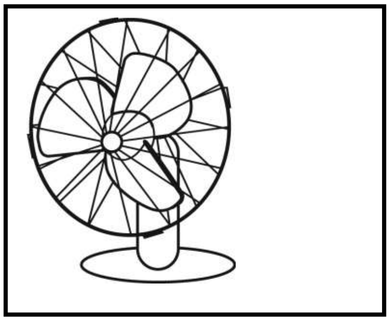
2. ☐ Place the tip of the sensor in a container of water and record the temperature of the water overnight.

3. ☐ Show the graph to your students the next day.

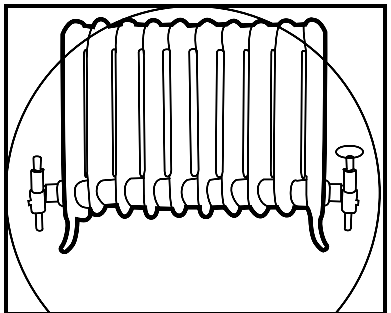
4. ☐ Repeat the data recording the following night with the water container in a freezer. Bring in the data and block of ice for your students to see.

For Inside Temperatures

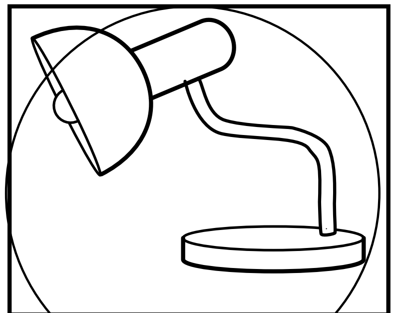
Circle the pictures that show places where the temperature will be warm or hot.



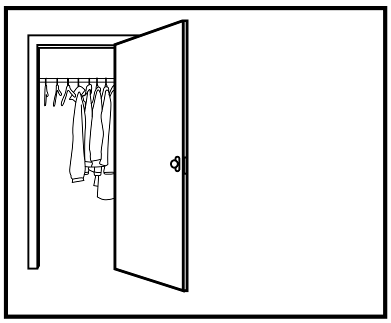
Near a fan



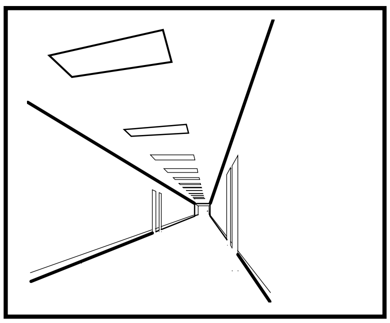
Near a heater



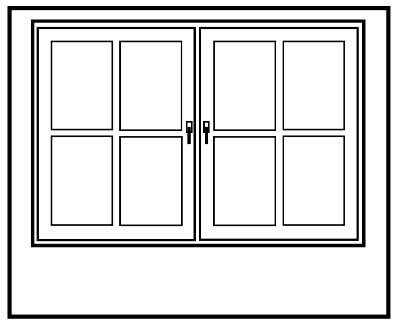
Near a lamp



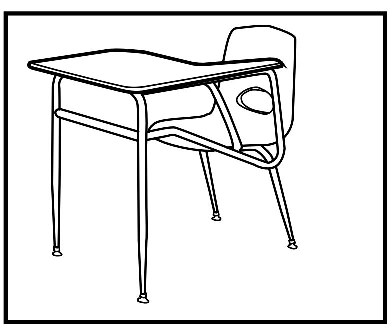
In a dark place



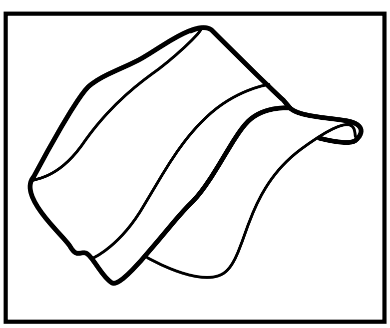
In a hallway



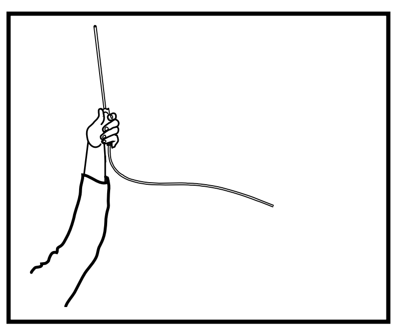
Near the window



Under a desk



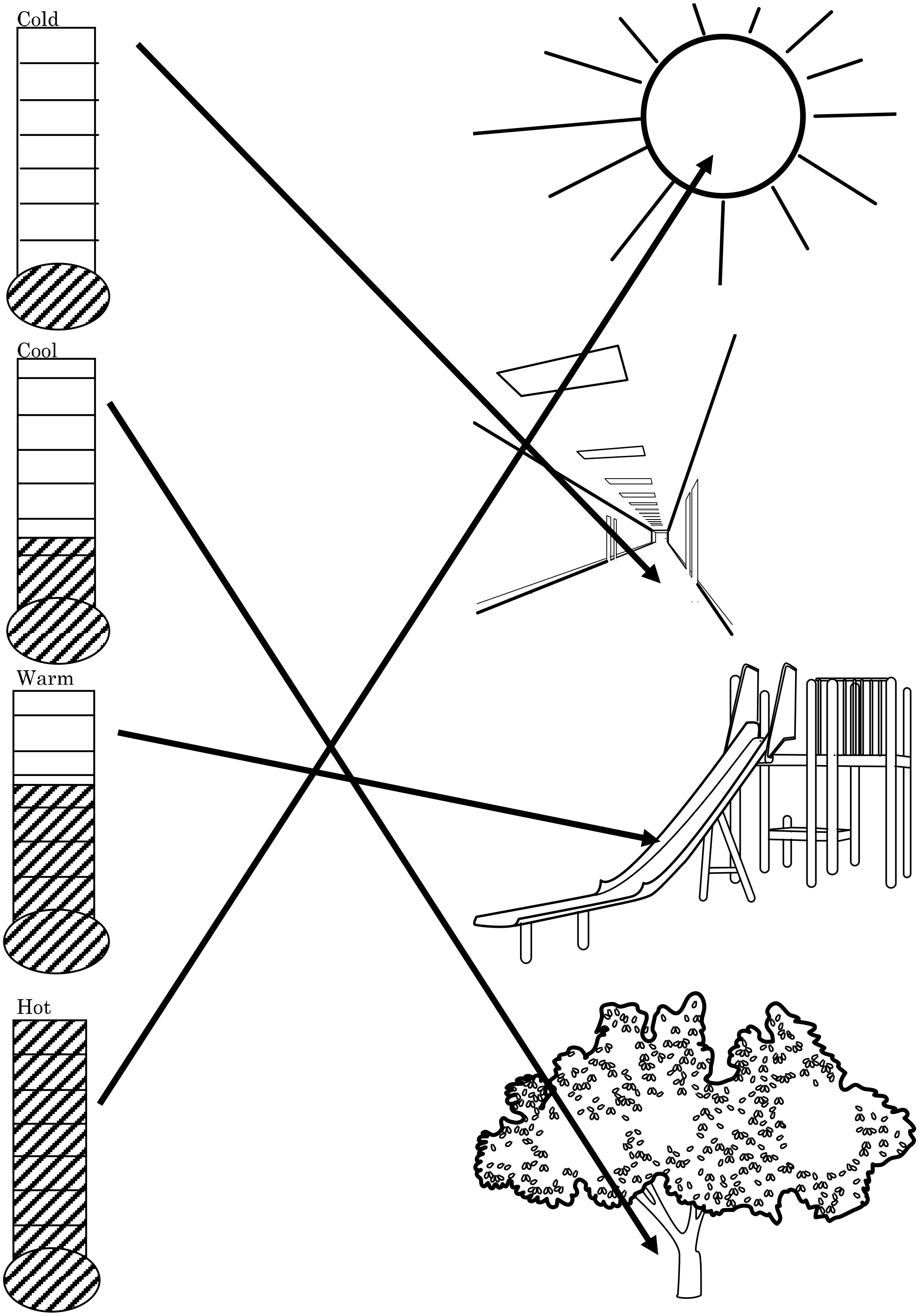
Under a hat



High up in the air

For Outside Temperatures

Draw lines to connect the pictures with the words. Color the thermometer to match the words.



Answers will vary based on your local conditions

6. Hot and Cold

Recommended Grade Levels: K – 1

Objectives

Students recognize that one of the observable properties of objects is temperature, and that this property can be measured using a thermometer or temperature sensor.

Procedural Overview

To understand this content, students:

- Observe the temperature of different objects
- Classify materials as cold or hot

Time Requirement

Teacher Preparation	10 – 15 minutes
Activity	20 – 30 minutes
Student Response Sheet	5 – 10 minutes

Materials

For teacher demonstration:

- ☐ Data collection system
- ☐ Temperature sensor
- ☐ Buckets or containers for water[1] (2)
- ☐ Towels
- ☐ Ice cubes (several[1]), for cold water container
- ☐ Plastic water or soda bottles, several,[1] filled with warm water (no warmer than 30 °C or 86 °F), tightly capped[2]

[1]The size of the buckets, number of ice cubes and number of bottles depend on the size of your class and the number of students you want to be able to hold them simultaneously.

[2]Recycled 500-mL water bottles, with labels removed, work well for this activity.

Safety

Follow all standard classroom practices.

Preparation

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

- Place the ice in one bucket and bottles of warm water in the other bucket.
- Set up the data collection system for displaying the temperatures of ice and warm water during the "Tell Me More" portion of the activity:

a. Start a new activity on the data collection system.

b. Connect the temperature sensor to the data collection system.

c. Display Temperature on the y-axis of a graph with Time on the x-axis.

d. Set the data collection systems to the temperature scale that is most familiar to your students.

e. Adjust the scale of the graph to best represent the range of temperatures you will measure.

Background

Most students will only be familiar with one temperature scale. Use the scale that is most familiar to your students for the activity.

Temperature: A Measure of Internal Energy

All objects in the universe have some internal energy. This internal energy is due to the energy of the random motion of an object's particles (atoms or molecules). It is also due to the energy resulting from how tightly bound the particle is to surrounding particles. Energy associated with motion is called kinetic energy, while energy associated with bonding is called potential energy. Temperature is a measure of the average kinetic energy of the particles in a substance.

Temperature Scales

In the United States, temperature is most commonly measured using the Fahrenheit scale. On this scale, the freezing point of water is 32 degrees and the boiling point of water 212 degrees. Elsewhere the metric or Celsius scale is used to measure temperature. This is also the temperature scale used frequently in science. This scale is sometimes referred to as the centigrade scale, because there are 100 degrees between the freezing point and the boiling point of water. In the Celsius scale, 0 degrees is defined to be the freezing point of water, with the boiling point at 100 degrees at sea level.

Scientists also use the Kelvin scale to measure temperature. On this scale, water freezes at 273 Kelvin, so 273 Kelvin refers to the same as 0 degrees Celsius. A difference in temperature of 1 degree Celsius is the same as 1 Kelvin, but 1.8 times the difference of 1 degree Fahrenheit.

How Cold Can It Go?

Zero on the Kelvin scale (–273 degrees Celsius) is known as absolute zero. It is a theoretical point at which particles have zero kinetic energy and has never been reached in laboratory experiments. Scientists can currently achieve low temperatures of about one-billionth of a degree above absolute zero. At such low temperatures matter can behave strangely. For example, metals can conduct electricity with no resistance (superconductivity) and liquid helium can flow with no viscosity (superfluidity).

Energy Flows from Warmer to Cooler

Energy is transferred between objects as heat. This energy is transferred because one object is at a higher temperature than the other. Heat itself does not flow, nor does cold; heat is energy "on the move." If two objects at different temperatures are in contact with one another, the energy will be transferred from the warmer object to the colder object until both reach the same temperature. The point at which each object is the same temperature is referred to as the "point of equilibrium."

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

What do we mean when we say "hot" and "cold?"

How do we tell if something is hot or cold?

Get Started

1. ☐ Set out a container or bucket of ice cubes where students can see them.

2. ☐ Pick up an ice cube and react as if it is warm or even hot. Exaggerate all of your movements.

   Follow up on students' reactions to your behavior with such questions as:

   Q Do you think ice cubes are hot?

   Q What makes you think an ice cube is hot?

   Have students point to the container holding the objects or materials they think are cold. Ask questions such as:

   Q Are these things cold because they are shiny?

   Q Are they cold because they are clear or see-through?

   Q Are they cold because they taste like water?

Let's Explore

3. ☐ Have students take turns picking up and holding an ice cube and a bottle of warm water in their hands.

   Encourage students to hold an ice cube in one hand, then a bottle of warm water in the same hand before holding it in the other hand. The bottle of water may seem to students to be two different temperatures.

   Note: Not all students may be willing to hold an ice cube.

   Teacher Tip: Keep towels handy to help students dry their hands after holding the ice cubes.

4. ☐ Ask students to sort the ice cubes and water bottles into two groups, cold and hot.

Explain It

5. ☐ Ask students:

   Q Which things are cold?

   Q Which things are hot?

   Q How do you know if something is hot or cold?

6. ☐ What do you think …?

   Q Is it hot because it is made of water?

   Q Is it hot because it is wet?

   Q Is it cold because it has this shape?

   Q Is there one of these things that you would not like to have put down the back of your shirt?

Tell Me More

7. ☐ Ask, "What tool can be used to measure hot or cold?"

   Thermometer or temperature sensor

8. ☐ Have students examine the temperature sensor.

9. ☐ Begin recording a run of temperature data.

10. ☐ Insert the sensor in the bucket with ice to measure the temperature of the ice cubes. Allow the temperature graph to go as low as it will go.

11. ☐ Move the temperature sensor to the container with the bottles of hot water. Measure the temperature of the hot water in the bottles: Open the lid of one of the bottles and place the temperature sensor inside.

12. ☐ Allow the temperature graph to go as high as it will go.

13. ☐ Help students observe that "hot" is higher on the graph than "cold" is.

Sum It Up

14. ☐ Ask students:

    Q What do we mean when we say "hot" and "cold?"

    Q How do we tell if something is hot or cold?

15. ☐ Have students look at the graph of hot and cold temperature data. Ask them how the graph helped show us whether something is hot or cold.

    Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the hotter water. They should be able to point to lower points on the graph and relate these to the ice.

16. ☐ Have students complete the student response sheet.

Further Investigations

Let your students measure the temperature around the classroom. Have them place the temperature sensor in their arm pit to compare their temperature to the room temperature. The idea is to get them familiar with expressing temperature as a number, and with seeing the range of temperatures associated with objects in their environment.

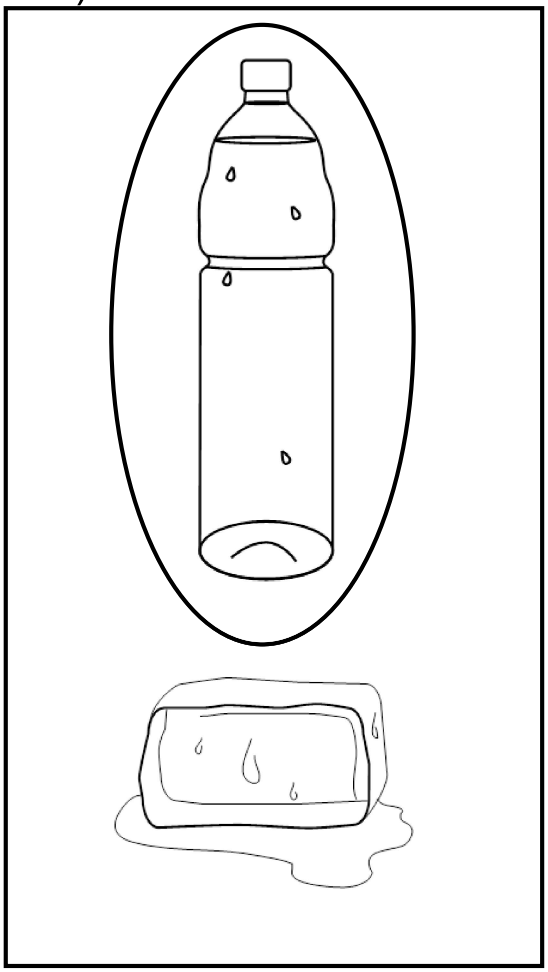
1. Display Temperature in a digits display.

2. Change the units of the temperature if necessary.

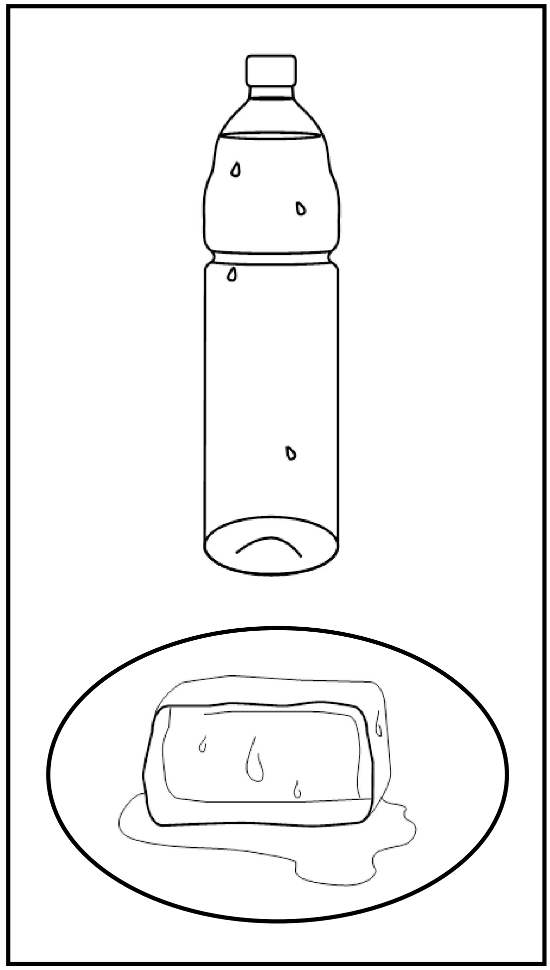
Note: The temperature sensor is not for internal use.

Name: Answer key Activity by PASCO Sensors

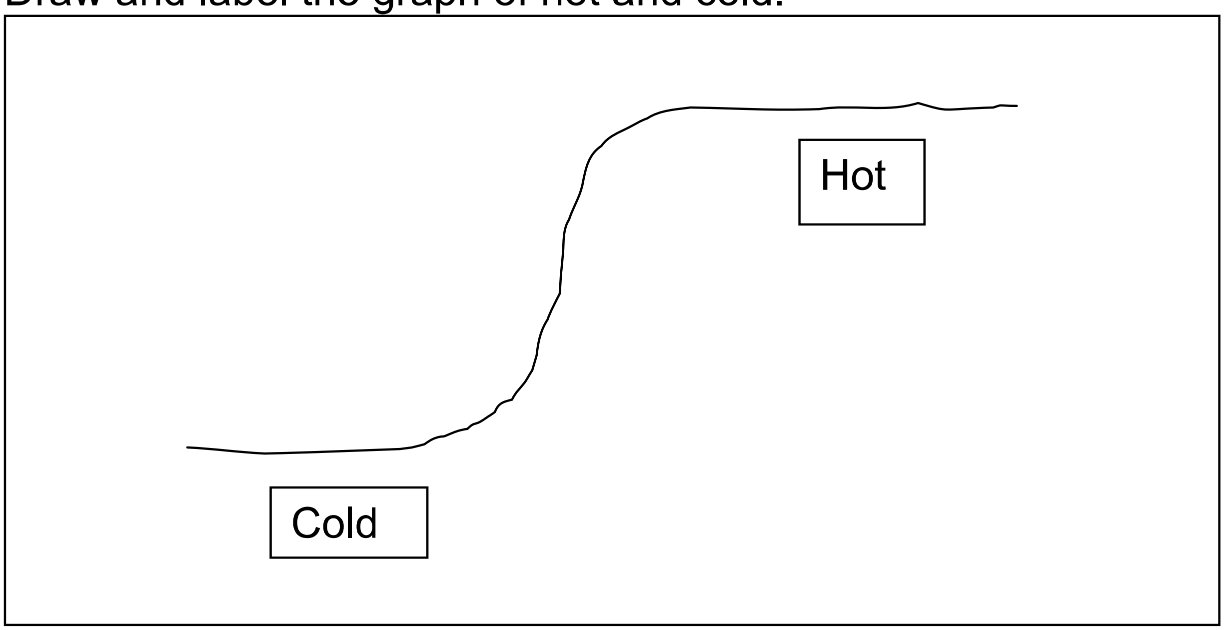
Which one is hot? (circle one)



Which one is cold? (circle one)



Draw and label the graph of hot and cold.



7. Weather Instruments

Recommended Grade Levels: K – 1

Objectives

Students develop the language for describing weather conditions, and observe the measurements used to determine weather conditions.

Procedural Overview

To understand this content, students:

- Observe and describe the weather they see out their window.
- Compare the weather they see from one day to the next.

Time Requirement

■ Teacher Preparation	10 – 15 minutes
■ Activity	20 – 30 minutes
■ Student Response Sheet	5 – 10 minutes

Materials

- ☐ Mobile data collection system[1]
- ☐ Weather sensor
- ☐ Sensor extension cable
- ☐ Leaf
- ☐ Feather

[1]A mobile data collection system is necessary if you plan to measure weather conditions outdoors,

Safety

Follow all standard classroom practices.

Preparation

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

- Set up your data collection system for measuring the weather.
    1. Start a new activity on the data collection system.
    2. Connect the weather sensor to the data collection system.
    3. Display Temperature on the y-axis of a graph with Time on the x-axis.
    4. Change the units of temperature data to units that are most appropriate for your students.

Background

Weather or Climate?

Weather is the term used to describe atmospheric conditions at any given moment. Such conditions include temperature, moisture, and wind. Averaged over several decades, the patterns of weather experienced in a region make up that region's climate. When we think of a region's climate, we often think about the temperature and precipitation we can expect in a particular season.

Moisture and Precipitation

Moisture in the air in the form of water vapor is what causes precipitation. Humidity refers to the amount of water vapor in the air. Meteorologists, or weather scientists, may speak of absolute or relative humidity. The absolute humidity is the mass of water vapor in a given volume of air. Air can hold only a certain amount of water vapor. Cold air can hold less water vapor than warm air.

Relative humidity is the amount of water vapor in the air compared to the maximum amount it can hold at a given temperature. Relative humidity is usually expressed as a percent.

When moist air cools as it rises, clouds form. Rain, snow, hail, and sleet come from clouds that form from moisture that has risen, cooled to its dew point, and condensed. Tiny cloud droplets are so light they can take as long as 48 hours to fall one kilometer (1000 meters or about 3300 feet). They evaporate before they reach Earth's surface. However, the tiny droplets of water may clump together, or coalesce, into drops heavy enough to fall all the way down to the Earth's surface. Rain, snow, hail and sleet are collectively known as precipitation.

Wind

Wind blows because there are regions of different pressures in the atmosphere. These pressure differences exist vertically and horizontally, and are the result of the uneven heating of the atmosphere by the sun. You may be familiar with the rush of "wind" that accompanies the opening of a vacuum-sealed tin of coffee, or a container of new tennis balls. The pressure in the container is lower than the pressure in the surrounding atmosphere of the room, so the air from the room rushes into the container. Likewise, you can experience the "wind" produced by an inflated balloon that is allowed to deflate. The air inside the balloon is at a greater pressure than the surrounding atmosphere of the room, and so it rushes into the room.

On the Earth's surface, the wind flows toward areas of lower pressure and away from areas of higher pressure. Typically, only horizontal airflows are called wind.

Temperature

There are three main ways that air cools. The heat absorbed by the Earth from the sun during the day radiates away at night, so the land, water, and air become cooler. Air cools as it rises because it expands. The expansion occurs because the pressure decreases with altitude. You may have noticed this if you have ever opened a bag of chips on an airplane. The bag contains air from the factory where the chips were packed, which is at a higher pressure than the cabin pressure of the airplane. The expansion of the air due to a decrease in pressure requires the air to do work, using up some of its energy, and cooling in the process. Air also cools when it comes into contact with a cooler surface. Moisture in the air may condense on cool surfaces as dew or frost.

The Weather Sensor

The weather sensor allows students to collect and observe six key measurements: temperature, barometric pressure, relative and absolute humidity, dew point and altitude. It can be used to take a current reading or to monitor weather over an extended period of time, such as days or weeks. If you plan to monitor weather over time and leave the sensor outdoors, it needs to be protected from becoming wet or from being immersed in water. For examples and ideas of how to construct and operate a weather station, see the Weather Station (Grades 4–5) activity in this manual.

Activity with Answer Key and Teacher Tips

Each step has a box next to it. (☐) If you find it convenient, after you complete a step or answer a question, check off that step.

Driving Question

How do we describe the weather?

Get Started

1. ☐ Sing or read the following poem to students:

   Like a Leaf or a Feather

   Like a leaf or a feather

   In the windy, windy weather,

   We will twirl around

   And all sink down—together.

   —Anonymous

   Note: If you enjoy singing with your students, make up a tune for this poem and teach the class to sing it. At the line "And all sink down—together" everyone sinks or falls in unison. At the same time, drop the leaf and feather.

2. ☐ Ask students:

   Q What happens to a leaf or a feather in windy weather?

   Q What happens to raindrops and snowflakes?

   Q Do they fall down?

   Q Do they sometimes fall sideways?

   Teacher Tip: Accept all answers. Help students describe what they have seen or experienced during windy or stormy weather. If students have seen lightning or heard thunder, they may mention these events at this time. If you live in an area that experiences severe weather such as hurricanes or tornadoes, students may discuss these weather events.

Let's Explore

3. ☐ Look outside the windows of the classroom, or go outside into the play yard to observe today's weather.

4. ☐ Ask students to describe what the weather is like today.

   Depending on the weather typical in your area, students may be familiar with terms used to describe certain conditions such as "humidity." They may use words they have heard at home, including humid, muggy, and damp. This is an opportunity for you to assess students' prior knowledge about weather and the language they use to describe it.

Explain It

5. ☐ Return to your regular class positions.

6. ☐ Lead your students in a discussion to describe the weather with the following questions:

   Q Is there wind today?

   Q Is there rain or snow today?

   Q Is the weather warm or cold today?

   Q Is it sunny or cloudy?

   If there is wind, ask students:

   Q Where will a leaf go if we drop it?

   Q What does this tell us about the direction the wind is coming from?

   Q Is the wind strong enough to blow a feather? How about a jacket or a backpack?

   If there is rain or snow, ask students:

   Q Where are those raindrops or snowflakes coming from? Are there clouds?

   Q What happens to the raindrops or snowflakes when they fall on the ground?

   Q How does our play yard look different today from a sunny day?

7. ☐ Guide students in a discussion about how rain makes surfaces wet and forms puddles in some places and how snowflakes pile up and get deeper if they don't melt.

8. ☐ Ask students to describe how their play is different when the weather is rainy or snowy from when it is sunny.

9. ☐ Compare the weather you are currently experiencing to a day that had very different weather.

10. ☐ Discuss how quickly weather can change with the following questions:

   Q Have you ever woken up to a sunny day, but had rain by lunch time?

Q Have you ever seen a week of rain followed by a week of clear skies and sunshine?

Q Have you ever had fog early in the morning that was gone by the middle of the morning?

11. ☐ Take a moment to discuss changes due to seasons:

Q How does lunch time in the summer compare to lunch time in the winter?

Q Is the weather in the spring different from the weather in the fall?

Tell Me More

12. ☐ What tools can be used to measure the weather we see and feel today? What is the temperature today? How can we measure the temperature?

13. ☐ Have students examine the weather sensor. Show them the slits in the end and explain that the air can go inside the tool so its temperature can be measured.

Note: Although the weather sensor measures barometric pressure, absolute humidity, relative humidity, dew point, and relative altitude in addition to temperature, students will most likely not have experience with these concepts or measurements.

14. ☐ Start recording a data run of weather data, and display a graph of temperature versus time.

15. ☐ Measure the air temperature inside the classroom and then outdoors.

16. ☐ If there is a noticeable difference in the indoor and outdoor temperatures, help students compare the measurements of air temperature.

■ The weather sensor measures temperature. Show students the graph and point out that warmer air is higher on the graph than colder air is.

17. ☐ Stop recording data.

Sum It Up

18. ☐ Ask students, "How did the graph show us where the air was warmer and where it was cooler? Could we use this tool to tell us the weather again tomorrow?"

Students should be able to look at the graph and point to places where the line is higher and lower, and relate the higher points to the air being warmer. They should be able to indicate that lower points on the graph signify cooler air.

19. ☐ Ask students, "How do we describe the weather?"

Answers should include the various terms they've discussed as well as the method of using the weather sensor and other tools to obtain data that helps describe the weather.

20. ☐ Depending on the level of your class, you may wish to add a discussion of humidity:

a. Change the y-axis of your graph of Temperature versus Time to Relative Humidity versus Time to show your students the graph of humidity.

b. Let your students know that you we can also measure the amount of water in the air.

21. ☐ Ask students, "Why do you think we are interested in the amount of water in the air?"

Answers will vary; remind your students of your discussion of clouds, rain, and snow.

22. ☐ Have students complete the student response sheet.

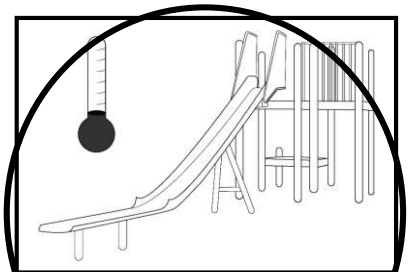
Further Investigations

Explain why there are many different measurements that are made of the weather. Show your students another weather measurement, such as barometric pressure.

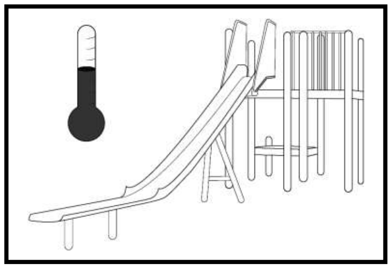
Record a set of temperature data overnight to show students how temperature changes over time.

Circle the pictures that describe the weather today.

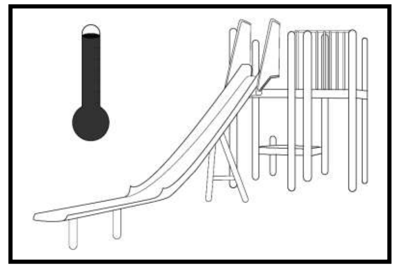
Note: Answers will vary depending on weather conditions.



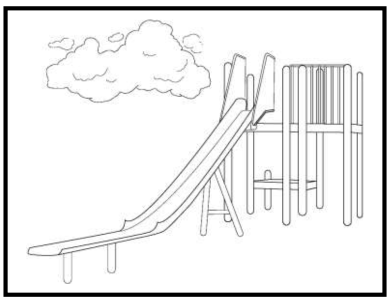
Cold



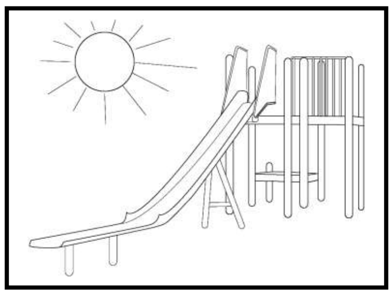
Mild



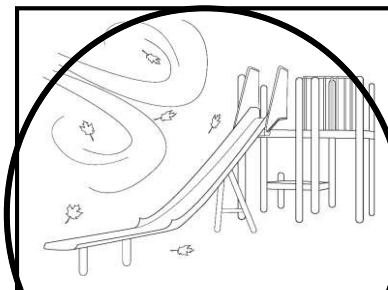
Hot



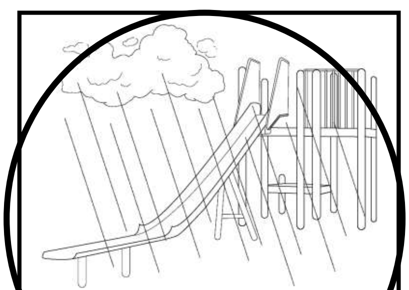
Cloudy



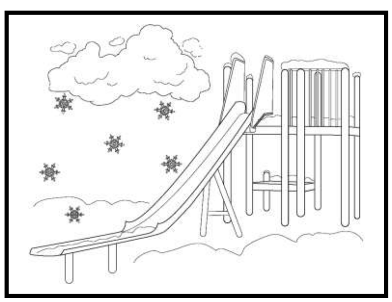
Sunny



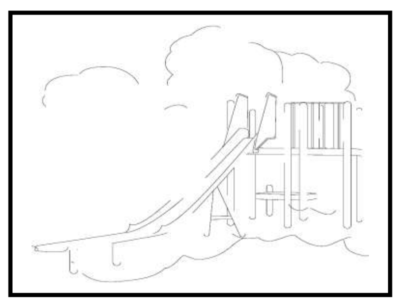
Windy



Raining



Snowing



Foggy