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

"Data collection system" refers to PASCO's DataStudio®, the Xplorer GLX™, SPARKvue™, and SPARK Science Learning System™ and PASCO Capstone™. Each of these can be used to collect, display, and analyze data in the various lab activities.

Activities are designed so that any PASCO data collection system can be used to carry out the procedure. The DataStudio, Xplorer GLX, SPARKvue, or SPARK Science Learning System Tech Tips provide the steps on how to use the data collection system and are available on the storage device that came with your manual. For assistance in using PASCO Capstone, refer to its help system.

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.

Lab Activity Components

Each activity has two components: Teacher Information and Student Inquiry Worksheets.

Teacher Information is in the Teacher Guide. It contains information on selecting, planning, and implementing a lab, as well as the complete student version with answer keys. Teacher Information includes all sections of a lab activity, including objectives, procedural overview, time requirements, and materials and equipment at-a-glance.

Student Inquiry 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.

This table identifies the sections in each of these two activity components.

TEACHER INFORMATION	STUDENT INQUIRY WORKSHEET
Objectives	Driving Questions
Procedural Overview	Background
Time Requirement	Pre-Lab Activity
Materials and Equipment	Materials and Equipment
Concepts Students Should Already Know	
Related Labs in This Guide	
Using Your Data Collection System	
Background	
Pre-Lab Activity	
Lab Preparation	
Safety	Safety
Sequencing Challenge	Sequencing Challenge
Procedure With Inquiry	Procedure (+ conceptual questions)
Data Analysis	Data Analysis
Analysis Questions	Analysis Questions
Synthesis Questions	Synthesis Questions
Multiple Choice Questions	Multiple Choice Questions
Extended Inquiry Suggestions	

Electronic Materials

The storage device accompanying this manual contains the following:

- Complete Teacher Guide and Student Guide with Student Inquiry Worksheets in PDF format.
- The Scientific Inquiry activity for SPARK™, SPARKvue™, Xplorer GLX®, and DataStudio® and the Student Inquiry Worksheets for the laboratory activities are in an editable Microsoft™ Word format. PASCO provides editable files of the student lab activities so that teachers can customize activities to their needs.
- Tech Tips for the SPARK, SPARKvue, Xplorer GLX, DataStudio, and individual sensor technologies in PDF format.
- User guides for SPARKvue and GLX.
- DataStudio and PASCO Capstone® 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.

Master Materials and Equipment List

Italicized entries indicate items not available from PASCO. The quantity indicated is per student or group. NOTE: Some activities 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 and probes 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
1	**Determining Soil Quality** Use a carbon dioxide gas sensor, a pH sensor, and a conductivity sensor to analyze the capacity of soil to support plant growth by examining the physical, chemical, and biological characteristics of different types of soil.	Data Collection System	1
		PASPORT Carbon Dioxide Gas Sensor and sampling bottle	1
		PASPORT pH Sensor	1
		PASPORT Conductivity Sensor	1
		PASPORT Sensor Extension Cable	1
		Beaker, 100-mL	4
		Beaker, 50-mL	1
		Digging tool	1
		Dissecting microscope	1
		Distilled or deionized water	300 mL
		Graduated cylinder, 100-mL	1
		Labeling tape	1 roll
		Microscope slides and cover slips	3
		Microscope with magnification up to 400x	1
		Microwave oven	1 per class
		Permanent marker	1
		pH calibration standard solution, pH 4	25 mL
		pH calibration standard solution, pH 7 or 10	25 mL
		Pipet, disposable, 1-mL	1
		Plastic bags	4
		Soil samples (from 3 different locations)	3
		Stirring rod	1
		Wash bottle containing distilled or deionized water	1
		Waste container	1
		White household vinegar	4 mL

Lab	Title	Materials and Equipment	Qty
2	**Insolation and the Seasons** Use a stainless steel temperature sensor to measure the temperature of a solar panel positioned at different angles relative to the sun in order to determine how the earth's tilt and rotation around the sun is related to climate and the seasons.	Mobile Data Collection System PASPORT Stainless Steel Temperature Sensor *Black construction paper, 15 x 15 cm* *Cardboard, 15 x 15 cm* *Drinking straw* *Glue, bottle* *Protractor* *Scissors* Small Tripod Base and Rod *Tape* Three-fingered clamp	1 1 1 1 1 1 1 1 1 1 roll 1
3	**Investigating Specific Heat** Use fast-response temperature probes and stainless steel temperature sensors to determine and compare the specific heat of water to that of sand, as a model of land, and consider the effects of these differences on global weather and climate.	Data Collection System PASPORT Stainless Steel Temperature Sensor PASPORT Fast Response Temperature Sensor *Beaker, glass, 500-mL* *Beakers, glass, 250-mL* *Buret clamp* *Disposable insulated cup (2) and lid* *Heat lamp or 150 W incandescent lamp* *Hot plate* Mass balance or scale *Sand, 200 g* Small tripod base, and rod *Stirring rod* *Test tube, glass, 18 x 150-mm (large)* *Tongs* *Water*	1 2 2 1 2 2 2 1 1 1 per class 200 g 1 1 1 1 650 mL
4	**Monitoring Microclimates** Use a weather/anemometer sensor to identify factors that affect measurements for reporting weather and climate information.	Mobile Data Collection System PASPORT Weather/Anemometer Sensor *Cardboard box, (20 cm)3 or larger* *Marking pen* *Scissors*	1 1 1 1 1

Lab	Title	Materials and Equipment	Qty
5	**Sunlight Intensity and Reflectivity** Use a light sensor, a fast-response temperature probe, and a stainless steel temperature probe to explore the concept that air temperatures near the earth's surface result largely from the interplay of the sun's incoming energy and the absorption, reflection, and radiation of that energy by materials on the earth's surface.	Mobile Data Collection System PASPORT Light Sensor PASPORT Fast Response Temperature Sensor PASPORT Stainless Steel Temperature Sensor PASPORT Sensor Extension Cable *Dark rock* *Dark sand* *High intensity incandescent lamp* *Large disposable plate* *Marking pen* Mass balance *Paper* Rod and clamp *Scissors* *Small cardboard box, (20 cm)3 or larger* *Tape* *Three-finger clamp* *Tripod base and support rod* *White rock* *White sand*	1 1 1 1 1 500 g 500 g 1 1 1 1 per class 1 piece 1 1 1 1 roll 1 1 500 g 500 g
6	**Tracking Weather** Use a weather/anemometer sensor to determine how variations in temperature, humidity, barometric pressure, dew point, wind speed, and sky conditions relate to each other and produce specific weather conditions.	Mobile Data Collection System PASPORT Weather/Anemometer Sensor *Brick or block to lift sensor off ground (optional)* *Weather data for comparison* *Weather shield*	1 1 1 1
7	**Earth's Magnetic Field** Use a magnetic field sensor to visualize the magnetic field lines surrounding Earth.	Data Collection System PASPORT Magnetic Field Sensor Degree wheel template Magnetic field demonstrator plate, 2-D Map of Earth template *Bar magnet* *Clear plastic cup* *Pin* *Sewing needle* *Small cork (or a bit of polystyrene)* *Water, 500 mL*	1 1 1 4 1 1 1 1 1 1 500 mL
8	**Radiation Energy Transfer** Use a temperature sensor to determine the effect the color of a container has on the temperature of water in the container as it is heated using radiant energy.	Data Collection System PASPORT Temperature Sensor (stainless steel or fast response) *Graduated cylinder, 100-mL* *Heat lamp (or 150 W lamp)* *Insulated pad* *Radiation cans (one black, one silver)* *Ring stand* *Water, room temperature*	1 2 of the same 1 1 2 2 1 0.5 L

Lab	Title	Materials and Equipment	Qty
9	**Seafloor Spreading and Plate Tectonics** Use a magnetic field sensor to explore the movement of Earth's crustal plates and the evidence that is used to support the theory of plate tectonics.		
	Station 1	*Strip of paper, 10 cm × 28 cm*	1
		Cardboard or card stock, 15 cm × 20 cm	1
		Colored pencils or markers, red and green	Several
		Scissors	1
		Tape	1 roll
	Station 2	Data Collection System	1
		PASPORT Magnetic Field Sensor	1
		Bar magnet	1
	Station 3	Data Collection System	1
		PASPORT Magnetic Field Sensor	1
		Basalt, hand size specimen	1
		Magnetite, hand size specimen	1
	Station 4	Data Collection System	1
		PASPORT Magnetic Field Sensor	1
		Seafloor spreading model	1
10	**Modeling an Ecosystem** Use a variety of sensors to explore the use of terrariums as a closed system for environmental studies, designing ways to explore the interrelationships of biotic and abiotic structures in ecosystems.	Data Collection System	1 or more
		Sensors (some of the sensors that can be used): PASPORT Oxygen Gas Sensor PASPORT Carbon Dioxide Sensor PASPORT Temperature Sensor* PASPORT pH Sensor PASPORT Conductivity Sensor PASPORT Weather Sensor PASPORT Sensor Extension Cable PASCO EcoZone™ System PASPORT Water Quality Colorimeter and sample vials (nitrate and ammonia recommended)	1 or more
		Compost or soil (quantity determined by student design)	1
		Different types of living organisms	Several
		Plant seeds or seedlings, or moss	Several
		Pollution sources (depends on students' design): *Detergent (10 mL liquid soap)* *Fertilizer (10 g)* *HCl or white vinegar (16.6 mL)*	1
		Strong incandescent or full-spectrum fluorescent light source	1
		USB hub (depending on data collection system)	1
		Water, dechlorinated (quantity determined by student design)	1

Lab	Title	Materials and Equipment	Qty
11	**Photosynthesis and Primary Productivity** Use a dissolved oxygen sensor to determine the primary productivity of an aquatic plant.	Data Collection System PASPORT Dissolved Oxygen Sensor or PASPORT Water Quality Sensor *Black cloth, opaque, 50 cm x 50 cm* *Dechlorinated tap water* *Elodea sp.* plant *Lamp, 100 W or high-intensity* *Magnetic stirrer and stir bar* Photosynthesis Tank Rubber stopper, #3 (included with Photosynthesis Tank) *Alternative to the photosynthesis tank:* *Erlenmeyer flask, 250-mL* Large base and support rod *Mineral oil* *Shallow pan or dish, large* Three-finger clamp	1 1 1 1 L Several 1 1 1 1 1 1 1 1 1
12	**Photosynthesis and Cell Respiration in a Terrarium** Use an oxygen sensor, a carbon dioxide sensor, and a temperature sensor to demonstrate that a terrarium, as a closed system, is an excellent tool for conducting environmental studies and to design additional investigations on photosynthesis and cellular respiration.	Data Collection System PASPORT Oxygen Gas Sensor PASPORT Carbon Dioxide Gas Sensor PASPORT Temperature Sensor* PASPORT Sensor Extension Cable PASCO EcoChamber *Fast-growing, small, potted plant* *Opaque cloth, about 1 m^2* *Strong incandescent or full-spectrum fluorescent light source* USB hub (depending on data collection system)	1 1 1 1 1 1 1 1 1 1
13	**Cellular Respiration and Carbon Cycle** Use a carbon dioxide sensor to compare the respiration of dormant bean sees with germinating bean seeds, and to observe the contribution of cellular respiration to the global carbon cycle.	Data Collection System PASPORT Carbon Dioxide Gas Sensor PASPORT Sensor Extension Cable *Dissecting microscope or magnifying glass* *Dry bean seeds* *Knife or scalpel* *Parafilm® for Erlenmeyer flask* *Sampling bottle or Erlenmeyer flask, 125-mL*	1 1 1 1 22 1 1 2

Lab	Title	Materials and Equipment	Qty
14	**Energy Content of Food** Use a fast response temperature sensor to investigate and compare the energy content of four different food items: marshmallow, popcorn, peanut, and cashew.	Mobile Data Collection System PASPORT Fast Response Temperature Sensor *Aluminum pie pan* *Aluminum soda can* *Cardboard box, large* Electronic balance *Food samples: marshmallow, popcorn, peanuts, cashew* *Graduated cylinder, 100 mL* Large base and support rod *Marking pen* *One-hole rubber stopper, ~1 1/2" top diameter* *Paperclip, large* *Plastic straw* Rod and clamp *Tape* *Water* *Wooden matches (or starter wand)*	1 1 4 4 1 1 per class 1 each 1 1 1 4 5 1 1 1 roll 200 mL Several
15	**Weather in a Terrarium** Use a weather sensor and light sensor in a terrarium to conduct and design an investigation of weather, using this closed system to help identify independent variables, dependent variables, and controlled variables.	Data Collection System PASPORT Light Sensor PASPORT Weather Sensor PASPORT Sensor Extension Cable PASCO EcoChamber *Fast-growing, small, potted plant* *Strong incandescent or full-spectrum fluorescent light source*	1 1 1 2 1 1 1
16	**Yeast Respiration** Use a dissolved oxygen sensor, a carbon dioxide sensor, and the EcoChamber™ to analyze aerobic and anaerobic respiration by yeast cells.	Data Collection System PASPORT Dissolved Oxygen Sensor PASPORT Carbon Dioxide Gas Sensor PASCO EcoChamber *Activated baker's yeast, 7-g packet* *Beaker, 1 L* *Graduated cylinder, 500-mL or 1-L* *Hot plate with magnetic stirrer and stir bar* *Magnetic stir plate with stir bar* *Microscope slide and cover slip* *Microscope with 400x magnification* *Pipet, disposable* *Sugar* *Water*	1 1 1 1 1 1 1 1 1 1 1 1 100 g 1 L

Lab	Title	Materials and Equipment	Qty
17	**Properties of Water** Use a stainless steel temperature sensor to explore how the properties of water can be explained by the molecular structure of water.	Data Collection System PASPORT Stainless Steel Temperature Sensor *Beaker, 100-mL* *Beaker, 600-mL* *Crushed ice* *Eyedropper or disposable pipet* *Foam tray* *Hot pads or mittens* *Hot plate* *Other materials to test* *Paper towel* *Ring stand* *Utility clamp* *Water* *Waxed paper* Data Collection System	1 1 1 1 300 mL 1 1 1 1 1 2 1 50 mL 1 1
18	**Air Pollution and Acid Rain** Use a pH sensor to investigate chemical reactions important in the formation of acid rain to understand the relationship between man-made emissions, acid rain, and problems arising from acid rain.	Data Collection System PASPORT pH Sensor *1 M HCl* *1-hole rubber stopper for flask* *Beaker, 40-mL* *Erlenmeyer flask, 50-mL* *Flexible Teflon® tubing to fit glass tubing* *Glass tubing for rubber stopper* *Graduated cylinder, 50- or 100-mL* *Graduated pipet, 4-mL and pipet bulb* *Sodium bicarbonate* *Sodium bisulfite* *Sodium nitrite* *Wash bottle containing distilled or deionized water* *Water or deionized wate*	1 1 15 mL 1 1 1 20 cm 1 1 1 5 g 5 g 5 g 1 1 L
19	**Monitoring Water Quality** Use a water quality sensor, turbidity sensor, and weather/anemometer sensor to monitor the pH, dissolved oxygen content, conductivity, and turbidity of a natural body of water, determining how water quality changes in response to changes in environmental factors.	Mobile Data Collection System PASPORT Water Quality Sensor PASPORT Turbidity Sensor PASPORT Weather/Anemometer Sensor PASPORT GPS Position Sensor (optional) Sensor User Guides with calibration instructions and tables Chemical test kit (optional) *Duct tape, roll* *Long-handled sampling device* *Scissors* *Wading boots (optional)* *Wash bottle containing distilled or deionized water* *Wide-mouth sampling jar or small plastic bucket with a handle*	1 1 1 1 1 Several 1 1 1 1 1 pair 1 1

Lab	Title	Materials and Equipment	Qty
20	**Toxicology Using Yeast** Use a carbon dioxide gas sensor and a pH sensor to evaluate the role of pH in toxicity and the role of cell culture in toxicology studies.	Data Collection System PASPORT Carbon Dioxide Gas Sensor PASPORT pH Sensor PASPORT Sensor Extension Cable PASCO EcoChamber *Beaker, 100-mL (for vinegar)* *Beaker, glass, 2-L* *Erlenmeyer flask, 125-mL* *Graduated cylinder, 1-L or 500-mL* *Graduated cylinder, 25-mL or 10-mL* *Household bleach, half-strength* *Magnetic stir plate and stir bar* *Rapid-rise activated baker's yeast (7-g packet)* *Rubber stopper for Erlenmeyer flask* *Stirring rod* *Sugar* *Water* *White vinegar*	1 1 1 1 1 1 1 1 1 1 50 mL 1 1 1 1 100 g 1 L 50 mL
21	**Water Treatment** Use pH, conductivity, and turbidity sensors to demonstrate how water treatment processes such as filtration, flocculation, and sedimentation improve water quality.	Data Collection System PASPORT Water Quality Sensor (or PASPORT pH and PASPORT Conductivity Sensors) PASPORT Turbidity Sensor *Activated charcoal* Balance *Beaker, 150-mL* *Beaker, 50-mL* *Beaker, large ("wastewater" container)* *Graduated cylinder, 100-mL* *Graduated pipet, 50-mL, and bulb* *Lint-free lab tissue* *Paper napkins, dinner, white, smooth* *Paper towels, white* *Soda bottle, empty, 500-mL* *Stirring rod* *Swimming pool water clarifier solution, 4%* *Test tube, 18-mm OD or greater* *Wash bottle containing water* *Wastewater sample (made from coffee, soil, and kitty litter if the soil has a low clay content)* *Water*	1 1 1 2 g 1 per class 4 1 1 1 1 box 12 4 1 1 2 to 4 mL 1 1 500 mL 300 mL

Lab	Title	Materials and Equipment	Qty
22	**Greenhouse Gases** Use a fast response temperature sensor and an EcoChamber to determine the effect of a man-made organofluorine compound, a greenhouse gas, on the trapping of heat in an isolated system.	Data Collection System PASPORT Fast Response Temperature Sensor EcoChamber with stoppers Balance *Canned keyboard duster (fresh)* *Dark aquarium rocks or dark sand* *Heating lamp* *Heavy-duty tape* *Ring stand* *Size 5 or 5 1/2 solid stoppers*	1 2 1 1 per class 1 ~200 g 1 1 1 2

* Either the PASPORT Fast Response Temperature Sensor or the PASPORT Stainless Steel Temperature Sensor can be used for this activity.

Calibration Materials

To calibrate various sensors, you will need the following:

pH Sensor

Item	Quantity	Activity Where Used
Buffer solution, pH 4 Buffer solution, pH 7 or 10 Beaker, small Wash bottle with deionized or distilled water	25 mL 25 mL 3 1	1, 10, 18, 20, 21

Dissolved Oxygen Sensor

Item	Quantity	Activity Where Used
Clean electrode storage bottle Distilled water	1 5 mL	11, 16, 19

Oxygen Gas Sensor

Item	Quantity	Activity Where Used
Sampling Bottle (included with the sensor)	1	10, 16

Carbon Dioxide Gas Sensor

Item	Quantity	Activity Where Used
Sampling Bottle (included with the sensor)	1	1, 10, 12, 16, 20

Turbidity Sensor

Item	Quantity	Activity Where Used
100 NTU Standard	1	19

Water Quality Colorimeter

Item	Quantity	Activity Where Used
Calibration Ampule	1	10

Activity by PASCO Equipment

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

Items Available from PASCO	Qty	Activity Where Used
Data Collection System	1	1, 3, 5, 7, 8, 9, 10, 11, 12, 13, 14, 15, 16, 17, 18, 19, 20, 21, 22
Mobile Data Collection System	1	6, 14, 19
PASCO EcoChamber	1	12, 15, 16, 20
PASCO EcoZone System	1	10
PASPORT Carbon Dioxide Gas Sensor	1	1, 10[1], 12, 16, 20, 22
PASPORT Conductivity Sensor	1	1, 10[1]
PASPORT Fast Response Temperature Sensor	1	3, 5, 22
PASPORT GPS Position Sensor	1	19 (optional)
PASPORT Light Sensor	1	5, 15
PASPORT Magnetic Field Sensor		7, 9
PASPORT Oxygen Gas Sensor	1	10[1],12
PASPORT pH Sensor	1	1, 10[1], 18, 22
PASPORT Stainless Steel Temperature Sensor	2	3
PASPORT Stainless Steel Temperature Sensor	1	2, 5
PASPORT Temperature Sensor[2]	1	8, 10[1], 12, 14
PASPORT Turbidity Sensor	1	19, 21
PASPORT Water Quality Colorimeter and sample vials	1	10[1]
PASPORT Water Quality Sensor	1	19, 22
PASPORT Weather Sensor	1	15, 10[1]
PASPORT Weather/Anemometer Sensor	1	4, 19
PASPORT Sensor Extension Cable	1	5

[1] The actual quantity of these items is determined by the student design of the activity.

[2] Either the PASPORT Fast Response Temperature Sensor or the PASPORT Stainless Steel Temperature Sensor can be used for this activity.

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 labs in our Advanced Environmental 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 lab activities also has a Safety section for procedures necessary for that activity.

General Lab Safety Procedures and Precautions

- Follow all standard laboratory procedures
- Absolutely no food or 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. Do not leave the lab with gloves on.
- Wash your hands after handling samples, glassware, and equipment.
- Know the safety features of your lab such as eye-wash stations, fire extinguisher, 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 or short pants 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

- Consult the manufacturer's Material Safety Data Sheets (MSDS) for instructions on handling, storage, and disposing of chemicals. Your teacher should provide the MSDS sheets of the chemicals that you are using. Keep these instructions available in case of accidents.
- 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.
- Sodium hydroxide, hydrochloric acid, and acetic acid are corrosive irritants. Avoid contact with the eyes and wash your hands after handling. In case of skin exposure, wash it off with plenty of water.
- Always add acids and bases to water, not the other way around, as the solutions may boil vigorously.
- Diluting acids and bases creates heat; be extra careful when handling freshly prepared solutions and glassware, as they may be very hot.
- Handle concentrated acids and bases in a fume hood; the fumes are caustic and toxic.
- Be sure that all acids and bases are neutralized before being disposed of down the drain.
- 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.
- When handling any bacterial species, follow aseptic techniques.
- 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, 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

- When handling any bacterial species, follow aseptic techniques.
- Always flame inoculating loops and spreaders before setting them down on the lab bench.
- Pipetting suspension cultures can create an aerosol. Keep your nose and mouth away from the tip of the pipet to avoid inhaling any aerosol
- Use caution when working with acids.
- Use appropriate caution with the matches, burning splint and foods, and other hot materials.
- 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.

Additional Resources

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