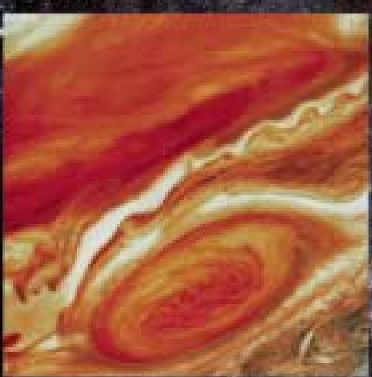
Project Earth Science

ASTRONOMY

REVISED SECOND EDITION



By Geoff Holt and Nancy W. West

NSTA press
National Science Teachers Association

Project Earth Science: Astronomy

Revised 2nd Edition

Project Earth Science: Astronomy

Revised 2nd Edition

by Geoff Holt and Nancy W. West

NSTA press
National Science Teachers Association
Arlington, Virginia

NSTA press®
National Science Teachers Association

Claire Reinburg, Director
Jennifer Horak, Managing Editor
Andrew Cooke, Senior Editor
Judy Cusick, Senior Editor
Wendy Rubin, Associate Editor
Amy America, Book Acquisitions Coordinator

Printing and Production
Catherine Lorrain, Director

National Science Teachers Association
Francis Q. Eberle, PhD, Executive Director
David Beacom, Publisher

Art and Design
Will Thomas Jr., Director
Tracey Shipley, Cover Design
Front Cover Photo: NASA and Punchstock.com
Back Cover Photo: NASA and Punchstock.com
Banner Art © Stephen Girimont / Dreamstime.com

Revised 2nd Edition developed, designed, illustrated, and produced by
Focus Strategic Communications Inc.
www.focussc.com

13 12 11 4 3 2 1

Library of Congress Cataloging-in-Publication Data
Holt, Geoff, 1963-

Project Earth science. Astronomy / by Geoff Holt and Nancy W. West. -- Rev. 2nd ed.

p. cm.

Previous ed. by P. Sean Smith.

Includes bibliographical references.

ISBN 978-1-936137-33-6 -- ISBN 978-1-936137-52-7 (e-book) 1. Astronomy--Experiments. 2. Astronomy--Study and teaching (Secondary) I. West, Nancy W., 1957- II. National Science Teachers Association. III. Title. IV. Title: Astronomy.

QB61.S553 2011

520.78--dc22

2011000491

Table of Contents

Readings

Acknowledgments

Many people contributed to this revision of *Project Earth Science: Astronomy*, as others did to previous editions. This volume began as a collection of Activities and Readings for Project Earth Science (PES), a professional development program for middle school teachers, funded by the National Science Foundation. The Project Earth Science team consisted of middle school teacher leaders, college professors and scientists, and innovators in educational research. The Activities were written and adapted by this team, and have undergone many revisions as a result of using them in the classroom, and feedback provided by other teachers through in-service training.

The principal investigators on the original project were Iris R. Weiss, Diana Montgomery, Paul B. Hounshell, and Paul D. Fullagar. The teacher leaders were Kevin Barnard, Kathy Bobay, Pam Bookout, Betty Dean, Lynanne (Missy) Gabriel, Flo Gullickson, Michele Heath, Cameron Holbrook, Linda Hollingsworth, Geoff Holt, Kim Kelly, Laura Kolb, Karen Kozel, Kim Taylor, Dana White, Tammy Williams, and Lowell Zeigler. Significant contributions were made to the original publication by Kevin Barnard, Missy Gabriel, and Geoff Holt. The original manuscript was reviewed for scientific accuracy by Wayne Christiansen, professor of astronomy at the University of North Carolina at Chapel Hill. We would like to thank all who contributed to the previous editions of *Project Earth Science: Astronomy*. P. Sean Smith was author of the first edition, and part of the PES team.

This edition benefited greatly by the invaluable contributions made by our talented reviewers for their suggestions and feedback, including Gary Sampson, Elaine Lewis, and Paul D. Fullagar. We also thank Adrianna Edwards and Ron Edwards of Focus Strategic Communications Inc., Oakville, Ontario, Canada, for their considerable efforts in preparing this volume for publication. We would also like to thank the rest of the Focus team: Nancy Szostak, designer and formatter; Sarah Waterfield and Carolyn Tripp, illustrators; and Linda Szostak, copyeditor and proofreader.

Project Earth Science: Astronomy, Revised 2nd Edition, is published by NSTA Press. We thank everyone at NSTA who helped with this volume, and especially appreciate the efforts of the publisher, David Beacom. NSTA safety columnist, author, and consultant Ken Roy reviewed the entire manuscript for safety compliance. NSTA Press managing editor Jennifer Horak and project editor Mark Farrell led NSTA's in-house team for the revised second edition.

Introduction

Project Earth Science: Astronomy is part of a four-volume series of Earth science books. The remaining three are *Meteorology*, *Physical Oceanography*, and *Geology*. Each volume contains a collection of hands-on Activities developed for the middle and junior high school level, and a series of background Readings pertaining to the topic area.

Additions and Changes to Revised 2nd Edition

Activities and Readings have been rewritten to improve clarity and scientific currency, and to suggest additional teaching and learning strategies. The Resources section at the back of this book is almost entirely new. At the beginning of each Activity, there now is a Planner to quickly provide information about that Activity. Material specifically for students, and material specifically for teachers, is more clearly delineated. There are new sections for students within Activities titled What Can I Do? and Fast Fact. Additional new sections included for teachers are How Do We Know This?, Safety Alerts!, Connections, Differentiated Learning, and Assessment.

Within each Activity, there is a section for teachers titled Preconceptions containing a series of questions designed to help draw students into a discussion of the subject. These discussions should reveal students' preconceptions. A preconception is an opinion or view that a student might have prior to studying a particular topic. These opinions may not be accurate because the student does not have the correct information or does not understand that information. Asking students about their preconceptions at the outset of a new instructional topic can provide useful information about what students already know and what misinformation needs to be corrected for them to have a good understanding of the topic.

About *Project Earth Science: Astronomy*

Project Earth Science: Astronomy is based on the concept of the uniqueness of Earth among all the planets in the solar system. Concepts and Activities were chosen that elaborate on this theme. This volume focuses on planetary astronomy and aims to give students a sense of viewing Earth from some point beyond the solar system. By placing Earth in the context of the solar system and viewing it as "just another planet," it is hoped that students will begin to grasp the unique aspects of the planet. Chief among these aspects is that Earth is the only planet in the solar system capable of sustaining life.

This book is divided into three sections: Activities, Readings, and Resources. The Activities in this volume are designed to be hands-on. In collecting and developing these Activities, we tried to use materials that are either readily available in the classroom or inexpensive to purchase.

Each Activity has a student section and a teacher guide. The student section has background information that briefly explains the concepts behind the Activity in non-technical terms. Following this is the procedure for the Activity and a set of questions to guide students as they draw conclusions.

The teacher versions of the Activities, titled Teachers' Guide to Activity X, contain a more detailed version of the background information given to students, and a summary of the important points that students should understand after completing the Activity.

You will find the approximate time to allow for each Activity in the section titled Time Management. The Preparation and Procedure section describes the setup for the Activity and gives sources of materials. Extended Learning gives ideas for challenging students to extend their study of the topic. Use these ideas within the class period allotted for the Activity if time and enthusiasm allow. Interdisciplinary Study includes ideas for relating the concepts in the Activity to other science topics and to other disciplines such as language arts and social studies. The final section of the teachers' guide provides answers to the questions in the student section of the Activity, and discussions on Assessment.

The Activities are followed by a section of Readings for the teacher. One or more of these Readings are referred to in the guide to each Activity. The Readings provide both background information on the concepts underlying the Activities as well as supplementary information to enhance classroom discussions.

A guide to astronomy resources for students and teachers follows on page 163. Though not exhaustive, the guide should give teachers the means to explore this fascinating subject.

Creating Scientific Knowledge

Everyone has wondered if there is life elsewhere in the universe. Could those distant, tiny points of light seen in the night sky have orbiting planets that might also have intelligent life forms? What is it about planet Earth that makes life possible? Do any other planets in our solar system have the same or similar conditions? Do they have water or oxygen? Where are the other planets located in relation to Earth and the Sun?

Ever since the dawn of the space age in 1957, space exploration has advanced our knowledge of the neighboring planets that share our Sun. Robot spacecraft have flown past each of the planets, and orbited Mercury, Venus, Mars, Jupiter, and Saturn. Robotic spacecraft have landed on Venus and Mars. For the first time, we can compare their geological and meteorological conditions with those of Earth. As scientists accumulate this new data, it also reveals how life, as we know it, is unique to Earth.

The space program has given us a snapshot of our own blue and white planet as photographed by journeying spaceships. Imagine what you would see if you could look at Earth from a point above the entire solar system. What would Earth look like, and how big would it be compared to the other planets? Does it spin and revolve like the others? Do the other planets have a moon like Earth's? Is the solar system crowded?

To answer these questions, we must first know where Earth is in relation to all the other planets. The Sun is at the center of the solar system with fast-orbiting Mercury in the first planet position. Venus is next, followed by Earth and Mars as you move out from the Sun. Moving still farther away are the giant planets—Jupiter, Saturn, Uranus, and Neptune.

Only when Earth is placed in the context of the solar system and considered as just another planet do its unique features come to light. NASA's Earth Science Program studies Earth as one global system. This is the perspective NASA has taken in studying every other planet. Now it is turning its attention back to our planet. Some of Earth's unique aspects have already been discovered using this approach. As NASA wrote, "If Earth were much smaller, it could not retain an atmosphere. If it were much closer to or much further from the Sun, the oceans would boil or freeze. If its orbit and axis of rotation did not fluctuate, the cyclical variations in climate that have spurred evolution would not exist."

Getting Ready for Classroom Instruction

The Activities in this volume are designed to be hands-on. In developing them, we tried to use materials that are either readily available in the classroom or inexpensive to purchase. Note that many of the Activities also could be done as demonstrations.

Each Activity has two sections: a Student section and a Teachers' Guide. Each Student section begins with Background information to explain briefly, in nontechnical terms, what the Activity is about; the Objective states what students will learn. Then there is Vocabulary, which includes important astronomical terms students should know. This is followed by a list of the Materials needed and an estimate of the amount of Time that the Activity will take. Following this introduction is a step-by-step Procedure outline and a set of Questions and Conclusions to facilitate student understanding, encourage constructive thinking, and advance the drawing of scientific conclusions.

Each Student section concludes with additional activities for students in What Can I Do?

The Teachers' Guide contains What Is Happening?, a more thorough version of the background information given to students. The How Do We Know This? section explains techniques or research methods astronomers currently use to generate knowledge related to the Activity. This is followed by possible student Preconceptions, which can be used to initiate classroom discussions. Next comes a summary of What Students Need to Understand. Then Time Management discusses the estimated amount of time the Activity will take. Preparation and Procedure describes the setup for the Activity. Extended Learning challenges students to extend their study of each topic. Interdisciplinary Study relates the science in each Activity to other disciplines, such as language arts, history, and social sciences. Connections links astronomy to a similar process or concept in geology, meteorology, or physical oceanography. The final portion of each Teachers' Guide includes possibilities for Differentiated Learning, Answers to Student Questions, and suggestions for Assessment.

Although the scientific method often has been presented as a "cookbook" recipe—state the problem, gather information, form a hypothesis, perform experiments, record and analyze data, and state conclusions—students should be made aware that the scientific method provides an approach to understanding the world around us, an approach that is rarely so straightforward. For instance, many factors can influence experimental outcomes, measurement precision, and the reliability of results. Such variables must be taken into consideration throughout the course of an investigation.

As students work through the Activities in this volume, make them aware that experimental outcomes can vary and that repetition of trials is important for developing an accurate picture of concepts they are studying. By repeating experimental procedures, students can learn to distinguish between significant and insignificant variations in outcomes. Regardless of how carefully they conduct an experiment, they can never entirely eliminate error. As a matter of course, students should be encouraged to look for ways to eliminate sources of error. However, they also must be made aware of the inherent variation possible in all experimentation.

Finally, controlling variables is important in maintaining the integrity of an experiment. Misleading results and incorrect conclusions often can be traced to experimentation where important variables were not rigorously controlled. Teachers should encourage students to identify experimental controls and consider the relationships between the variables under study and the factors held under control.

Key Concepts

The Activities in this volume are organized under three broad astronomical concepts:

Key Concept I: Earth's position in the solar system
Key Concept II: Earth's unique properties
Key Concept III: Earth's characteristic phases and seasons

First, students investigate techniques that are used to measure distances and sizes of the magnitude found in the solar system. Using the information gained from these methods, students then place Earth in the solar system in relation to the rest of the planets. Second, students perform activities that stress the uniqueness of Earth. This section focuses on comparisons of Earth to other planets, particularly Venus and Mars. In the third section of the book, students are confronted with two areas of planetary astronomy about which many people have preconceptions: the reason for the phases of the Moon and the explanation of Earth's seasons.

We suggest organizing *Project Earth Science Activities* around these key concepts. To facilitate this approach, the conceptual outline for Astronomy is presented below, with the numbers of the Activities that pertain to each concept.

I. While Earth's position relative to the Sun and other planets is always changing, its distance from the Sun is almost constant. To understand many features of Earth that make it unique and habitable, we need to know where Earth is in relation to the Sun and other planets. Several tools are available to learn where Earth is in the solar system. (Activities 1, 2, 3, 4, and 5)

II. Earth's position in the solar system is responsible for its unique properties. Among these properties is the fact that Earth is the only planet in the solar system that sustains life. (Activities 6, 7, 8, and 9)

III. Many preconceptions exist about Earth and its characteristics. Looking at Earth as "just another planet" can help correct these preconceptions. (Activities 10 and 11)

Project Earth Science: Astronomy and the *National Science Education Standards*

Effective science teaching within the middle-level age cluster integrates the two broadest groupings of scientific activity identified by the National Science Education Standards: (1) developing skills and abilities necessary to perform scientific inquiry, and (2) developing an understanding of the implications and applications of scientific inquiry. Within the context of these two broad groupings, the Standards identify specific categories of classroom activities that will encourage and enable students to integrate skills and abilities with understanding.

To facilitate this integration, a Standards organizational matrix for *Project Earth Science: Astronomy* appears in the front matter on pages xvi–xvii. The categories listed along the x-axis of the matrix, also listed below, correspond to the categories of performing and understanding scientific activity identified as appropriate by the Standards.

Subject and Content. Specifies the topic covered by an Activity.
Scientific Inquiry. Identifies the "process of science" (i.e., scientific reasoning, critical thinking, conducting investigations, formulating hypotheses) employed by an Activity.

Unifying Concepts. Links an Activity's specific subject topic with "the big picture" of scientific ideas (i.e., how data collection techniques inform interpretation and analysis).

Technology. Establishes a connection between the natural and designed worlds.

Personal/Social Perspectives. Locates the specific astronomy topic covered by an Activity within a framework that relates directly to students' lives.

Historical Context. Portrays scientific endeavor as an ongoing human enterprise by linking an Activity's topic with the evolution of its underlying principle.

Safety in the Classroom Practices

The teaching and learning of science today through hands-on, process, and inquiry-based activities make classroom and laboratory experiences effective. Addressing potential safety issues is critical to securing this success. Although total safety cannot be guaranteed, teachers can make science safer by adopting, implementing, and enforcing legal standards and best professional practices in the science classroom and laboratory. Safety in the Classroom Practices includes both basic safety practices and resources specific to the Project Earth Science series. It is designed to help teachers and students become aware of relevant standards and practices that will help make activities safer.

1. When working with glassware, meter sticks, wires, projectiles, or other solid hazards, students use appropriate personal protective equipment (PPE), including safety glasses or goggles, gloves, and aprons.
2. When working with hazardous liquids, indirectly vented chemical splash goggles, gloves, and aprons must be used.
3. Always review Material Safety Data Sheets (MSDSs) with students relative to safety precautions when working with hazardous chemicals.
4. Be careful to wipe up any spilled water on the floor quickly—slip and fall hazard.
5. Be careful when working with the hot plate and hot water—skin can be burned. Have students notify you immediately if someone is splashed with boiling water.
6. Be careful when working with a hot lamp—skin can be burned. Have students notify you immediately if someone is burned.
7. When working with lamps, keep away from water or other liquids—electrical shock hazard.
8. Handle glass thermometers with care so as not to drop or break them—broken glass is a sharp hazard.
9. Know the source of dirt used in an Activity and make sure the source is pesticide- and fungicide-free.
10. Use caution when working with sharp items such as scissors and floral or electrical wires, as they can cut or puncture skin.
11. Wash hands with soap and water upon completing the lab.
12. Use caution when working with pointed objects such as compasses or stakes—impalement hazards.
13. Make sure all trip and fall hazards are removed from the floor prior to darkening the room for an Activity.
14. Keep extension cords off the floor—trip and fall hazards.
15. Make sure that students never look directly at the Sun without appropriate eye protection—major eye hazard.
16. Never eat food or beverage that has been either brought into the lab or used in the lab—potential hazardous chemical contamination.
17. Make sure to abide by school and school district rules on using candy as a reward.
18. When heating liquids, use only heat-resistant glassware (Pyrex- or Kimax-type equipment). Remember that glass labware is never to be placed directly on heating surfaces. Hot containers are potential hazards.
19. When heating liquids on electrical equipment such as hot plates, use ground-fault-protected circuits (GFI).
20. Always remind students of heat and burn hazards when working with heat sources such as hot plates, heating water, and more.

21. Select only markers with low volatile organic compounds (VOC). Some students may be allergic to VOC vapors.
22. Use only asbestos-free vermiculite. Vermiculite containing asbestos will expose students and teacher to this health hazard.
23. Teachers should always model appropriate techniques before requiring students to cut, puncture, or dissect.

For additional safety regulations and best professional practices, go to

NSTA: Safety in the Science Classroom: *www.nsta.org/pdfs/SafetyInTheScienceClassroom.pdf*

NSTA Safety Portal: *www.nsta.org/portals/safety.aspx*

Standards Organizational Matrix

Activity	Subject Matter and Content	Scientific Inquiry	Unifying Concepts and Processes
Activity 1 Measuring the Moon Indirectly	Indirect measurement of solar system objects	Understanding how to measure large distances	Use of mathematics in astronomy
Activity 2 Light Year as Distance	Concept of light year as a unit of distance	Expressing large distances in astronomy	Measurement of large distances
Activity 3 Solar System Scale	A scale model of size and distance in the solar system	Determining scale in the solar system	Measurements and models
Activity 4 The Speed of Light	Light has a finite speed	Understanding the consequences of light having a finite speed	Effect of finite speed of light on observation of distant objects
Activity 5 How Far to the Star?	Parallax (indirect measurement)	Measuring large distances using parallax	Relationship between explanation and evidence
Activity 6 The Formation of the Solar System	Solar nebula theory	Modeling accretion	Evidence and models
Activity 7 Habitable Zone	Distance and light	Investigating conditions necessary for life on a planet	Interactions among variable conditions within a system
Activity 8 The Greenhouse Effect	Nature and behavior of light	Modeling the heat-trapping effect of greenhouse gases	Relationship between explanation and evidence
Activity 9 Creature Feature	Compare Earth to Mars and Venus	Comparing possible life conditions on Venus and Mars to Earth	Relationship of life forms to physical environment
Activity 10 Reasons for the Seasons	Earth's seasons	Investigating the causes of Earth's seasons	Relationship of Earth's orbit and tilt of axis
Activity 11 Phases of the Moon	Moon's phases	Modeling the causes of the Moon's phases	Effects of the Moon's orbit around Earth and solar illumination

Technology	Personal/Social Perspectives	Historical Context	Key Concept
Technology of measuring devices		Cross-staffs used by ancient peoples for navigation	I
Communicating over large distances			I
		Copernicus developed a scale model of the solar system	I
Finite speed of light and all forms of electromagnetic radiation	The challenges of observing distant objects		I
Technology of measuring devices		Parallax predicted by ancient Greeks	I
		Examining theories of solar system formation	II
Measuring temperatures and distances	Evaluating the conditions for life as we know it		II
	Climate change		II
Technology to measure environmental conditions	Adaptation to extreme environments		II
Use of photocell and multimeter			III
	Evaluating preconceptions about Moon phases		III

Activities at a Glance

Activity	Pages	Subject and Content	Objective	Materials
Activity 1 Measuring the Moon Indirectly	1–9	Indirect measurement of solar system objects	Learn how angular diameter can be used to measure the true diameter of the Moon.	Each group of students will need: paper plate, metric ruler, metric tape measure, index card, scissors, safety glasses or goggles
Activity 2 Light Year as Distance	11–18	Concept of light year as a unit of distance	Develop an understanding of the concept of a unit known as the "light year."	Each group of students will need: watch with second hand or a stop-watch, metric tape measure (30 m or more works best), calculator (helpful but not essential), safety glasses or goggles
Activity 3 Solar System Scale	21–29	A scale model of size and distance in the solar system	Build a scale model of the solar system.	Each group of students will need: trundle wheel, masking tape, eight stakes, eight index cards, sharp pencil, one ball (23.2 cm diameter), drawing compass (optional), solar viewing glasses for each student (optional)
Activity 4 The Speed of Light	31–36	Light has a finite speed	Understand the consequences of light having a finite speed.	Each student will need: a piece of candy or other treat
Activity 5 How Far to the Star?	39–48	Parallax (indirect measurement)	Investigate the factors affecting parallax.	Each group of students will need: construction paper (or manila folder), pencil, metric ruler, chalkboard or large sheets of A1 paper (594 mm x 841 mm), chalk or markers, scissors (if manila folders are used), tape (if manila folders are used), single-hole punch
Activity 6 The Formation of the Solar System	51–58	Solar nebula theory	Observe a model of how the solar system would have originated according to the solar nebula theory.	The class will need: one bag of vermiculite, containers of water placed centrally in the room, 100 mL graduated cylinder, 1,000 mL beaker or comparable container for overhead demonstration Each group of students will need: one stirring rod, one bucket (11 L) for student exercise, basin for collecting used water, 15 mL of vermiculite, indirectly vented chemical splash goggles and apron

Time	Vocabulary	Key Concepts	Margin Features
50 minutes or less	Indirect measurement, Angular diameter, Similar triangles	I	Safety Alert!, Fast Fact, What Can I Do?, Connections
50 minutes or less	Light year	I	Fast Fact, What Can I Do?, Connections
More than 50 minutes but less than 100 minutes	Scale model, Scaling factor	I	Fast Fact, Safety Alert!, What Can I Do?, Connections
Less than 50 minutes	Radio wave, Speed of light, Speed of sound	I	What Can I Do?, Fast Fact, Safety Alert!, Connections
50 minutes	Direct measurement, Indirect measurement, Parallax effect, Baseline	I	Fast Fact, Safety Alert!
Less than 50 minutes	Solar nebula theory, Nebula, Protostar, Protosun	II	Safety Alert!, Fast Fact, Connections

Activity	Pages	Subject and Content	Objective	Materials
Activity 7 Habitable Zone	61–68	Distance and light	Investigate the relationship between distance from a light source and temperature, and apply this relationship to understand why life in the solar system has been found only on Earth.	Each group of students will need: four Celsius thermometers (nonmercury); meter stick, a lamp with a 75-watt bulb, a clamp, and a stand; safety glasses or goggles for each student
Activity 8 The Greenhouse Effect	71–80	Nature and behavior of light	Observe and investigate a model of how light and the atmosphere interact to make Earth suitable for life.	The class will need: one large bag of potting soil, one box of plastic wrap, graph paper for each student Each group of students will need: two large disposable plastic cups, dirt to fill each cup (use commercial potting soil free of pesticide or fungicide), something to prop up thermometers (e.g., a slightly smaller cup or stack of books), one rubber band, two Celsius thermometers (nonmercury), hole punch
Activity 9 Creature Feature	83–90	Compare Earth to Mars and Venus	Consider some of the characteristics of Venus and Mars that make the planets uninhabitable for life as we know it.	Each group of students will need: construction paper (at least three different colors), scissors, glue, aluminum foil, straws, toothpicks, paper cups, transparent tape, floral wire
Activity 10 Reasons for the Seasons	93–103	Earth's seasons	Understand why Earth has seasons.	The class will need: one or two globes mounted so that the axis of rotation is tilted to 23.5° from vertical, a bright light source (lamp with at least a 75-watt bulb and without a shade), (optional) photocell such as a mini panel solar cell, (optional) multimeter or voltmeter
Activity 11 Phases of the Moon	105–116	Moon's phases	Understand the cause of the Moon's phases.	For Part 1, the class will need: one bright lamp (at least 75-watt) without shade, one extension cord, one Ping-Pong ball for each student (an option is polystyrene balls), safety glasses or goggles for each student For Part 2, each pair of students will need: cardboard, 15-cm diameter Styrofoam ball, pencil, black paint suitable for Styrofoam, safety glasses or goggles for each student

Time	Vocabulary	Key Concepts	Margin Features
50 minutes or less	Habitable zone	II	Fast Fact, Safety Alert!, Connections, Resources
50 minutes	Greenhouse effect, Radiant heat, Infrared light	II	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resource
50 minutes		II	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resources
50 minutes	Orbit, Ellipse, Axis, Rotation axis	III	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resources
100 minutes (50 minutes per part)	Phases of the Moon	III	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resources

Activity 8 Planner

Activity 8 Summary
Students measure the temperature in two soil-filled cups sitting in the Sun for about 50 minutes. One cup is uncovered; the other has a clear plastic cover. Students then graph and compare the data from the two cups.

Activity	Subject and Content	Objective	Materials
The Greenhouse Effect	Nature and behavior of light	Observe and investigate a model of how light and the atmosphere interact to make Earth suitable for life.	The class will need: one large bag of potting soil, one box of plastic wrap, graph paper for each student, safety glasses or goggles for each student Each group of students will need: two large disposable plastic cups, dirt to fill each cup (use commercial potting soil free of pesticide or fungicide), something to prop up thermometers (e.g., a sightly smaller cup or stack of books), one rubber band, two Celsius thermometers (nonmercury), hole punch

Time	Vocabulary	Key Concept	Margin Features
50 minutes	Greenhouse effect, Radiant heat, Infrared light	II: Earth's unique properties	Fast Fact, Safety Alert!, What Can I Do?, Connections, Resource

Scientific Inquiry	Unifying Concepts and Processes	Personal/Social Perspectives
Modeling the heat-trapping effect of greenhouse gases	Relationship between explanation and evidence	Climate change

The Greenhouse Effect

Activity 8

Background

Greenhouses are made almost completely of glass for two reasons. First, glass allows the maximum amount of sunlight into the building. Plants need the sunlight for photosynthesis. Second, glass prevents heat produced in the greenhouse from escaping. Clear plastic can also serve these same two functions. When materials like glass and plastic let sunlight, but not heat, pass through them, this is known as the **greenhouse effect**, which is a form of solar heating. How does the greenhouse effect work?

Visible light is only one form of light. **Radiant heat** is **infrared light**, another form. When visible light (sunlight) passes through the glass of a greenhouse, it strikes the objects in the building and its energy is absorbed. These objects begin to heat up. As they heat up, they give off radiant heat—infrared light. While visible light can pass through the glass of the greenhouse, the infrared light cannot. This means that the heat given off by objects in the greenhouse is trapped in the building. Therefore, even on cold, sunny days, the building can stay warm.

Some gases are like the glass of a greenhouse in that they trap heat. Several of these gases, including carbon dioxide (CO_2), water vapor (H_2O), nitrous oxide (N_2O), and methane (CH_4), are present in Earth's atmosphere. The amounts of these gases are increasing daily because of human activities such as driving cars and burning fuel, and because of natural processes such as decomposition in swamps, where methane is released

Vocabulary

Greenhouse effect: A planet's atmospheric layers act like the glass of a greenhouse, permitting sunlight to pass through and strike a planet's surface but reducing the escape of heat (infrared light) radiated from that surface. As a result, the atmosphere warms up.

Radiant heat: Infrared light.

Infrared light: Heat or a form of electromagnetic radiation (light), which has a wavelength ranging from 1 μm to 1 mm. The wavelength of visible light is between 100 and 1,000 times shorter than infrared.

Fast Fact

Cattle are efficient producers of methane, a greenhouse gas. The average cow produces about 81,000 L of methane per year. That's about the amount of methane that seven Toyota Priuses produce. Here's the clincher: In midsummer 2009, there were slightly more than 100 million head of cattle in the United States. That's a lot of methane.

Objective

Observe and investigate a model of how light and the atmosphere interact to make Earth suitable for life.

Materials

The class will need

- one large bag of potting soil
- one box of plastic wrap
- graph paper for each student
- safety glasses or goggles for each student

Each group of students will need

- two large disposable plastic cups
- dirt to fill each cup (use commercial potting soil free of pesticide or fungicide)
- something to prop up thermometers (e.g., a slightly smaller cup or stack of books)
- one rubber band
- two Celsius thermometers (nonmercury)
- hole punch

Time

50 minutes

SAFETY ALERT

1. Safety glasses or goggles are required for this Activity.

2. Handle glass thermometers with care so as not to drop or break them by applying too much force—broken glass is a sharp hazard.

3. Wash hands with soap and water upon completing the lab.

into the atmosphere by decomposing plants and animals. At present, the atmosphere traps only a small part of the heat given off by the surface of Earth. As the amount of carbon dioxide and methane increases, however, Earth may become more like a greenhouse, growing warmer as the atmosphere traps more heat.

This Activity will model how a greenhouse effect can occur.

Procedure

1. Put on eye protection.
2. About 2 cm from the top of each plastic cup, use the hole punch to make a hole big enough for you to insert a thermometer.
3. Fill each cup with dirt until the dirt is about 2.5 cm below the hole you made.
4. Insert a thermometer through each hole so that the bulb is about 2.5 cm above the dirt and centered near the middle of the cup (see **Figure 8.1**). Caution: Do not force the thermometer through the hole. If it will not go, punch a bigger hole.
5. Turn the thermometer so that you can read it.
6. Cover one cup with plastic wrap, and leave the other cup uncovered. Secure the plastic wrap on the cup with a rubber band. The final arrangement should look like **Figure 8.1**.
7. On a sunny day, take the two cups outside at the beginning of the class period, and place them where they will not be disturbed. Stabilize the thermometers so they will not move.
8. Record the initial temperature on each thermometer in **BLM 8.1**.
9. Record temperatures every 5 min. for 30 min. During the first 5 min., write a prediction of what you think will happen to the temperatures of the two cups and give a reason for your prediction. Do this in the space below the data table in **BLM 8.1**.

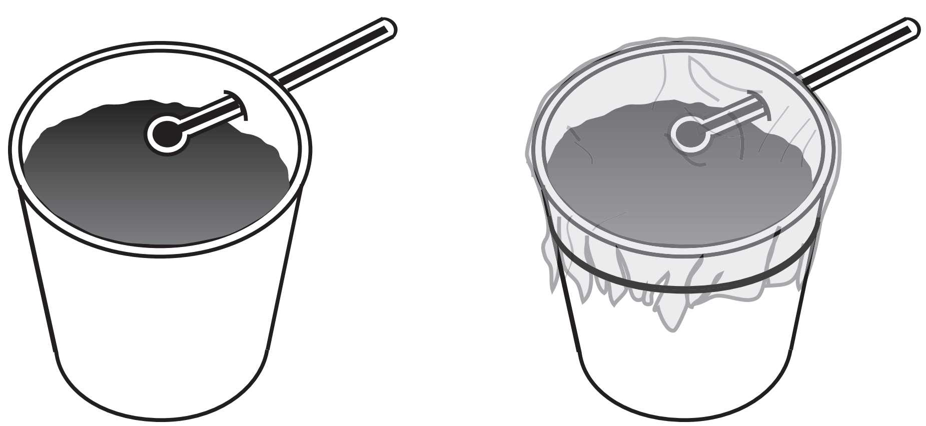


Figure 8.1
Thermometers measure temperature in the cups, the right one covered with plastic wrap.

10. Make a graph for the temperatures in each cup on a sheet of graph paper (**BLM 8.2**). Graph the temperatures on the vertical scale and the elapsed time on the horizontal scale. Designate each line as representing either the covered or the uncovered cup.

Questions and Conclusions

1. This Activity is a model of what happens on Earth. What do the dirt and plastic wrap represent in this model?
2. What did you predict would happen?
3. Do your graphs support your prediction?
4. How does what you observed in each cup compare with your prediction? If the two are different, how can you account for this?
5. Describe how you think Earth would be with a thicker atmosphere, and explain your reasoning.
6. What would Earth be like without an atmosphere? Explain your reasoning.

SCILINKS THE WORLD'S A CLICK AWAY

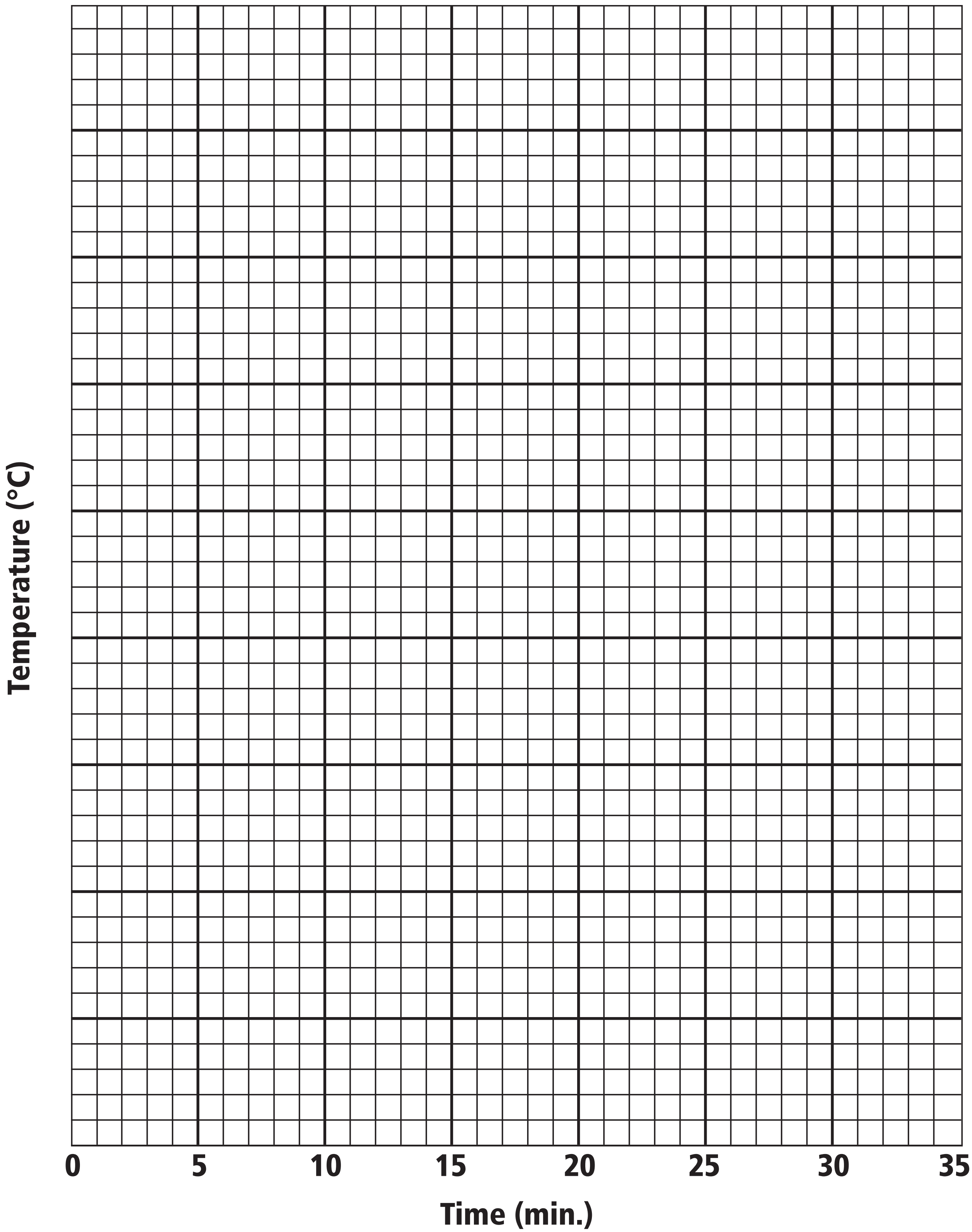
Topic: greenhouse effect/global warming
Go to: *www.scilinks.org*
Code: PSCA073

What Can I Do?

You can be thrifty about your energy use. You can shorten your showers, use only the lights you really need, unplug chargers when they are idle, and turn off a computer at the power strip. Why? Almost half of the electricity Americans use comes from burning coal (49.65% in 2005). When coal burns, it combines with oxygen to make carbon dioxide. When you use less electricity, you reduce the generation of greenhouse gases.

Data Table			
Time (min.)	**Temperature of Covered Cup (°C)**	**Temperature of Uncovered Cup (°C)**	**Other Observations**
0			
5			
10			
15			
20			
25			
30			
35			
Total Difference in Temperature			

Date________________________



The Greenhouse Effect

What Is Happening?

The term *greenhouse effect* refers to the fact that visible light can pass through glass uninhibited, but infrared light (heat) essentially cannot. The term was coined because this effect is most evident in greenhouses. The phenomenon is a consequence of the nature and behavior of light.

Light takes the form of X-rays, gamma rays, ultraviolet light, infrared light, radio waves, and microwaves—not just visible light. As objects in a greenhouse absorb light, they heat up and give off infrared light. While visible light can pass through the glass of the greenhouse, the infrared light cannot and it is reflected back in. So, the heat given off by objects in the greenhouse stays in the greenhouse.

Some gases in Earth's atmosphere, notably carbon dioxide (CO_2), water vapor (H_2O), and methane (CH_4), act like the glass in a greenhouse. Sunlight passes through the atmosphere, strikes the ground, and the ground begins to heat up. The ground then gives off infrared light, which CO_2, H_2O, and CH_4 partially block from escaping the atmosphere. There has always been a natural and beneficial greenhouse effect operating on Earth due primarily to naturally occurring CO_2 and H_2O. Burning fossil fuels, especially since the Industrial Revolution, has increased the concentration of CO_2 in Earth's atmosphere. Estimates for concentration in 1750 were 275 to 285 parts per million (ppm). Measured concentrations in 2005 were 370 ppm. Measurements at the top of Mauna Loa since 1958 show a steady upward trend modulated by seasonal cycles of biological productivity. Global deforestation has compounded the problem by reducing flora that use CO_2 for photosynthesis. As the quantities of these gases grow in the atmosphere, they will prevent more and more of the heat from escaping—which may be causing the temperature of Earth to rise.

For more information on climate change, visit the Intergovernmental Panel on Climate Change (IPCC) at *www.ipcc.ch/*.

How Do We Know This?

How do we know which gases are in a planet's atmosphere?

Astronomers study the light coming from a planet to determine which gases are in its atmosphere. This is called spectroscopy. By spreading out the light reflecting off a planet's atmosphere, or the light passing through a planet's atmosphere, astronomers can study its rainbow of colors, or *spectrum*. Each gas absorbs specific colors. So, by looking at which colors are missing, or dim, in a planet's spectrum, astronomers can determine which gases are present. This method is even being used for learning about the atmospheres of planets orbiting other stars!

Objective

Observe and investigate a model of how light and the atmosphere interact to make Earth suitable for life.

Key Concept

II: Earth's unique properties

Materials

The class will need

- one large bag of potting soil
- one box of plastic wrap
- graph paper for each student
- safety glasses or goggles for each student

Each group of students will need

- two large disposable plastic cups
- dirt to fill each cup (use commercial potting soil free of pesticide or fungicide)
- something to prop up thermometers (e.g., a slightly smaller cup or stack of books)
- one rubber band
- two thermometers (nonmercury)
- hole punch

Time

50 minutes

Preconceptions

Ask students what they know about greenhouses, especially about how they stay warm. Because greenhouses are warmed by infrared radiation, you might also ask them what they know about infrared radiation.

What Students Need to Understand

- Light comes in many forms, not just the visible form that we can see.
- The passage or transmittance of the infrared light (heat) is inhibited by certain things, including glass, CO_2, H_2O, and CH_4.
- CO_2, H_2O, and CH_4 only partially inhibit the passage of heat. Higher concentrations trap more heat.

Time Management

This Activity should take about 50 minutes. You may want to give students assignments to complete between temperature readings. You can save time by having students set up their cups the day before the Activity. It is important to remember that the success of this Activity depends on having a sunny—but not necessarily warm—day.

SAFETY ALERT

1. Safety glasses or goggles are required for this Activity.

2. Handle glass thermometers with care so as not to drop or break them by applying too much force—broken glass is a sharp hazard.

3. Wash hands with soap and water upon completing the lab.

Preparation and Procedure

Place all the materials in a central location so that students can obtain them easily. Keep track of the weather report and pick a sunny day for the Activity.

Reading 8: Global Warming shows how scientists have come to understand that humans are artificially increasing the amounts of greenhouse gases in the atmosphere, causing the global temperature to rise. Also refer to Reading 10: The Greenhouse Effect, and Reading 11: The Coming Climate Crisis?

Extended Learning

Students may want to see what happens if the cups are left out all day long. Do the temperatures continue to rise? If not, why not? How does this relate to Earth?

This is an excellent place for students to investigate what happens on other planets with regard to the greenhouse effect. Venus and Mars are especially good to research. Students will almost certainly want to know what will happen if the greenhouse effect increases dramatically on Earth. Venus provides a model of what might occur.

Students also can experiment with the effect of the color of the soil on temperature rise. They might want to compare differences between white sand and brown soil on the temperature rise in their greenhouse cups.

Finally, students may want to look into current research on the greenhouse effect, and global climate change. This can be a controversial topic in popular media; however, there is a strong consensus among scientists that global surface temperatures have increased in recent decades, and that this is caused mostly by human actions. Have students investigate the human activities that have led to an increase in carbon dioxide in the atmosphere.

Interdisciplinary Study

The oceans play a major role in moderating the amount of carbon dioxide in the atmosphere. The gas dissolves in the ocean and eventually becomes a part of some shells and ocean sediments. Students can investigate research that is being done on the role of the ocean in carbon dioxide regulation.

The greenhouse effect and global climate change are societal as well as environmental problems. Solutions based on environmental concerns alone are incomplete. Industrialized societies depend heavily on burning fossil fuels, the chief source of carbon dioxide in the atmosphere. Solutions to these problems must take into account societal and technological factors as well as environmental ones. What would be the impact on the United States and other industrialized countries of shifting away from fossil fuels? What technology would be required to do this? Are there other possible solutions besides alternative energy sources?

Connections

The greenhouse effect spans all Earth science disciplines: many climatologists, oceanographers, and geologists study the effect of Earth's greenhouse gases through time. Have students learn about the research these scientists do on climate change. What does a geologist or an oceanographer study that is related to climate change (e.g., microfossils and deep ocean currents, respectively)?

Differentiated Learning

Ask students in pre-algebra or algebra classes to confirm their graphing with a graphing calculator, and to extrapolate 10 or 15 min. more than their longest measurement.

Answers to Student Questions

1. The dirt represents the surface of Earth. The plastic wrap represents Earth's atmosphere.
2. Predictions may vary slightly. Pay careful attention to what students predict—it will provide clues for what preconceptions exist in your class and give you guidance about whether to extend this Activity.
3. Students should see a graphical representation of the answer to question 2.
4. The temperature in both cups should have increased, but at different rates. As the dirt in each cup gives off heat, the temperature of each increases. In the covered cup, however, the heat does not escape, so the temperature rises more rapidly.
5. Answers will vary.

Resource
www.ipcc.ch/

6. Answers will vary. Have students applied their experimental results logically to their knowledge about Earth's atmosphere?

Assessment

- While students are doing their experiments, ask them about their procedures and results. Do they believe their results? Do the measurements surprise them or do they seem to make sense? Why? Why not? Would they like to do the experiment differently? If so, how and why?
- For formal summative assessment, you could ask students to graph data or to interpret a graph, you could ask them to write a lab report, or you could grade the answers to the questions.

Index

H

I

J

K

L

M

U

V

W

X