Science as Inquiry

Second Edition

ACTIVE LEARNING, PROJECT-BASED, WEB-ASSISTED, AND ACTIVE ASSESSMENT STRATEGIES TO ENHANCE STUDENT LEARNING

Jack Hassard, Ph.D.
Georgia State University

GOOD YEAR BOOKS

v 1.1

Cover: PhotoDisc, Inc.; Interior: Unless otherwise acknowledged, all photos are property of Good Year Books.
Photo credits: 1.1 photos.com; 3.4 photos.com; 4.6 photos.com; 5.1 Kathy Sloane/Photo Researchers; 5.7a NASA; 7.1 photos.com; 7.5b NASA; 8.1 photos.com; 11.2 photos.com; 11.3 photos.com

GOOD YEAR BOOKS
are available for most basic curriculum subjects plus many enrichment areas. For more Good Year Books, contact your local bookseller or educational dealer. For a complete catalog with information about other Good Year Books, please write:

Good Year Books
A Division of Social Studies School Service
10200 Jefferson Boulevard
Culver City, CA 90232-0802
www.goodyearbooks.com
(800) 421-4246

Project Manager: Bill Williams
Second Edition Editor: Will Slattery
Second Edition Graphic Designer: Amy Shimoshige
Book design by Foster Design.
Cover illustration assembled by Jack Foster.
Line art by Douglas Klauba.
Electronic art by Karen Kohn and Associates.

Printed in the United States of America.

ISBN 978-1-59647-384-3

For Mary-Alice

CONTENTS

PREFACE

Themes of Science As Inquiry 3
Assessing Active Learning 5

PART I: THE TOOLS OF INQUIRY 7

CHAPTER 1 COOPERATIVE LEARNING STRATEGIES 9

Key Concepts 10
The Strategies...............................10
- Collaborative Inquiry Strategy.....10
- Numbered Heads Together Strategy23
- Round Table Strategy 24
- Circle of Knowledge Structure 25
- Think Aloud Pair Problem Solving35
- Questions:...............................36
- Jigsaw 36

Summary 38

CHAPTER 2 EEEPS: EXCITING EXAMPLES OF EVERYDAY PHENOMENA. 43

What Is an EEEP?.........................44
How Can EEEPs Enhance My Science Lessons? 44
An EEEP Example: Where Did the Water Go?................44
When Should I Use EEEPs?............46
Using the EEEP Activity Sheet.........46
Earth Science EEEPs 46
- A Cool Experiment....................46
- Water Evaporation 46
- Hot Water Freeze 46
- Typical Answers 46
- The Punctured Can...................48
- The Foggy Cloud 48
- Breaking Rocks 48
- The Mini-Telescope 49

Life Science EEEPs.......................49
- Earthworm Investigation 49
- Gravity and Plant Growth 49
- The Case of the Mealworms 49

Physical Science EEEPs..................50
- The Penny and a Glass of Water ...50
- Electric Balloons 50
- Why Does the Water Rise? 50
- The Egg and the Bottle 52
- Fill the Beaker! 52
- The Coin Drop and Throw 52

Summary 53

CHAPTER 3 FUZZY SITUATIONS 55

What Is a Fuzzy Situation? 56
Using Fuzzy Situations....................56
- Assessing Prior Knowledge 56
- Ongoing Challenge 57
- Assessment..............................57
- Taking Action on Social Issues 57

Putting Fuzzy Situations into Action..................................58
Life Science Fuzzies 59
- No Insects 59
- Human Population Growth 60
- GENES Committee....................60
- Crazy Virus 60

Physical Science Fuzzies 62
- Icy Situation 62
- Anonymous Letter 62

Earth Science Fuzzies.....................63
- Water or Gas 63
- Aqua City 64
- A Smelly Dilemma 64

Environmental Science Fuzzies 65
- Should We Make the Plunge? 65

Summary 66

CHAPTER 4 ACTIVE LEARNING STRATEGIES 67

Pre-Assessment Strategies 68
- T-charts 68
- Surveys 69
- Interviews 69
- Cushioning/Underexplaining 72
- Concept Mapping.....................72

Collaborative Questioning 73
The Q-M-S Strategy 75
- Task 1. The Onion Lab...............75
- Task 2. The Drifting Continents ...77
- Task 3. The Geoblock 77

The K-W-L Strategy 77
Visualizations: Guided Imagery.........81
- Using Guided Imagery in Science Teaching................................82
- Creating Your Own Visualizations .84

Games 84

The Disaster Game 84
Earth Science Games 89
Environmental Science Games 89
Life Science Games....................89
Physical Science Games.............89
Summary 90

CHAPTER 5 PROJECT-BASED TEACHING 91

What Is a Science Project?..............92
Rationale for Using Projects 93
Types of Projects............................93
Construction or Engineering Projects 93
Experimental/Research/ Measurement Projects 93
Search and Find Projects 93
Using the Group Investigation Method 93
Evaluating Projects and Presentations 93
Projects for the Active Science Class ..97
Earth Science Projects 97
Life Science Projects 100
Physical Science Projects.......... 101
Summary 103

PART II USING THE INTERNET TO ENHANCE SCIENCE INQUIRY 105

CHAPTER 6 THE ONLINE SCIENCE CLASSROOM 107

Early Experiences with the Net 108
Some Problems with the Internet..... 108
Web 2.0 Tools for Science Teaching.. 110
The Pedagogies That Emerged From Practice 110
Computer-Mediated Communication (CMC)............ 113
Computer Supported Collaborative Learning (CSCL) 113
Mobile/Wireless Computing (MWC)................................ 114
Web 2.0 Science Innovations & Tools 115
Mind-to-Mind Activities........... 115
Keypals and the Global Classroom 115
Telementoring and Question and Answer Sessions 117
Information Exchanges and Virtual Learning.............................. 119
Network Science: Pooled Data Analysis 119
Virtual Field Trips 124
The Virtual Classroom.......... 125
Problem-Solving Projects 126
Summary 127

CHAPTER 7 PROJECT OZONE: A WEB ASSISTED SCIENCE UNIT 131

Introduction to Project Ozone 132
Goals of Project Ozone 133
The Project Ozone Web Site........... 133
Special Materials for Project Ozone . 133
Activity 7.1 Ozone: The Good and the Bad 133
Activity 7.2 The Changing Ozone Layer 138
Activity 7.3 Ozone in Your Community 143
Activity 7.4 Ozone: A Global Project 148
Activity 7.5 Ozone: What Can Be Done? 152
Student Materials 154
Project Ozone Mini Learning Log 154
Project Ozone Portfolio............ 154
Project Ozone Certificate.......... 154

PART III ACTIVE ASSESSMENT FOR ACTIVE LEARNING 161

CHAPTER 8 ASSESSING PERFORMANCE IN SCIENCE. 163

Multiple Methods of Assessment 163
Assessment: The Big Picture 164
Diagnostic Assessment Strategies 164
Formative Assessment Strategies 165
Observing 168
Asking Questions 168
Student Talk.......................... 169
Student Writing as an Assessment Strategy 170
Rocky Writing: An Alternative

Writing Assignment 171
Alternative Multiple Choice........... 172
Open-ended Questions 172
Designing Open-ended Questions 173
Examples of Open-ended Questions174
Performance Tasks 174
Characteristics of Performance Tasks............... 178
Examples of Performance Tasks . 178
The Student Log......................... 180
How Should Logs Be Organized? 181
When Should Logs Be Used?...... 181
How Should Logs Be Used? 182
The Portfolios 182
Model 1: Basic Portfolio for Any Science Class 184
Model 2: Biology/Life Science Portfolio.............................. 185
Assessing Student Perfromances and Attitudes 189
(Psycho)motor Skills 191
Cognitions and Cognitive Skills .. 191
Attitudes 194
Summary 195

PART IV CONSTRUCTIVISM IN THE BAG: ACTIVE SCIENCE LESSONS 197

Developing the Lessons 198
Creating Constructivist Science Lesson Sequences................................. 199
Creating Constructivist Science Lesson Sequences................................. 200
Using the Lessons 202

CHAPTER 9 EARTH SCIENCE LESSONS 205

Making a Cloud.......................... 207
Igneous Rocks: Granite................. 208
The Center of the Earth 209
Rock Types: Igneous, Metamorphic, 210
Sedimentary.............................. 210
Geysers................................... 211
Mohs' Scale of Mineral Hardness 213
Project River Watch 214

CHAPTER 10 ENVIRONMENTAL SCIENCE LESSONS 217

Acid Rain 219
Rain Forest Deforestation.............. 220
Project Green Classroom 222
Waste Disposal........................... 224
Clean Water 225
Hydroelectric Power 226

CHAPTER 11 LIFE SCIENCE LESSONS 229

Endangered Species 231
Dinosaur Biographies................... 232
Dinosaur Defense 233
Life in a Seashell 235
Fossils 236
Fossilization: Making a Plaster Mold 238
Classification Systems................... 238

CHAPTER 12 PHYSICAL SCIENCE LESSONS. 241

Electromagnetism........................ 243
Power: Watts in the Water 244
Pendulum Variables..................... 245
Gravity 247
Mixtures: Iron in Cereal Flakes....... 248
Evaporation Is Cool 250
Magnetic Fields 251
Surface Tension: The Stress 252
$H_2$0 Feels................................. 252
Water and Air Surface Interactions:. 253
Bubbles 253
The Visible Spectrum: A Rainbow ... 255

RESOURCES FOR SCIENCE TEACHING . 257

The Tools of Science Inquiry 257
Internet Resrouces 257
Assessment Tools 257
Science Activities......................... 258

ACKNOWLEDGEMENTS 259

INDEX 260

SCIENCE AS INQUIRY CORRELATION CHARTS

Correlation charts can be found online at the Science As Inquiry Website for each of the following sets of Standards. Please follow the link to access each of the correlation charts that are described here. http://www.science-as-inquiry.org/standards.html

THE COMMON CORE STATE STANDARDS: SCIENCE & TECHNICAL SUBJECTS

As part of the Literacy component of the Common Core State Standards, the standards for Science & Technical Skills have been correlated to the content of Science as Inquiry. The standards are arranged into three clusters by grade level: Grades 6 – 8, Grades 9 – 10, and Grades 11 – 12.

THE CONCEPTUAL FRAMEWORK FOR SCIENCE EDUCATION

In a new initiative the National Research Council has published a document entitled A Framework for Science Education, which is a new conceptual framework which will be the basis for a new set of National Standards for Science Education. The document identifies three Dimensions to organize the conceptual framework for science education as follows:

- Dimension 1: Core Disciplinary Ideas in life sciences, Earth and space sciences, physical sciences, and engineering and technology.
- Dimension 2: Cross-cutting elements including cross-cutting scientific concepts, and topics in science, engineering, technology and society.
- Dimension 3: Scientific and engineering practices including how scientists and engineers work, and practices for science education.

CORRELATION OF SCIENCE AS INQUIRY TO SCIENCE AND TECHNICAL SUBJECTS COMMON CORE STANDARDS[1]

ID	Standard	1 Cooperative Learning	2 EEEPs	3 Fuzzy Situations	4 Active Learning	5 Projects	6 Internet	7 Project Ozone	8 Assessment	9 Earth Science Activities	10 Environmental Science Activities	11 Life Science Activities	12 Physical Science Activities
Key Ideas and Details													
RST 6-8.1	Cite specific textual evidence to support analysis of science and technical texts.			X			X	X		X	X	X	X
RST 6-8.2	Determine the central ideas or conclusions of a text; provide an accurate summary of the text distinct from prior knowledge or opinions.				X				X	X	X	X	X
RST 6-8.3	Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.	X	X			X		X		X	X	X	X

CONNECTIONS: SCIENCE AS INQUIRY AND THE CONCEPTUAL FRAMEWORK FOR SCIENCE EDUCATION[1]

		1 Cooperative Learning	2 EEEPs	3 Fuzzy Situations	4 Active Learning	5 Projects	6 Internet	7 Project Ozone	8 Assessment	9 Earth Science Activities	10 Environmental Science Activities	11 Life Science Activities	12 Physical Science Activities
DIMENSION 1: CORE IDEAS													
LIFE SCIENCE													
LS1	Organisms have structures and functions that facilitate their life processes, growth, 4 and reproduction. (From Molecules to Organisms – Structures and Processes)											X	
LS2	Organisms have mechanisms and processes for passing traits and variations of traits from one generation to the next. (Heredity -- Inheritance and Variation of Traits)											X	
LS3	Organisms and populations of organisms obtain necessary resources from their environment which includes other organisms and physical factors. (Ecosystems: Interactions, Energy, and Dynamics)											X	
LS4	Biological evolution explains the unity and diversity of species. (Biological Evolution: Unity and Diversity)											X	

[1] *The Common Core Standards for Science and Technical Subjects is a very small part of the Common Core State Standards Initiative. Within a section entitled Grades 6 – 12 Literacy in History/Social Studies, Science, & Technical Subjects is the organization of the Standards for science. The author has used these standards in the Science, & Technical strand to create this analysis. For more information please consult: http://www.corestandards.org/.*
Further information can also be found on the Science as Inquiry website: http://www.science-as-inquiry.org/"

Science As Inquiry, 2nd Edition weaves together ideas about science teaching and inquiry that were developed over many years of work with practicing science teachers in the context of seminars conducted around the U.S.A, in school district staff development seminars, and courses that I taught at Georgia State University.

Science As Inquiry provides the practical tools, based on theory and research, that science teachers use in their classrooms to involve their students in inquiry learning, including hands-on investigations, project-based activities, Internet-based learning experiences, and science activities in which students are guided to construct meaning and develop ideas about science and how it relates to them and their community.

Inquiry science teaching by its very nature is a humanistic quest. It puts at the center of learning not only the students, but also how science relates to their lived experiences, and issues and concepts that connect to their lives. Doing science in the classroom that is inquiry-based relies on teachers and administrators who are willing to confront the current trend that advocates a standards-based and high stakes testing paradigm. The dominant reason for teaching science is embedded in an "economic" argument that is rooted in the nation's perception of how it compares to other nations in science, technology, and engineering. This led to the development of new science curricula, but it also led to the wide scale use of student achievement scores in measuring learning. Student achievement, as measured on "bubble tests," has become the method to measure effectiveness of school systems, schools, and teachers, not to mention the students.

Although the organizations that have developed the science standards (National Research Council) advocate science teaching as an active process, and suggest that students should be involved in scientific inquiry, there is a disconnect between the standards approach and the implementation of an inquiry-based approach to science teaching. We need to pull back on the drive to create a single set of standards and complementary set of assessments, and move instead toward a system of education that is rooted locally, driven by professional teachers who view learning as more personalized, and conducted in accord with democratic principles, constructivist and inquiry learning, and cultural principles that relate the curriculum to the nature and needs of the students.

Science education researchers have reported that inquiry-based instructional practices are more likely to increase conceptual understanding than are strategies that rely on more passive techniques, and in the current environment emphasizing a standardized-assessment approach, teachers will tend to rely on more traditional and passive teaching techniques.[1] Inquiry-based teaching is often characterized as actively engaging students in hands-on and minds-on learning experiences. Inquiry-based teaching also is seen as giving students more responsibility for learning. Given that the evidence is somewhat supportive of inquiry-based science, our current scheme of national science standards emphasizing a broad array of concepts to be tested would tend to undermine an inquiry approach.

Teachers who advocate and implement an inquiry philosophy of learning do so because they want to inspire and encourage a love of learning among their students. They see the purpose of schooling as inspiring students, by engaging them in creative and innovative activities and projects. Here is how Kareen Borders[2], a science teacher, frames this view:

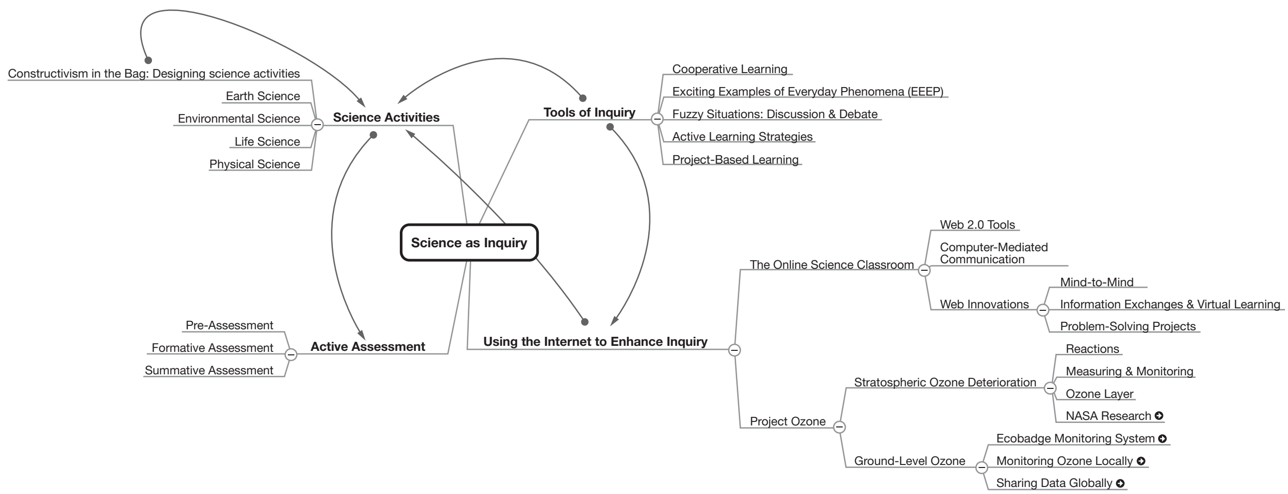
> *"My students are not passive learners of science, they ARE scientists. They embrace the idea that they are empowered to own their learning. In addition to creating a*

---

[1] *Minner, Daphne D.; Levy, Abigail Jurist; and Century, Jeane; "Inquiry-Based Science Instruction—What Is It and Does It Matter?"* Journal of Research in Science Teaching, *Vol. 47, NO. 4, PP. 474-496 (2010)*

[2] *Presidential Awards for Excellence in Mathematics and Science, 2011, from Lakebay, Washington*

Figure I.1.
The Organization of Science As Inquiry into Four Parts and 12 Chapters



love of learning within my students, I am intentional about equipping students with wonder, teamwork strategies, and problem-solving skills for jobs that may not exist yet."

Science As Inquiry embraces 21st century teaching in which inquiry becomes the center and heart of learning. *Science As Inquiry* provides a pathway to make your current approach to teaching more inquiry-oriented, and to embrace the digital world that is ubiquitous to our students and the world they inhabit.

Here are some things to look for as you make use of *Science As Inquiry*.

Organization of *Science As Inquiry*

Science As Inquiry is organized into four parts, including the Tools of Inquiry, Using the Internet to Enhance Science Inquiry, Active Assessment for Active Learning, and Constructivism in the Bag activities. Figure I.1 depicts the organization of *Science As Inquiry* and identifies the chapters comprising each part of the book.

Part I. Tools of Inquiry:

There are number of tools that teachers who embrace inquiry use in their classrooms. In this first part of the book, you will be introduced to collaborative or cooperative learning, which is fundamental to promoting a classroom ecology that supports student inquiry. As a teacher, knowing how to work with students in groups is essential. I have provided details on seven approaches to working with students in groups, based on a series of seminars and research on cooperative learning that I have done with practicing science teachers, grades 6 – 12. Additional tools of inquiry include EEEPs, Fuzzy Situations, active learning strategies, and project-based learning.

Part II. Using the Internet to Enhance Science Inquiry:

We live and work in a digitally transformed world, and science teachers have invented powerful ways of using the Internet to promote inquiry learning. This part of *Science As Inquiry* explores innovations and pedagogies that have emerged from the integration of Web 2.0 and science curriculum. Practical examples of projects and activities are described, showing how the more social and a communicative nature of the Internet results in students sharing, publishing, creating and exploring real science issues locally and globally. I have also included Project Ozone, presented in Chapter 7, an environmental science inquiry in which students design research studies, in collaboration not only with students in their own classes, but with students globally.

Part III. Active Assessment for Active Science:

In this section of the book, you will find an active approach to science assessment that focuses on integrating three aspects of an assessment system: diagnostic ways of assessing students' prior knowledge, formative assessments that help students learn and progress in science, and summative tools that provide feedback to students and teachers about learning.

Part IV. Constructivism in the Bag:

The title is a play on words based on an activity I did with thousands of science teachers in which they were given a plastic baggie of science teaching materials (such as a collection of rocks, a magnifier, a metric ruler, a streak plate) and then were asked, as members of a team, to develop an activity based on a constructivist model of teaching. In this part of the book you will find 31 activities and projects, some of them Internet-based that you can use and implement in your science curriculum.

Themes of *Science As Inquiry*

Tools of Inquiry: The tools of inquiry showcase five tools that are shown in Figure I.2, including Collaborative Learning, EEEPs, Fuzzy Situations, Active Learning Strategies, and Project-Based Learning. You will find specific ways to implement cooperative learning in your class, and for each cooperative learning model, you will find a science activity which you can use both to teach your students the method and to also hone your own cooperative/collaborative teaching skills. EEEPs are Exciting Examples of Everyday Phenomena. An EEEP is a tool in which you present an a demonstration-like event (some call these discrepant events) to the whole class, but students explore the EEEP in collaborative groups. You will find Earth, life, and physical science EEEPs to use with your students. Fuzzy Situations are science- related social issues in story form that engage students in research, discussion and debate of important issues. You can conduct these sessions in class, or use the Internet for students to participate in online discussions of important science- related social issues. Six Active Learning Strategies are presented that will offer ways to enhance student motivation and attitudes in science. The final tool of inquiry is the use of

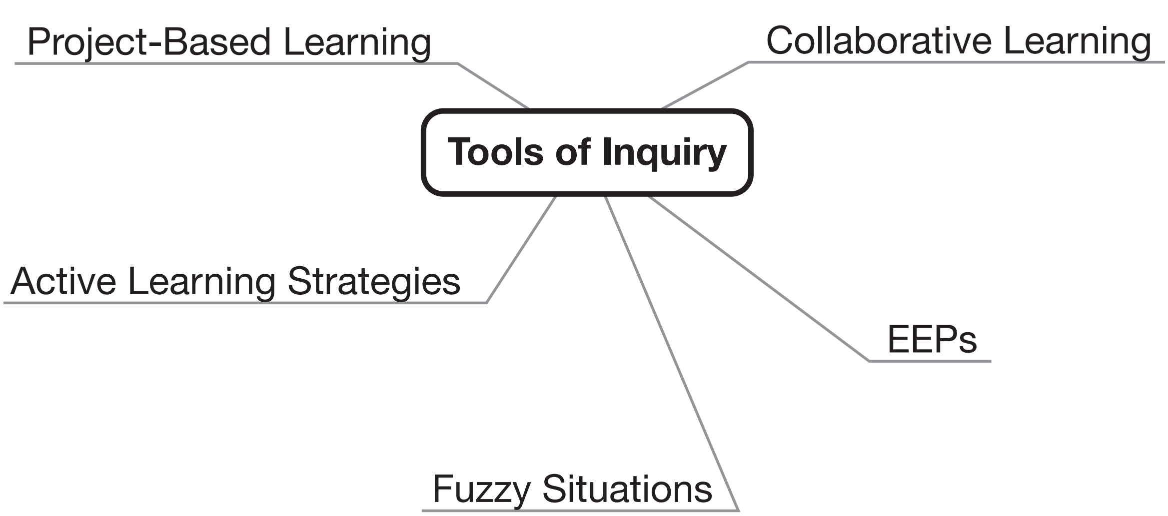
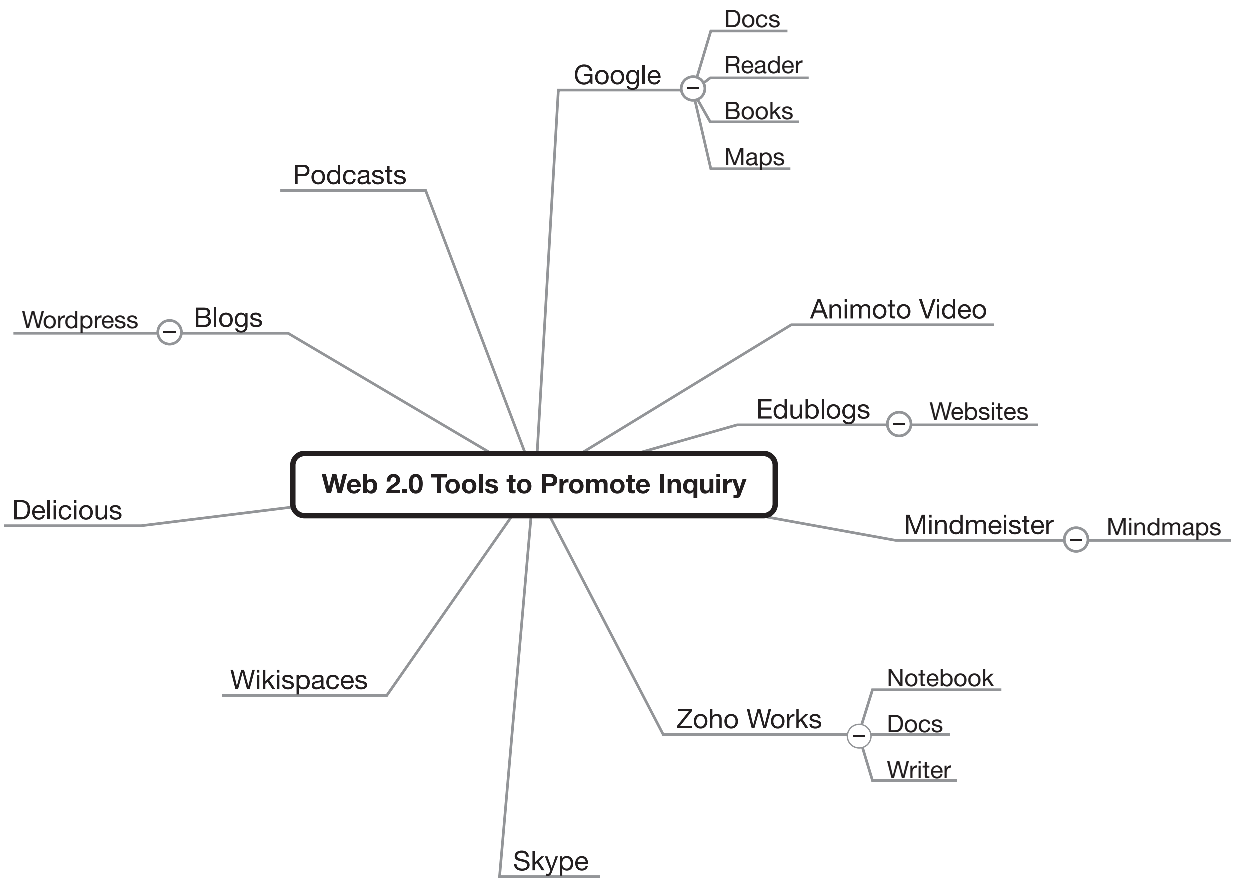


Figure I.2.
The Tools of Inquiry as Teaching Strategies that Promote Inquiry Learning in the Science Classroom

Figure I.3.
Web 2.0 Tools that promote inquiry and that are explore in Part II of the book.



Project-Based Learning activities as a fundamental part of the science curriculum. A cooperative learning model is presented that you can use to implement projects in your class. You will find examples of projects drawn from Earth science, environmental science, life science, and physical science.

Active Learning. This theme is connected to the way students learn science. There is no doubt that students come to science classes from varied backgrounds and with different skills and abilities. Science teaching that engages students in activities that draw on multiple abilities and learning styles will tend to reach a greater number of students than teaching that does not. Active learning, as the concept is used in *Science As Inquiry,* finds students involved in small cooperative groups whose tasks are interesting and problem-oriented. Teachers organize and facilitate group activities by making use of a variety of strategies—for example, cooperative learning groups, hands-on inquiry activities, and collaborative Internet-based studies. Underlying the active learning theme is the idea that learning is best promoted in communities of learners, and that new ideas are linked to previous knowledge and constructed by the learner. Active learning is a metaphor for a humanistic and constructivist model of teaching.

The Internet as a Path to Inquiry. The Internet as a theme of *Science As Inquiry* is viewed as an essential feature of inquiry science teaching. The Internet or Web has become more interactive and social, and consequently students can create, share, publish, and work together in collaborative groups within their own classroom, but also with students in other schools around the world. You will find the world of Web 2.0 presented here with examples of tools of the Internet that you can use with your students to enhance their ability to do inquiry. Figure I.3 is a chart showing the variety of Web 2.0 tools we can use in our classes to help promote inquiry science. The tools that are presented under this theme are exemplified with a variety of activities, as well three project-based science projects, Project Ozone, Project Green Classroom, and Project River Watch.

Assessing Active Learning. Assessment is an important theme in *Science As Inquiry*, and you will find a three-stage model of assessment with practical examples. Diagnostic (or pre-instruction) assessment is designed to assess students' prior knowledge by means of several active assessments. During instruction, formative assessment strategies become the tool that we use to help students learn, and to provide feedback to students. These assessments are embedded in instruction, and include a wide range of activities. After instruction, the goal is to evaluate students' progress and provide feedback about the effectiveness of the methods used by science teachers. Portfolios, interviews with students, written assessments, and performance tasks are explored.

Constructivist Activities. This theme explores the nature of instructional design that fosters inquiry science teaching. In *Science As Inquiry*, a four-stage constructivist design is used to present 31 activities representing Earth science, environmental science, life science, and physical science. Each activity was developed using a cyclic constructivist model of teaching. The elements of the cycle include: Invitation, Exploration, Explanation, and Taking Action.

The *Science As Inquiry* Website To make a seamless connection between the ideas in *Science As Inquiry*, I have designed a website that makes accessible activities, projects and links that are

Figure I.4.
Constructivist Learning Cycle in actiity design

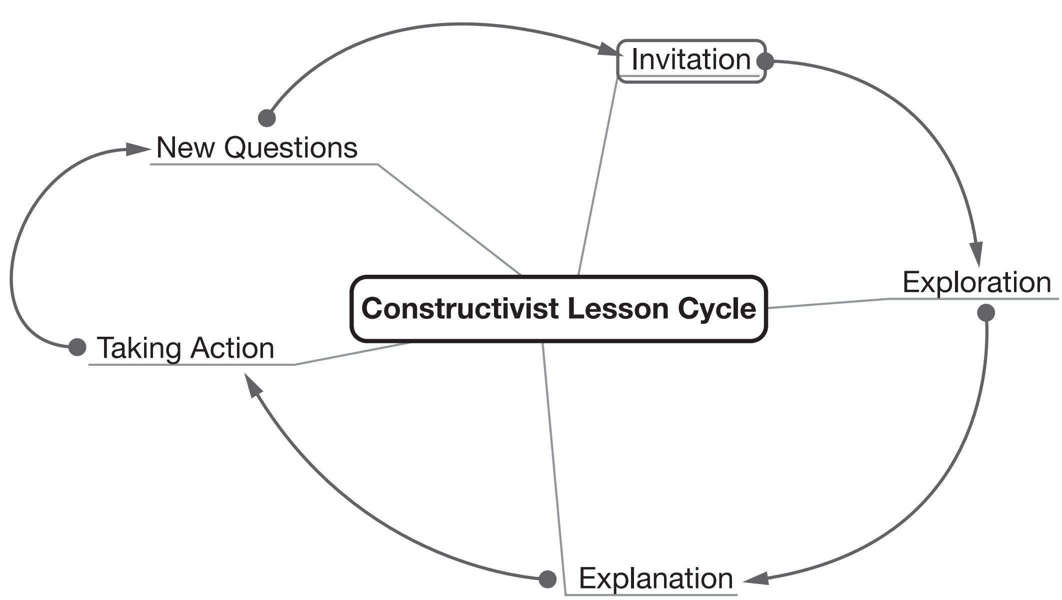
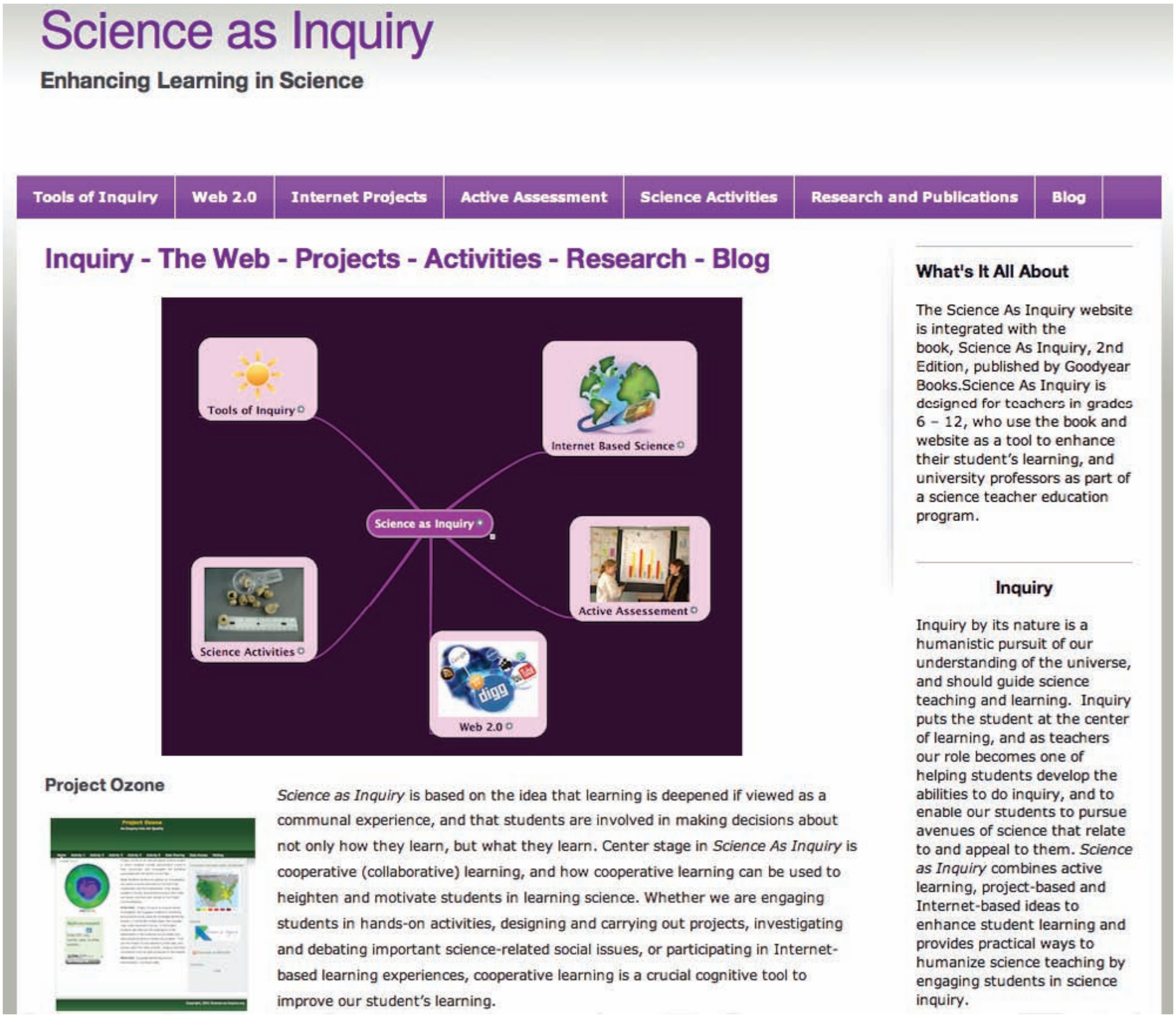


Figure I.5.
Screen shot of the *Science As Inquiry* Website:
http://www.science-as- inquiry.org



discussed and presented in *Science As Inquiry*. You will find science activities, links to teh Tools of Inquiry projects that you can do with your students using the Internet, and links to key research and publications. The website has a link to the *Science As Inquiry* blog enabling you to connect with other teachers using the book.

Part I The Tools of Inquiry

Chapter 1 Cooperative Learning Strategies

Figure 1.1
Cooperative learning is fundamental to learning and brings students together to work on important problems. Learning this way mirrors some of humanity's best efforts at solving real problems.

This chapter will introduce you to several cooperative learning strategies designed to enhance the way students work together in small groups. Science education research has shown that cooperative learning, when used effectively, can lead to greater cognitive gain, better (more positive) attitudes toward science, and a higher motivation to learn science.

Key Concepts

Two concepts are fundamental to implementing cooperative learning strategies: positive interdependence and individual responsibility. The roles of each can best be understood by considering the examples in Figure 1.2. Engendering positive interdependence is the most important thing that we as teachers can do to help students work in small groups. Interdependence can be achieved in science activities by having students collaborate on an activity that requires a single product, by dividing the labor, by assigning roles, or by rewarding all of the students in a group.

Individual responsibility is just as important as positive interdependence. In the activities that we plan, we can encourage individual responsibility by focusing on individual outcomes, by giving feedback on each student's progress, by having students work alone at first and then share their work with the group, or by using experts.

Figure 1.2
Two Key Cooperative Learning Concepts

Positive Interdependence	Individual Responsibility
• We sink or swim together.	• I must learn this material.
• None of us is as smart as all of us.	• I cannot "hitchhike."
• I win when you win.	• My teammates depend on me.
• The whole is greater than the sum of the parts.	

The Strategies

The strategies presented in this chapter will show that cooperative learning is much more than putting students in groups and telling them to work together. Discussed here are seven cooperative learning strategies that have been used successfully in teaching seminar. Each is a stand-alone strategy, which means you can use any strategy in this chapter in any order that you wish.

Collaborative Inquiry Strategy

This approach combines the principles of cooperative learning—individual responsibility and positive interdependence—with science inquiry. On the one hand, each student in the group has a specific role; on the other hand, all students in the group are involved in science inquiry.

Students engaged in collaborative inquiry play one of the four roles shown in Figure 1.3. In science inquiry, students explore problems in

Figure 1.3
Cooperative Inquiry Roles

Communicator	Tracker	Checker	Materials Manager
• Helps resolve problems • Can leave team to communicate • Sends and downloads Internet messages	• Helps track progress • Records data/information for the team • Collaborates with communicator on Internet activity	• Helps team understand the activity • Facilitates talk about the activity • Is not the leader; is a facilitator	• Picks up/returns materials • Facilitates cleanup • Checks to make sure equipment is in working order

SIDEBAR 1.1

Collaborative Inquiry[2]

- Students explore problems in natural world.
- Students "do" science.
- Knowledge about natural world is "constructed" through talk, activity, and interaction.
- Talk is focused through small-group activity.

the natural world. Students "do" science. In Collaborative Science Inquiry, students construct knowledge about the natural world through small-group talk, hands-on activity, and discussion. Sidebar 1.1 lists the key characteristics of "collaborative (science) inquiry."

Thus, in the Collaborative Inquiry approach to cooperative learning, students are not only individually responsible for a part of the activity, they are also interdependent on each other because they have different tasks, all of which play a part in solving a science problem. As you get started with Collaborative Inquiry, it is helpful to provide students with a "role card" describing their collaborative responsibilities. To do this, make each group of students a copy of Figure 1.4, which describes the various roles in Collaborative Inquiry. Have students cut out the cards and distribute them so that each student receives the card describing his or her role. You might also want to make a poster identifying the four roles. By hanging it prominently in your classroom, you can quickly and effectively review the roles with your students.

[2] After Rosebery, A., Warren, B., and Conant, F. Appropriate Scientific Discourse: Findings from Language Minority Classrooms. Working paper 1–92, Cambridge, MA: TERC.

LESSON PLAN: THE FOOTPRINT INQUIRY

Goals: To give students practice using the Collaborative Inquiry approach to cooperative learning; to generate alternative hypotheses to explain dinosaur footprints found in rocks dated to be 100 million years old; to encourage all group members to participate

Materials: Footprint Recording Sheet (Figure 1.5), Footprint puzzle(s) (Figures 1.6 and 1.7), photographs of dinosaurs

Web Site: http://dsc.discovery.com/dinoaurs/ *Dinosaur Central*

Procedure: Organize your class into teams of three or four students each. Have students number off within each group, and then assign each of the numbers one of the four Collaborative Inquiry roles. (If you decide to work with groups of three, have one of the

Figure 1.4

COOPERATIVE INQUIRY ROLES

Communicator

- Helps Resolve Problems
- Can Leave Team to Communicate
- Sends and Downloads Internet Messages

Communicator

- Helps Resolve Problems
- Can Leave Team to Communicate
- Sends and Downloads Internet Messages

Material Manager

- Picks Up/Returns Materials
- Facilitates Cleanup
- Checks to Make Sure Equipment Is in Working Order

Material Manager

- Picks Up/Returns Materials
- Facilitates Cleanup
- Checks to Make Sure Equipment Is in Working Order

Checker

- Helps Team Understand the Activity
- Facilitates Talk About the Activity
- Is not the Leader, Is a Faciliatator

Checker

- Helps Team Understand the Activity
- Facilitates Talk About the Activity
- Is not the Leader, Is a Faciliatator

Tracker

- Helps Track Progress
- Records Data/Information for the Team
- Collaborates with Communicator on Internet Activity

Tracker

- Helps Track Progress
- Records Data/Information for the Team
- Collaborates with Communicator on Internet Activity

students be the Communicator as well as the Materials Manager.) Give each team a copy of the Footprint Data Sheet and follow these steps:
1. Investigate the set of footprints with your teammates. Make a list of as many hypotheses to explain the pattern of the footprints as there are members of your team. Make sure that everyone contributes ideas and that you listen to each other's ideas.

2. Explain the task to the students. Tell them their job is to investigate, as a team, a set of footprints (show them Figure 1.6) found in rocks in central Connecticut. The rocks were dated to be about 100 million years old (which means they were deposited during the Cretaceous Period in the Mesozoic Era). Tell students they are to make a list of as many hypotheses as there are people in the group to explain the pattern of the footprints. Tell them to be sure that everyone participates. Give the students about five to eight minutes to generate their hypotheses.

SIDEBAR 1.2

Possible Hypotheses

- Two animals (birds) approached a water hole; one flew off, the other walked away.
- Two animals walked toward something; one spotted the other and tried to run; a fight ensued; one walked away.
- Two animals independently approached an area at different times.
- Two animals approached an area (mother, daughter); the daughter rode away on the mother's back.

3. At the end of this period, tell the students that you have some additional data from the footprint site—that is, scientists have sent you additional prints. Present Figure 1.7, using a bit of dramatic flair. Now have the students look over their hypotheses and, in light of the "new data," have them revise, discard, or accept their hypotheses. Have each team select one hypothesis to share with the class.

4. Select one student from each group to write the group's hypothesis on a chart or white posterboard. Divide the chart or board into four, so that each group has a space in which to write. Discuss the results, and ask students to defend their ideas with observations they made while working as a group.

5. Announce that the most likely explanation is that these are dinosaur prints, but that no one really knows for certain. Thus all the students' hypotheses can be considered plausible.

6. Going Further. Have your students investigate dinosaurs further. Here are two sites to visit:

http://lawrencehallofscience.org/bigdinos/dino.html
Big Dinos Return

http://paleo.cc/paluxy/ovrdino.htm
Overview of Dinosaur Tracking

Figure 1.5
Footprint Recording Sheet

FOOTPRINT INQUIRY
PRACTICING COLLABORATIVE INQUIRY

OBJECTIVES
1. Explore and investigate a problem from the natural world.
2. Generate alternative hypotheses to explain data in the form of footprints found in rocks that are 100 million years old.
3. Practice using Collaborative Inquiry roles.
4. Encourage everyone in the group to communicate ideas.

MATERIALS
1. One set of footprints per team
2. One data recording sheet per team

COLLABORATIVE INQUIRY ROLES

Role	Team Member
Communicator	____________
Materials Manager	____________
Tracker	____________
Checker	____________
Coach	____________

FOOTPRINT DATA SHEET

Tracker's Name: ______________________ Date: ______________

List of Hypotheses

Modified Hypothesis

Figure 1.6
Footprint Puzzle, Part A

Two adaptations of Figure 19-10 from *Investigating the Earth: Earth Science Curriculum Project,* p. 416. Copyright © 1967 by American Geological Institute. All rights reserved. Reprinted by permission of McDougal Littell Inc.

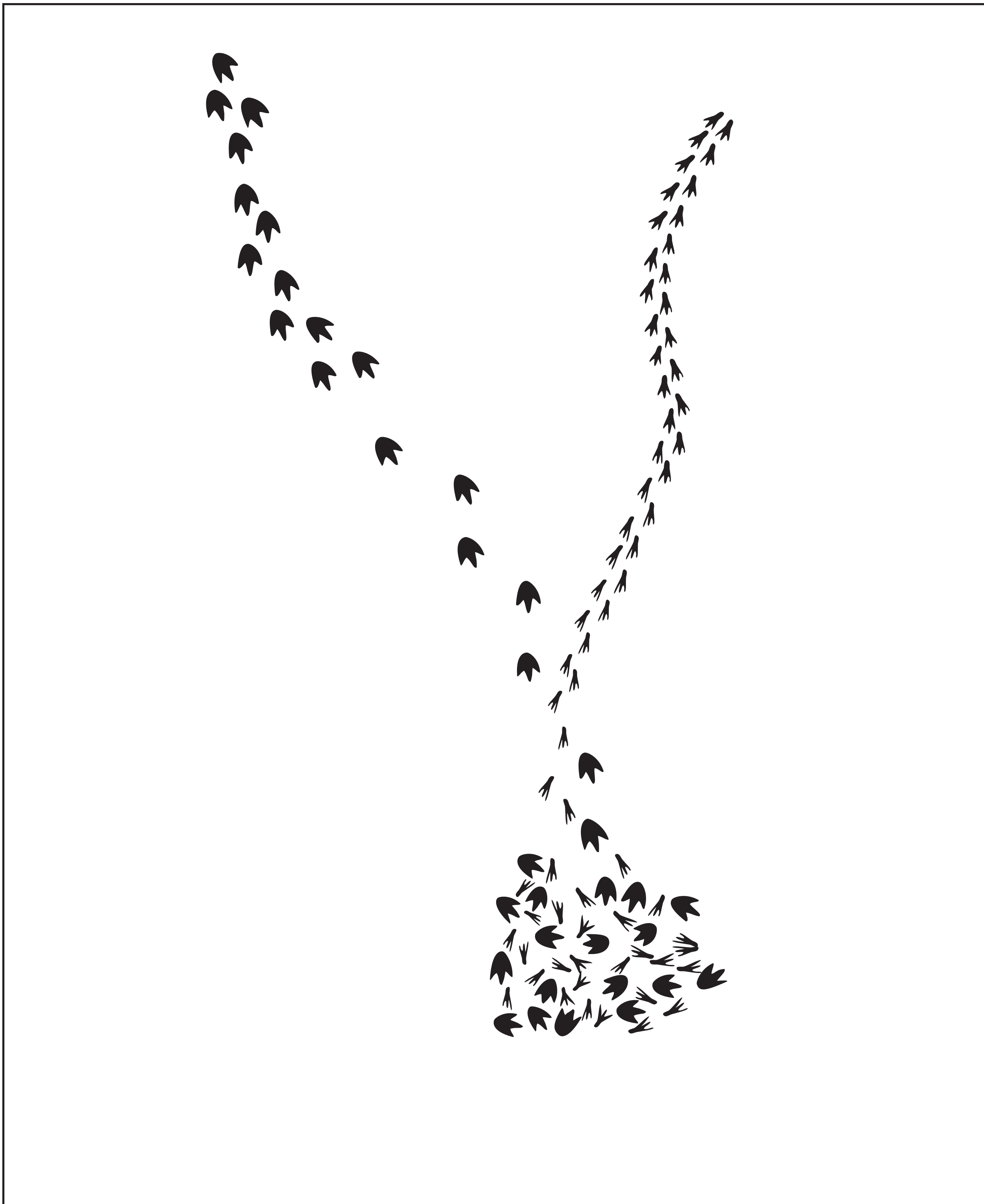


Figure 1.7
Footprint Puzzle, Part B

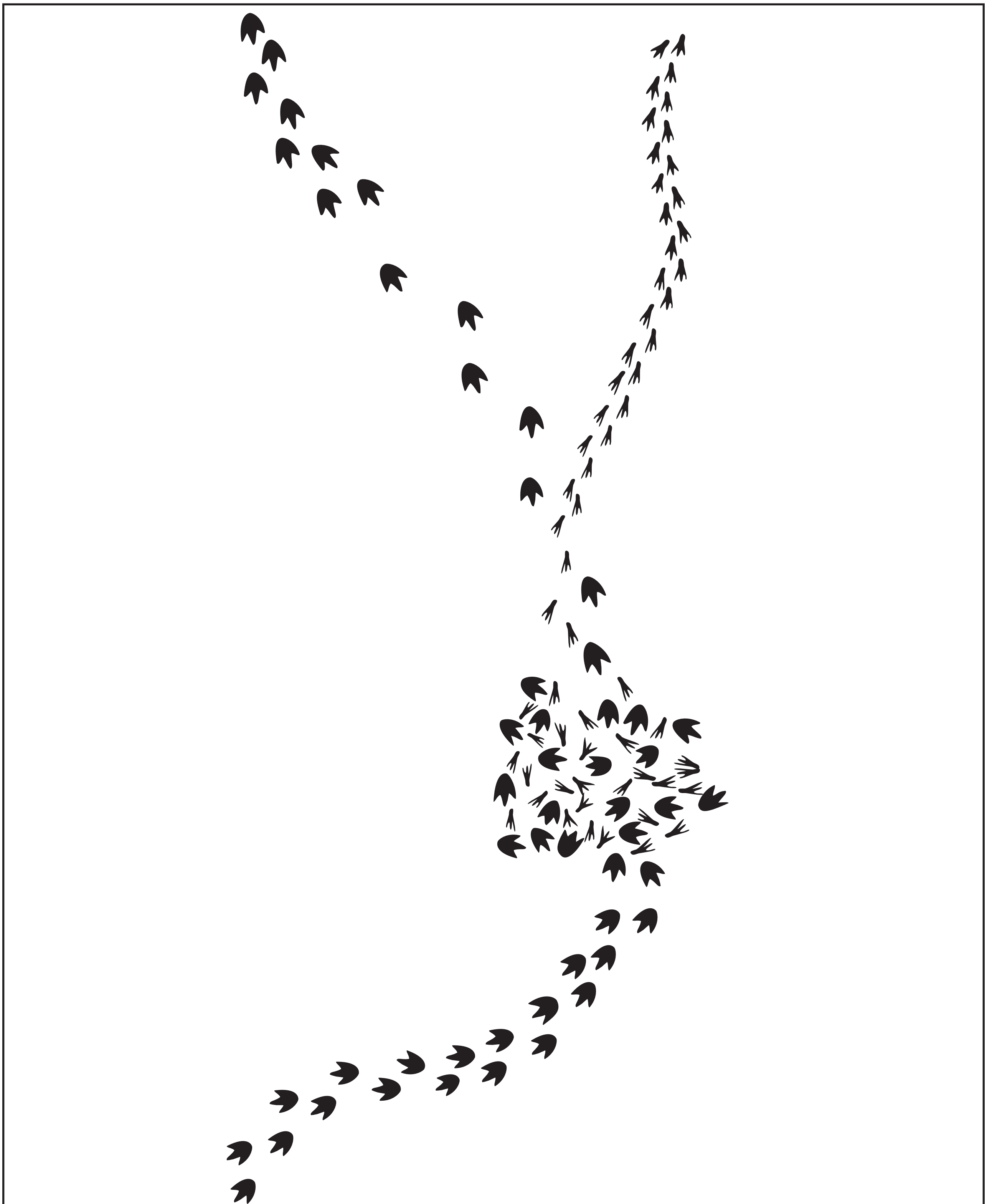


Figure 1.8
Abilities in Science Chart*

Verbal–Linguistic Word Smart	Visual–Spatial Picture Smart	Logical–Mathematical Minds-on-Smart	Bodily–Kinesthetic Hands-on-Smart
• Science word games • Use new science words in discussions • Create a science activities dictionary & pictionary • Word processing • Science writers, reporters	• Make diagrams of cells, atoms, Earth systems • Create video presentations • Mapping activities • Make 3-D models • Flowcharts, decision trees, concepts maps mind mapping • Multimedia presentation software • Draw and paint computer software	• Solve problems • Create problems; ask questions • Discuss and debate societal implications of science • Create data tables and spreadsheets • Find analogies • Work problems backward • Use science processes: observing, inferring, predicting, hypothesing, analyzing data, and drawing conclusions	• Build physical models • Express science concepts with bodily motion • Sensory awareness • Science probes plugged into computer (MBL, Science Toolkit)

*The abilities across the top of this chart are based on Howard Gardner's theory of multiple intelligences.

Multiple Abilities Strategy

Generally speaking, successful cooperative learning activities require multiple abilities among a team of students who work together to complete a task. Activities requiring only one or two abilities (especially if they are reading or mathematical calculations) tend to put many students at a disadvantage in cooperative groups. Thus, an activity that calls on students to make careful observations, to guess or make hypotheses, to record data, to manipulate hands-on materials, to construct a model, to role-play, and to write brief reports will tend to be more successful than one in which students read a section of the text and answer a set of questions.

Figure 1.8 identifies eight different abilities that students possess, in varying degrees, along with examples of activities that they might do in a science class to help them develop these abilities. Look it over, and use it as a checklist for the activities that you are assigning in your class.

When we use the Multiple Abilities approach to cooperative learning,[3] our goal is to convince students that many abilities are truly needed to successfully complete the activity or the task at hand. One way to do this is to make a list of all the abilities that will be required. In the case of the whirlybird activity, which follows, students will be doing the following:

- Designing helicopter-type vehicles
- Using trial and error
- Observing
- Predicting

[3] This approach is based on Cohen, E. (1994). Designing Groupwork: Strategies for the Heterogeneous Classroom. New York: Teachers College Press.

Figure 1.8
Abilities in Science Chart* (continued)

Musical Rhythm and Tone Smart	Interpersonal Cooperative Smart	Intrapersonal Reflective Smart	Naturalist Ecologically Smart
• Find and use science-related songs • Write and sing musical scores of science concepts • Play background music in class • Use natural music and sounds (birds, nature)	• Use cooperative groups, such as quality circles, tribes, and multiple abilities • Science board games • Computer games for pairs and groups • Teach active listening • Create a community of practice in class • From “I” to “W” • Networks • Join teacher discussion groups on computer networks • Link with others	• Journaling activities • Help students write goals and objectives • Portfolios • Provide time for reflection • Biographies • Motivational speakers	• Sensory awareness activities • Hikes and field trips into natural sites • Mini-field trips outside the classroom • Readings from nature magazines • Nature videos • Understanding, relating to, and functioning in the natural world

*The abilities across the top of this chart are based on Howard Gardner’s theory of multiple intelligences.

- Testing a hypothesis
- Interpreting data
- Controlling variables
- Writing observations
- Making drawings of their designs
- Making a poster report

Having made the list of abilities, it is helpful to create an environment of “mixed expectations” for the class. For example, you might say the following: “Isn’t it unlikely that any one member of the group will possess all of these abilities, but likely that each member will possess some of them?” Most students will agree. By posing this question, we help to close the gap between the high-ability student and low-ability student in each group. Typically, it is the low-ability student who is left out and not invited to participate. If we can convince the students that all students can contribute to the solution of the activity, then “permission” is given to every student to become involved. Further, by subtly focusing on the low-ability student in each group and by “catching” this student making intellectual contributions, the teacher can positively influence the group. Visit the groups frequently. When you hear something positive, clearly re-state for the group what you heard. This reinforces not only the low-ability student, but the group as a whole.

Lesson Plan: Whirlybirds

Goals: To test the Multiple Abilities approach; to build and fly whirlybirds; to investigate the effect of one variable on a whirlybird's speed of descent to the floor; to report results to the class

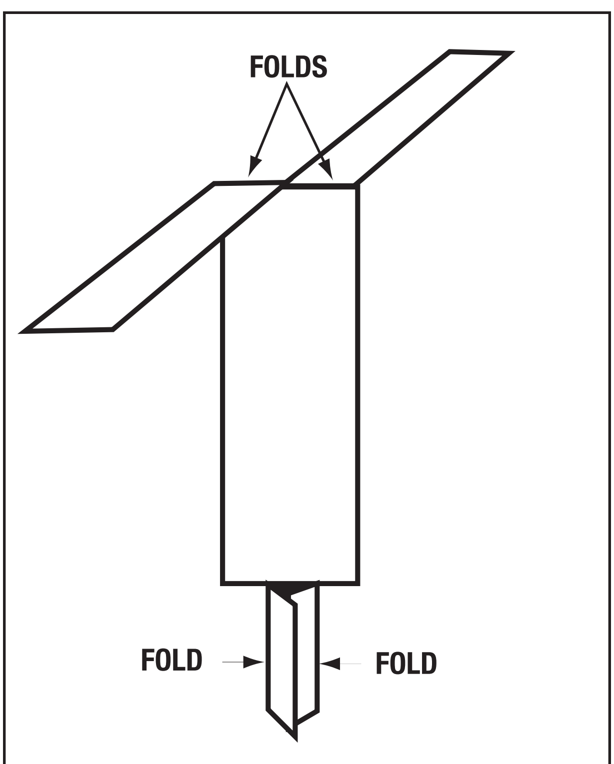
Materials: Scissors, Whirlybird Template (Figure 1.10), stopwatch, Group Mini-log (Figure 1.11), poster paper, markers

Procedure:

1. Show students a whirlybird that you have cut out and folded (see Figure 1.9). Ask students to brainstorm the factors (variables) that they think will affect the whirlybird's speed of descent to the floor. List students' ideas on chart paper. Students will likely suggest the following variables: wind, height from which the whirlybird is dropped, length of the wings, the length of the shaft, angle of the wings or blades, and weight of the whirlybird.

2. Have each group select one variable that it will investigate. Tell the students that they must conduct an experiment to find out how their variable affects the speed of the whirlybird. For example, groups that decide to study the length of the wings must keep the other variables constant. That is, when they build whirlybirds, they must be sure to keep the length of the shaft the same while they vary the length of the whirlybird wings. They will also need to consider the angle of the wings, the mass of the whirlybird, and the height from which the whirlybird is dropped.

Figure 1.9
Completed Whirlybird



3. Copy Figure 1.10 to use with the whirlybird activity. Students can use these strips to cut and make whirlybirds out of different materials (newspaper, construction paper, file folders). Each strip should be 2.5 cm 21.5 cm.

4. Have the Materials Manager pick up the necessary materials (scissors, whirlybird template [Figure 1.11], group mini-log). Give students time to build and test their whirlybird designs. Point out that they should have the Tracker use the group mini-log to record the team's ideas as well as to make illustrations of its whirlybirds.

5. Have the Materials Manager obtain a large piece of chart paper and markers. Tell students that they should create a poster report of their research. The poster should contain the results of their work and include (at a minimum) the following:

- The variable they investigated
- The method they used
- The data they collected
- The results they obtained—a statement explaining how the factor they studied affected the flight of a whirlybird
- Their whirlybird models
- The group mini-log

6. Give each team copies of the Whirlybird Assessment, located on the last page of the mini-log. Have a representative from each group present its poster to the class. When a

Figure 1.10
Whirlybird Template

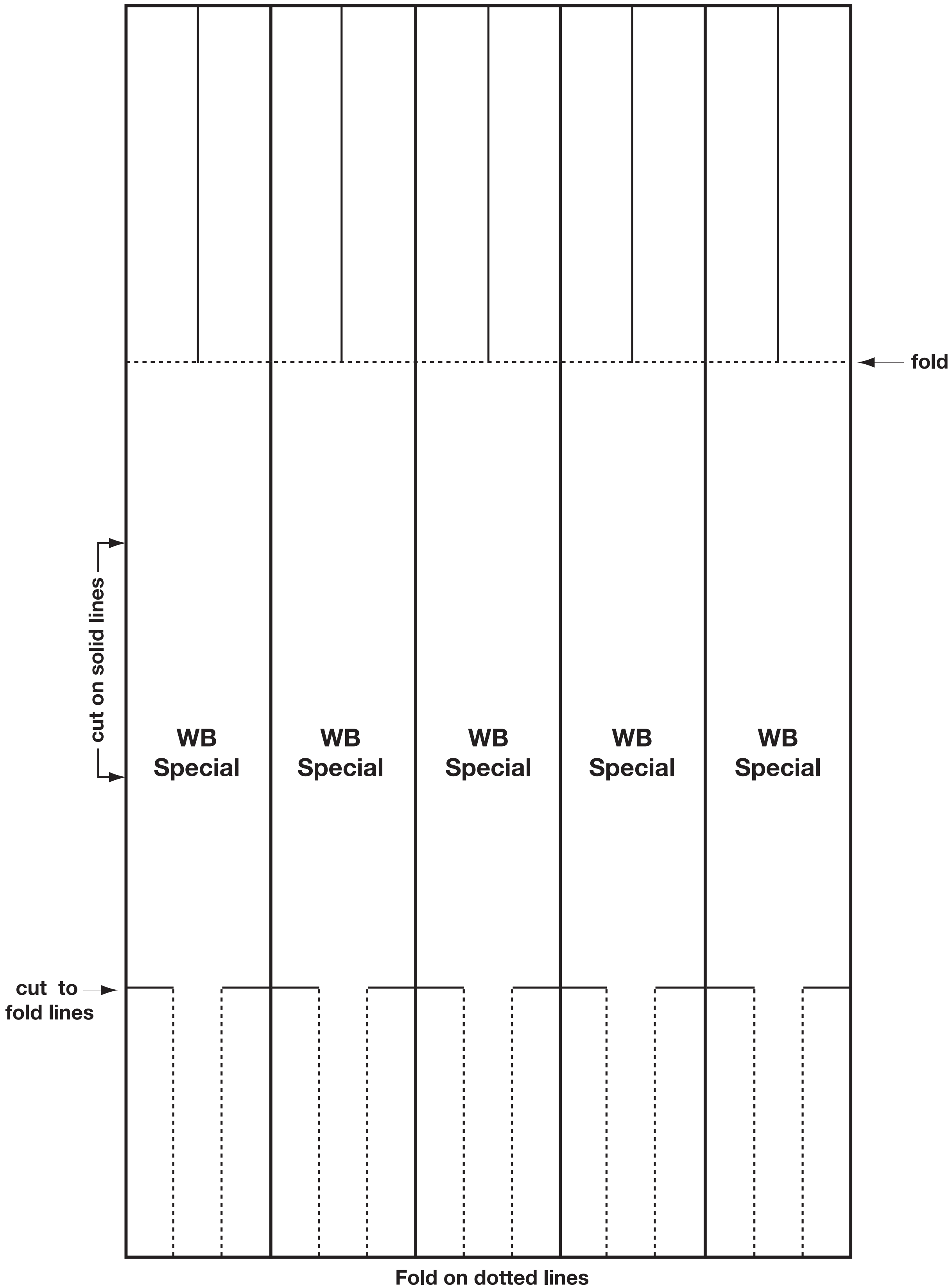
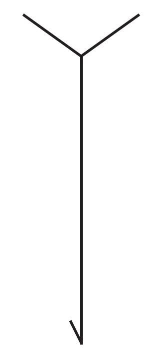


Figure 1.11
Whirlybird Group Mini-Log

THE WHIRLYBIRD PROJECT

GROUP MINI-LOG



Rubric 1

Response	Criteria	Rating
Outstanding	Showed expanded thinking and clear understanding of task; showed evidence of testing models and cooperative effort	4
Very good	Completed task, reached acceptable conclusions, completed models; cooperative effort in evidence	3
Satisfactory	Task nearly completed; conclusion incomplete	2
Fails to Complete	Could not communicate understanding of the task; attempted the task	1
No Attempt	No whirlybird was constructed; little cooperation in evidence	0

Rubric 2

Response	Criteria	Rating
Cooperative	To what extent did the group cooperate with each other to help solve the problem?	0 1 2 3 4
Content	To what extent is there evidence that the team understood the physics concepts in the task?	0 1 2 3 4
Completion	To what extent did the team use the allocated time wisely?	0 1 2 3 4

Rubric 3 Design Your Own

Figure 1.11
Whirlybird Group Mini-Log (continued)

Mini-record of your team's ideas, data, and exploration:

Illustration of your team's ideas:

Your team's hypothesis:

What abilities did your team use in this activity?

-
-
-
-
-

What criteria would you use to assess other students' progress on the whirlybird project?

-
-
-
-

Have your team assess itself as a group by using one of the rubrics on the last page of this log.

team completes its presentation, have the other teams use the assessment rubrics to evaluate the team's project. Collect these and, after looking them over, present them to the team. Hang the finished posters in the class for observation.

Numbered Heads Together Strategy

The Numbered Heads Together approach to co-operative learning can be used by students to complete a small-group activity, answer a question, or complete a hands-on task. It can be a powerful way to encourage student inquiry and problem solving. Here is how it works.

1. Have students number off into cooperative learning groups of four students each. Make sure students remember their numbers, as they will come into play later.

2. A demonstration, question, or task is posed. For example, show two identical balloons, one filled with helium and the other that you blew up. Release them. One falls to the floor, the other rises to the ceiling. Or ask: How are reptiles different from amphibians? Or present this hands-on task: Using a bag of shells, create a chart showing how your team would classify the shells.

3. Students then put their heads together. Teams work together for a specified period of time to brain-storm, answer the question, or complete the task.

4. When the time has elapsed, the teacher tells the students to take a half-minute to review their work so that each group member understands the groups' results. Let students know that numbers will be randomly called and that they will be expected to respond.

5. Call a random number. The student in each group whose number is called stands and responds for the group, goes to a designated area on a board and records the team's findings, or holds up a drawing or chart of the group's work.

LESSON PLAN: EGG IN THE JAR

Goal: To have students work together as a problem-solving team to answer questions, make predictions, and explain a phenomenon

Materials: White boards, marking pens, hard-boiled eggs, glass jars with mouths smaller than the cooked eggs, matches, four index cards numbered 1, 2, 3, and 4

Procedure:

1. Organize the students in cooperative groups with three or four team members. Have the students number off from 1 to 3 or 4. Tell them that you will use the numbers as a way to ask questions of team members.

2. Show the students a glass jar and a cooked egg that you have peeled. Place the egg in the mouth of the jar. Ask the students how they could get the egg in the jar without damaging or breaking the egg. Tell the students to put their heads together. Give each group two or three minutes to discuss their ideas. They should record them on the white board.

3. Present the four numbered index cards to the class. Have one student in the class draw one card. Read the number aloud. Ask the student in each group with this number to stand near his or her group. Go around the room and ask each standing student to tell one idea that his or her group thought would enable the egg to get in the jar. Record these on paper.

4. One way to get the egg in the jar is to light a match and drop it into the jar and then immediately put the egg over the mouth. The egg will slowly be pulled into the jar. If the students did not suggest this idea, present it to them and conduct the demonstration for the class.

5. After the demonstration, have the students put their heads together a second time. This time, they should draw a diagram showing the bottle and the egg, and use it to what they think causes the egg to go into the bottle. Give the students five minutes to do this. Encourage them to illustrate their diagram and be ready to share their explanations with others in the class.

6. Tell the students to make sure that everyone in their group understands the explanation that their team generated. Tell them that you will call on one student from each group by drawing one of the index cards. Draw the card, and have the student whose number was drawn do one of the following:

a. Stand near the group and briefly describe his or her team's explanation.
b. Go to another group in the class and sit with this group and explain their team's explanation. The group should ask questions, and share the idea that their team created.
c. Go to the board and briefly draw and write their team's explanation.

7. After the students have shared either by standing, visiting another group, or going to the board, discuss with the students the ideas that they generated to explain the egg in the bottle. What further questions do they have?

Round Table Strategy

In the Round Table approach to cooperative learning, each student completes an action and then passes on the responsibility for completing another action to a member of his or her group. Round Table is a good way to involve each and every student in a group activity because it gives students "permission" to participate; in so doing, it tends to increase low-ability student participation and reduce high-ability student domination.

Lesson Plan: Problem on the Way to Mars

Goals: To engage students in a problem-solving activity in which they practice the Round Table approach; to teach students how to take turns in a small-group activity; to solve a problem using group decision-making skills

Materials: Chart paper, markers, set of "Mooncards" (Figure 1.13), Mars Data Recording Sheet (Figure 1.15), NASA Scorecard (Figure 1.16)

Web site: http://www.nasa.gov/

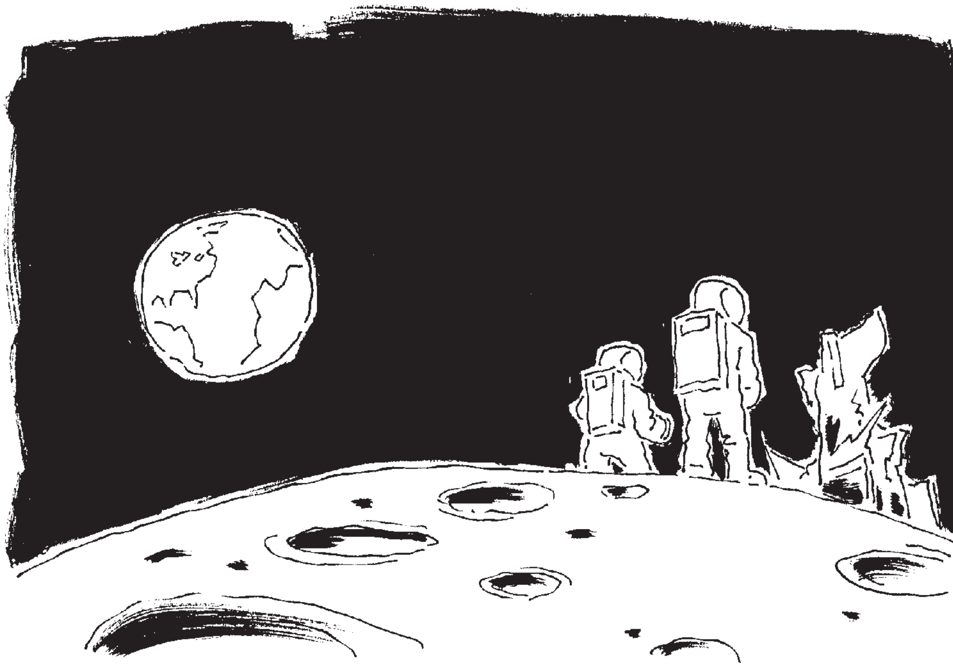
Procedure:
1. Read the following scenario to your class:

> You are members of an international space exploration team in the process of using a moonport in preparation for a human flight to the planet Mars. As astronauts, you frequently fly from a space station orbiting the moon to the surface of the moon, where the moonport is located. On your most recent flight to the moon, your space shuttle crashes to the moon's surface about 10 miles from the moonport (Figure 1.12). The rough landing ruins your shuttle and everything in it, except for the fifteen items you are about to see (Figure 1.13). Survival of your team depends on reaching the moonport as soon as possible. In order to do this, you must look over the fifteen items and rank them in order of importance from most important to least important, to getting back to the moonport.

2. Give each team an envelope containing the mooncards for the fifteen items and a sheet of chart paper with a line on it, labeled at one end "Most Important" and at the other end "Least Important," as in Figure 1.14.

After students in each group have numbered

Figure 1.12
Moon Scene



off from 1, tell the students to put the cards facedown on the table.

3. Astronaut 1 goes first by drawing a card from the deck and deciding where on the line the item should go. The decision as to the card's placement should be reached by group consensus. Astronaut 2 goes next by drawing a card, and so on. The process continues around the group until all cards have been drawn and placed on the line.

4. When all teams have completed the task, have one person in each group record the team's top five choices on a chart you have created on white posterboard or on a piece of chart paper. Meanwhile, give each team a copy of the Mars Data Recording Sheet (Figure 1.15) and the NASA Scorecard (Figure 1.16). Have teams score their work by recording their team ranks on the Data Recording Sheet, then comparing their results with those shown on the NASA Scorecard. Students can obtain a score by finding the difference between each of their ranks and those proposed by NASA.

5. Have teams discuss their rationale for the top five items, and discuss how their rationales compare with NASA's.

6. Going Further. Have students investigate the tMoon and Mars Exploration page at NASA: http://www.nasa.gov/topics/moonmars/index.html

Circle of Knowledge Structure

The structure of this approach to cooperative learning is like that of the Round Table, except that the task requires the Tracker to record data for the team. Circle of Knowledge requires turn-taking and serves as a powerful strategy for hands-on lab activities by ensuring that all
students participate. To help teams work more efficiently, you'll be distributing the Team Data Organizer, which is used by the Tracker to collect team observations, measurements, and inferences (or whatever type of information the students are collecting).

Figure 1.13
Mooncards

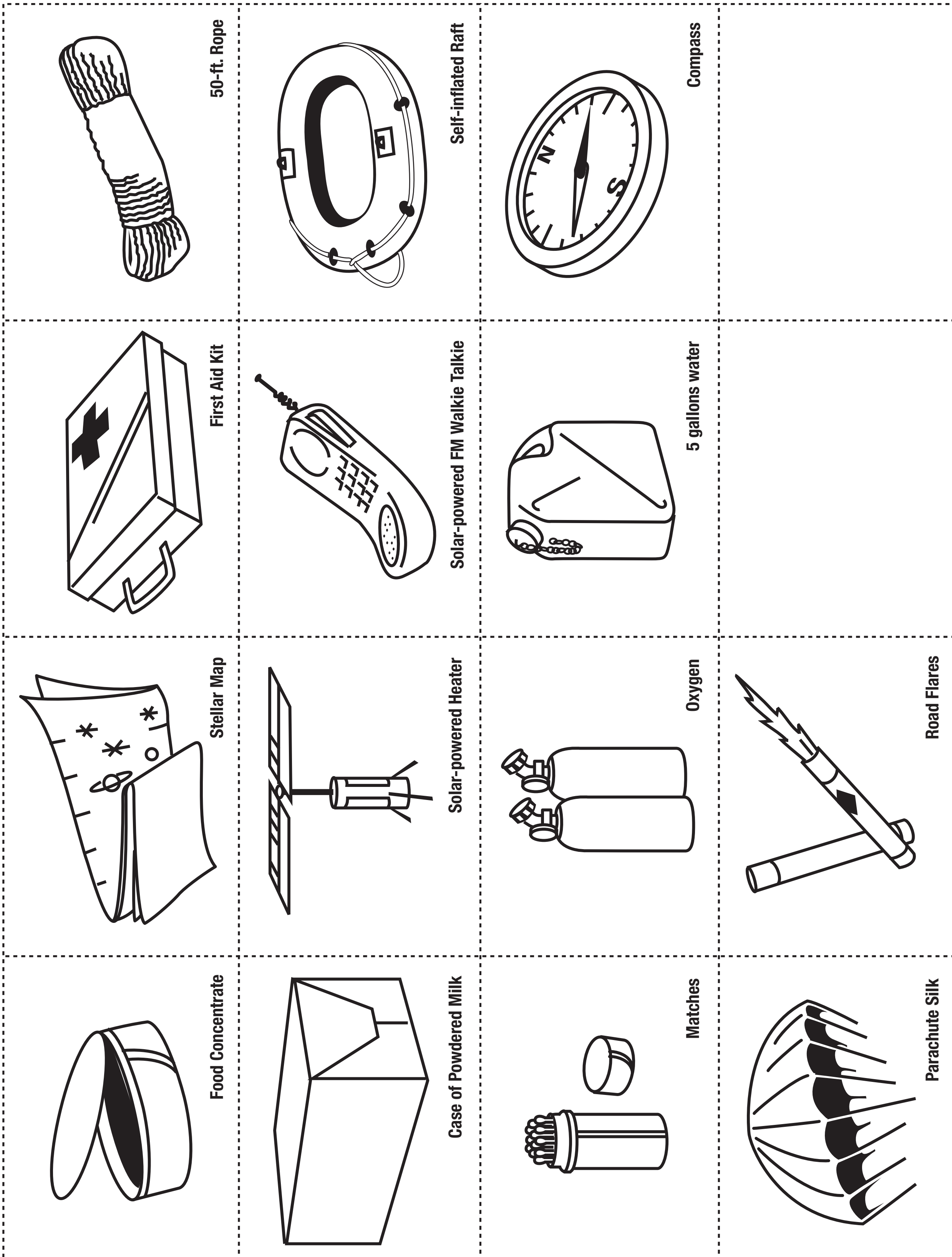


Figure 1.14
Arranging the Mooncards

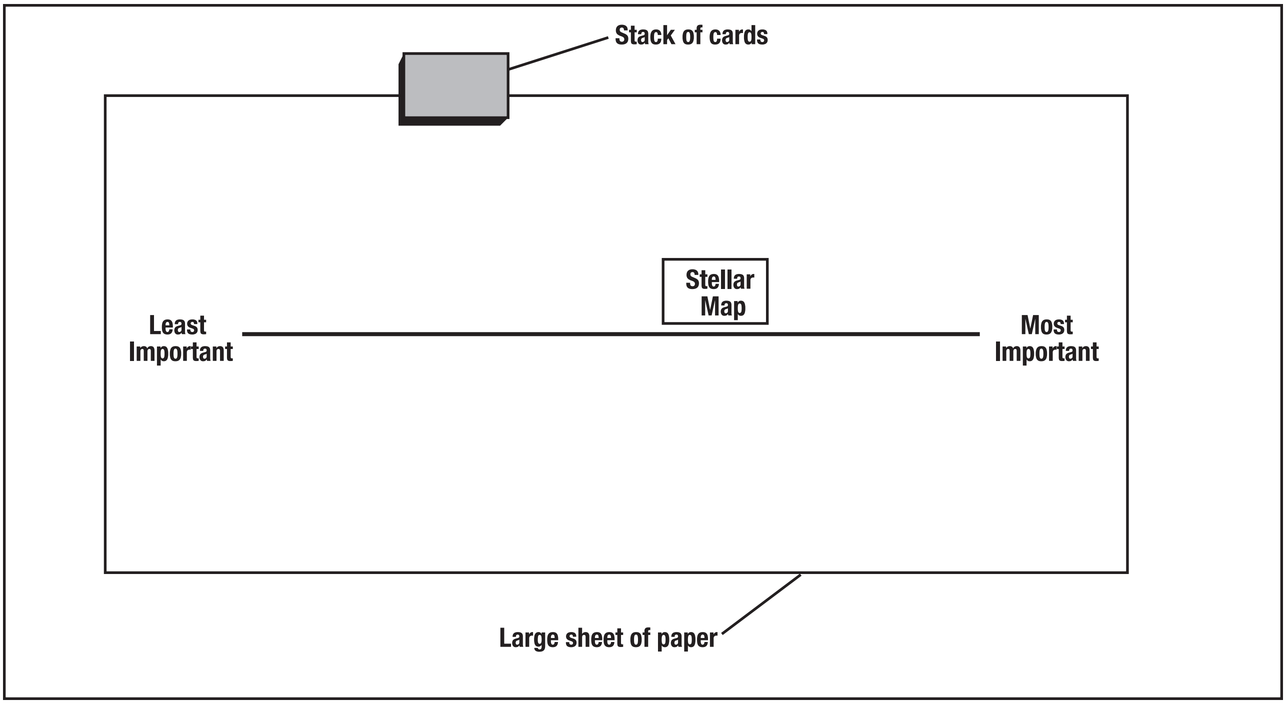


Figure 1.15 Mars Data Recording Sheet

PROBLEM ON THE WAY TO MARS

Item	NASA's Ranks	Your Ranks	Error Points	Group Ranks	Error Points
Box matches					
Food concentrate					
Fifty feet of nylon rope					
Parachute silk					
Solar-powered heater					
One case of powdered milk					
Two 100-pound tanks of oxygen					
Stellar map					
Self-inflating life raft					
Magnetic compass					
Five gallons of water in jug					
Signal flares					
First-aid kit					
Solar-powered FM walkie-talkie					
		Total			

Error points are the absolute difference between your ranks and NASA's.

Scoring for individuals:
0–25—excellent
26–32—good
33–45—average
46–55—fair
56–70—poor
71–112—very poor, suggests possible faking or use of Earth-bound logic

Figure 1.16 NASA Scorecard

Name	NASA's Reasoning	NASA's Ranks	Your Ranks	Error Points	Group Ranks	Error Points
Box matches	No oxygen on moon to sustain flame; virtually worthless	14				
Food concentrate	Efficient means of supplying energy requirements	4				
Fifty feet of nylon rope	Useful in scaling cliffs, tying injured together	6				
Parachute silk	Protection from sun's rays	8				
Solar-powered heater	Not needed unless on dark side	12				
One case of powdered milk	Bulkier duplication of food concentrate	11				
Two 100-pound tanks of oxygen	Most pressing survival need	1				
Stellar map of moon's constellations	Primary means of navigation	3				
Self-inflating life raft	CO_2 bottle in military raft may be used for propulsion	9				
Magnetic compass	Magnetic field on moon is not polarized; worthless for navigation	13				
Five gallons of water	Replacement for tremendous liquid loss on lighted side	2				
Signal flares	Distress signal when mother ship is sighted	10				
First-aid kit	Needles for vitamins, medicine, etc., will fit special aperture in NASA space suits	7				
Solar-powered FM walkie-talkie	For communication with mothership, but FM requires line-of-sight transmission and short ranges	5				

Lesson Plan: Mystery at the Ringgold[4] Roadcut

Goals: To introduce students to Circle of Knowledge as a method for collecting group data on fossils (or any object); to help students understand that fossils are remains of organisms that lived in the past and can be used to reconstruct the history of life on Earth; to make observations and inferences; to predict the nature of the environment at the time these now-fossilized organisms were alive

Materials: Fossil crinoid stems (Figure 1.17) (put four to eight each in a small plastic bag),[5] hand lens, metric ruler, geological time scale, copy of Team Data Organizer (Figure 1.18)

Procedure:

1. Divide students into cooperative teams and distribute the materials. Explain the task to the teams—namely, that the teams should collect information on the objects in front of them (do not tell students what the objects are). Point out that some of the information gathered will be in the form of observations about the objects, while the other information will be inferences students make based on their observations.

2. Explain that the Tracker collects data for the team. To begin, the Tracker asks each student, in order (from Student 1 to Student 4), to make and explain an observation. For example, it's brown; it's about 2 cm in diameter; it has grooves along the side; it's circular or cylindrical. The Tracker records each observation. Tell the Trackers to then go around again, asking each student for a second observation and recording it. To conclude, the Tracker asks each student to contribute an inference. For example, it is made of clay; it was once alive; it was a sea animal; it comes from the Earth's core. Again, the Tracker records each inference.

3. Circulate about the room and check on the groups, straightening out any problems you see developing. Notice that you can tell immediately from looking at the Team Data Organizer who is contributing and at what stage of the activity the group has arrived.

4. Have team members discuss the observations and inferences that were made. After a short discussion, have each team select what it thinks is the most important observation and inference, then record it on the data sheet. Collect this data and discuss the results.

5. Return the data sheets and let the groups know you will be presenting a series of questions that they should answer independently, using the Round Table method. Give the data sheet to Student 1. This person reads the question aloud, facilitates the discussion, and writes the answer on the data sheet. He or she then passes the sheet to Student 2, who repeats the process for question 2. This continues until each question has been answered. When all the teams are finished, go over each question using

[4] Ringgold is a small town located in Northwest Georgia in the folded Appalachian Mountains. During the early Paleozoic, this area was flooded with ocean water and was teeming with many varieties of marine life. Some of the remains of these living things were preserved as fossils. As one of my favorite fossil-hunting areas, I have used fossil remains as the main focus of this activity.

[5] Available from Two Guys Minerals & Fossils: http://www.twoguysfossils.com

Figure 1.17
Fossil crinoids. Students use the "circle of knowledge" structure to make observations and inferences.

the Numbered Heads Together approach. Read out the question, have a student draw a number from a deck of four cards, and ask students whose number was drawn to answer.

Questions:

- What kind of organism is this fossil? animal? plant? How do you know?
- How old do you think it is? Why?
- Of what kind of material is it composed?
- In what kind of environment did the organism live?

6. *Going Further*—Crinoid Task Cards. After students have completed their initial inquiry, they are ready for further activity. Distribute the Crinoid Task Cards (Figure 1.19), one to a group. Each task focuses on a different aspect of research. The tasks are summarized below:

Tasks 1a. & b. Students perform as scientists and refine their observations.
Task 2. Students perform as mathematicians, measuring all crinoids and graphing their results.
Task 3. Students perform as paleogeologists and try to imagine what the crinoids looked like when alive.
Task 4. Students perform as poets and write short poems about the crinoids.
Task 5. Students perform as artists and make crinoid pendants using craft materials.
Task 6. (Create your own.)
Task 7. (Create your own.)

Figure 1.18
Team Data Organizer

MYSTERY AT THE RINGGOLD ROADCUT

TEAM DATA ORGANIZER

	Student 1	Student 2	Student 3	Student 4	Student 5
Observation 1					
Observation 2					
Inference					

Observation:

Inference:

Analysis Questions

1

2

3

4

Figure 1.19
Crinoid Task Cards

TASK 1A

Your group is composed of scientists. Make as long a list of observations of the crinoid as your group can. When your group has completed the list, make a second list of inferences. Note: Be sure to write your list on a large sheet of chart paper; you can use more than words!

TASK 1B

Classify each of the observations your group made according to the human sense it used to make it—for example, F=feel; S=smell; E=eyesight; H=hearing; and O=other senses. How is your list of observations different from the list of inferences? What thinking skills did you use to make the observations? the inferences? How are the thinking skills you used for the observations different from those you used for the inferences? Which do you think is more important—observations or inferences? Why?

TASK 2

Your group is composed of mathematicians. Measure the diameter (in centimeters) of at least 20 crinoids. You will have to visit other groups in order to get a total of 20 measurements. Send out four members of your group to measure five crinoids each; have the remaining members measure your crinoids. Make a population graph of the crinoids you measured. Set up the graph to look like the one shown on this card.

Note 1: Draw your graph on a piece of chart paper. Make it large and colorful.

Note 2: Seek out another group that did this task. Compare your graphs. Are your populations different? How do you know?

GRAPH

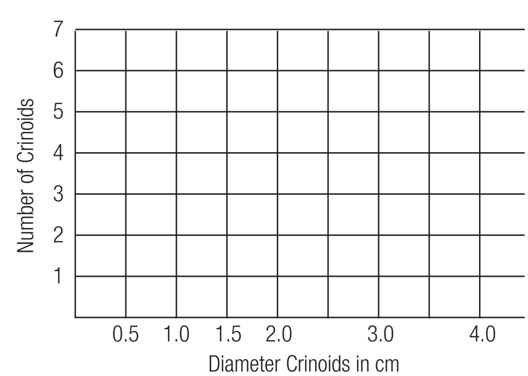


Figure 1.19
Crinoid Task Cards (continued)

TASK 3

Your group is composed of historians, anthropologists, and geologists. Use your imaginative side to draw a complete picture of what your team thinks the crinoid looks like. Remember, you are looking at only a piece of the animal. How do you think it looks as a complete creature? Does it have a head? Does it have feet? How does it move?

Note: When you draw your creature, place it in the context of an environment. Consider these questions: Where does this creature live? Does it live alone or are there others about? What does it eat? How does it get its food? What are its predators? its prey?

TASK 4

Your group is composed of writers… poets! Your task is to write several poems about the crinoid that your group will either publish or read aloud to your peers. Write several poems called Syntus, using the following formula:

Line 1: Single word or concept, such as fossil, crinoid, age, time, etc.

Line 2: An observation about line 1.

Line 3: An inference about line 1.

Line 4: A feeling or emotion about line 1.

Line 5: A synonym for line 1.

Note 1: Brainstorm as a group as many observations, inferences, and feelings about the crinoid as possible. Use the results of the brainstorming to create Syntus. Pair off and work on the poems together.

Note 2: Write your poems on sheets of chart paper. Make them colorful and easy to read from a distance.

Figure 1.19
Crinoid Task Cards (continued)

TASK 5

Your group is composed of artists. Your task is to make pendants using the crinoids, bell caps, gold or silver chain, and glue. After your group has made the pendants, show other groups how to do the same.

TASK 6

(Create your own.)

TASK 7

(Create your own.)

Think Aloud Pair Problem Solving

Thinking out loud about one's strategy for solving a problem can be an important aspect of learning. Think Aloud Pair Problem Solving is a cooperative learning strategy designed to help students acquire this skill. Students work in pairs. The teacher presents a problem in which Student 1 in the pair solves the problem by talking aloud, while Student 2 encourages and supports Student 1. Students alternate being "problem solver" and "encourager." Following are two lesson plans that make use of the Think Aloud strategy.

LESSON PLAN: FOREIGN LANGUAGE

Goal: To practice Think Aloud Problem Solving, which involves learning to talk aloud while thinking about a strategy for solving a problem and learning to listen and encourage

Materials: A sheet of paper with the following language problem printed on it:

> In a different language *luk eir lail* means "heavy little package," *bo lail* means "heavy man," and *luk jo* means "pretty package." How would you say "little man" in this language?[6]

Procedure:
1. Student 1 reads the problem out loud, then tries to solve the problem by talking aloud. Student 2 encourages Student 1. Encouragement does not mean giving away the answer; it does mean suggesting a method or telling one's partner to continue with a line of reasoning.

2. Discuss the results as a class. Ask a few students who were problem solvers to describe the method they used. Have the encouragers comment as well.

[6] This strategy and this problem is based on Whimbley and Lockhead, as cited in B. Pestel, 1992, "Teaching Problem Solving Without Modeling Through 'Think Aloud Pair Problem Solving,'" Science Education, 77 (1) 83–94.

Lesson Plan: Boston Harbor

Goal: To use the Think Aloud Problem Solving strategy to analyze an environmental science problem and suggest a solution to it.

Materials: A sheet of paper with the following language problem printed on it:

> I'm going to tell you a true story; it's sort of a mystery. It's about the Boston Harbor. In the last few years, people have noticed that there is something wrong with the water in the Harbor, but no one knows exactly what is wrong. Fishermen have noticed that there are fewer fish in the Harbor. And they have seen a lot more algae. People who spend time near the Harbor have noticed that the water looks dirty; it is brown and foamy. It also has garbage in it. Tin cans, paper, and old food float in the water. Sometimes you can even see dead fish floating on the waves. You are a famous scientist. The Mayor of Boston asks you to find out what is wrong with the water.[7]

Questions:

- What is the first thing you do?
- What do you think might be wrong with the water?
- How will you find out if you are right?
- Do you have any ideas about how you could make the water clean again?

Procedure:

1. Student 1 reads the problem out loud, then tries to solve the problem by talking aloud. Student 2 encourages Student 1. Encouragement does not mean giving away the answer; it does mean suggesting a method or telling one's partner to continue with a line of reasoning.

2. Discuss the results as a class. Ask a few students who were problem solvers to describe the method they used. Have the encouragers comment as well.

Jigsaw

Jigsaw is a cooperative learning strategy in which students become experts in some aspect of the material under investigation. By becoming an expert and then teaching other members of their team or working together with them to solve a problem, students become responsible for their own learning. The Jigsaw model has the advantage of encouraging students of all abilities to take equal responsibility for the subject matter; of course, the depth and quality of students' work may vary.

The overall strategy is depicted in Figure 1.20. Phase I of Jigsaw is to divide the content to be learned into chunks based on the number of students in each learning team. The sample lesson that follows divides the content into three sections—igneous, sedimentary, and metamorphic rocks. Thus each learning team will consist of three students. And each student will become an expert on one of the rock types.

In Phase II pairs of experts-to-be meet for about one class period to investigate and learn about the rock type to which they have been assigned. An expert sheet (see Figures 1.21, 1.22 and 1.23) guides their work. In addition, students receive hands-on materials and can consult a text. Students complete the expert sheet, perform the investigation, summarize their work, and prepare to return to their "home" team.

In Phase III the experts report back to their home teams. At this point, students do one of two things. They may give an informal report to the team, teaching their teammates about their "chunk" of content. (This can be viewed as direct teaching.) You may wish to provide the home team with a set of problems (see page 42) that the team must solve as a group. (In this case, the expertise of each team

[7] Figure 2, Problem 1: Boston Harbor from Appropriating Scientific Discourse: Findings from Language Minority Classrooms, Working Paper 1-92, January 1992 by Ann S. Rosebery, Beth Warren, and Faith R. Conant, p. 14. Reprinted by permission of TERC.

Figure 1.20
Jigsaw Strategy

JIGSAW II Robert Slavin (1978)

- Groups:
  - Expert groups are heterogeneous and made up of four to five students who represent a balance of academic ability, gender, and ethnicity.
  - Learning teams may be heterogeneous or homogeneous groups.
- Each student has a task which contributes to the group objectives.
- Student is a member of an expert group and a learning team.

Text & Learning Packets

- Teacher develops expert sheets and a quiz for each unit.
- Teacher divides the content into topics.
- Learning packets may contain:
  - Direction sheets
  - Should contain an outline of the topic in question form
  - Experiments
  - Manipulatives
  - Artifacts
  - Computer software

Expert Groups Talk

- Allow time for students to study and work on their topic before the expert groups meet.
- Each student works independently to learn a portion of the lesson.
- Experts teach their information to the group.
- Experts are responsible for learning what other group members share as well.

Team Report

- After experts have finished their work, they return to their learning team.
- During the team report students share what they've learned in expert groups with team members.
- Encourage a variety of teaching formats (please refer to chart).

Test

- After teams have finished their work, conduct a brief class discussion with convergent and divergent questions. Encourage experts to answer questions. Allow students to ask questions too for clarification.
- Administer quiz.

Team Recognition

Weekly Chart

Name	1	2	3	4	5	6	7	8
Bears								
Rocks								
Pulsars								
Yards								
Eagles								

- Establish a baseline score for each student. Decide on what minimum score each student must receive.
- Encourage academic performance. Identify several students who make improvement each week. Praise has a very positive effect on the way they perceive themselves & their achievements.

member is called on to help solve the problems.)

In Phase IV a test is given. It can be a written test or it can be more of a performance test, in which students have to apply what they have learned about the subject matter.

Phase V is a recognition and reward phase in which teams are presented a certificate for successful work.

Lesson Plan: Jigsaw Rocks

Purpose: To learn how to implement the Jigsaw learning strategy; to differentiate between igneous, sedimentary, and metamorphic rocks; to solve problems about rocks
Materials: Enough learning packets for pairs of students as follows:

Igneous Experts: granite, pumice, obsidian, basalt, hand lens, bottle of vinegar
Sedimentary Experts: sandstone, shale, conglomerate, limestone, any fossilized rock, hand lens, bottle of vinegar
Metamorphic Experts: gneiss, schist, slate, marble, hand lens, bottle of vinegar; also Expert Sheets (Figures 1.21, 1.22, and 1.23)

Procedure:
1. Divide the students into pairs based on the three expert areas. Student pairs should sit together on the same side of the table or push their desks together. Have one student obtain the set of materials (learning packet) for the pair. At the same time, the student should obtain an Expert Sheet for their team. Copy the expert sheets that are described below for the pair.

2. Students use the materials and work together as a pair to answer the questions on the Expert Sheet. They can also use references and the Internet to help complete the questions.

3. At the end of the allotted period, students return to their home teams. Give each team a Problem Sheet (Figure 1.24) that it must answer together as a team.

4. Discuss each problem one at a time by using the Numbered Heads Together strategy (see page 23).

5. Test students on their knowledge of rocks. You might use this approach: Give each student a rock (such as sandstone with fossils in it if possible, or granite), and a hand lens. Ask the students to write on a sheet of paper how they could make a rock from scratch that looked like the one that they have been given. Tell them to describe their procedures very carefully.

6. Design a certificate that you can present to each member of the class.

Summary

Cooperative learning is a key tool for facilitating inquiry in the science classroom. It's more than simply putting students into groups and asking them to complete a task. It involves making decisions that will lead to increased interdependence among team members so that their work together is greater than the individual efforts of team members. Creating teams that work together as a unit to solve problems not only can be a wonderful experience for your students, but also mirrors some of humanity's best efforts at working together to solve real problems.

Figure 1.21 Igneous Rock Expert Sheet

Rock	Color	Shape and Color of Crystals	Arrangement of Crystals (Even or Banded)	Effect of Vinegar (Acid)	Presence of Fossils	Use of the Rock
A						
B						
C						
D						

1. How were these rocks formed?
2. Under what environmental conditions were they formed?
3. Observe each rock and record your observations on the chart provided.
4. What, if any, minerals are contained in these rocks?
5. Where would you find these rocks?
6. Would you find these rocks in, on, or under your school grounds?
7. What can you tell from the size of the crystals: (a) rock cooled slowly, (b) rock cooled rapidly, or (c) rock cooled in water?
8. What is the difference between a rock that cooled above ground and one that cooled underground?
9. If you wanted to demonstrate how an igneous rock is formed, what would you do?
10. Do you think there are igneous rocks on other planets? Explain.

Figure 1.22 Sedimentary Rock Expert Sheet

Rock	Color	Shape and Color of Crystals	Arrangement of Crystals (Even or Banded)	Effect of Vinegar (Acid)	Presence of Fossils	Use of the Rock
A						
B						
C						
D						

1. How were these rocks formed?
2. Under what environmental conditions were they formed?
3. Observe each rock and record your observations on the chart provided.
4. What, if any, minerals are contained in these rocks?
5. Where would you find these rocks?
6. Would you find these rocks in, on, or under your school grounds?
7. Why might you expect to find fossils in sedimentary rocks?
8. Does shaking a jar of mixed-size sand and water, and observing the results demonstrate part of the sedimentary process? Explain by using a diagram and words.
9. Do you think there are sedimentary rocks on other planets? Explain.

Figure 1.23 Metamorphic Rock Expert Sheet

Rock	Color	Shape and Color of Crystals	Arrangement of Crystals (Even or Banded)	Effect of Vinegar (Acid)	Presence of Fossils	Use of the Rock
A						
B						
C						
D						

1. How were these rocks formed?
2. Under what environmental conditions were they formed?
3. Observe each rock and record your observations on the chart provided.
4. What, if any, minerals are contained in these rocks?
5. Where would you find these rocks?
6. Would you find these rocks in, on, or under your school grounds?
7. If you wanted to demonstrate how a metamorphic rock is formed, what would you do? Illustrate and explain.
8. Do you think there are metamorphic rocks on other planets? Explain.

Figure 1.24

Problem Sheet for Home Teams

1. Consider the following rocks: sandstone, granite, and marble. (a) Under what conditions is each formed? (b) Would they be found on other planets? (c) Where would you find these rocks in your state?

2. What are the differences among sedimentary, igneous, and metamorphic rocks?

3. Name some rocks that can be identified by an acid test. What does this tell you about the rock's composition?

4. Complete these sentences:

   a. Metamorphic rocks form when. . . .

   b. The southern part of our state contains rocks such as. . . .

   c. In a county next to ours, you'll find these rocks. . . .

   d. Fossils can be found in these rocks. . . .

Chapter 2 EEEPs: Exciting Examples of Everyday Phenomena

What Is an EEEP?

An EEEP is an exciting example of an everyday phenomenon. It is a science demonstration. It is an active learning tool designed to gain the attention and pique the curiosity of students. I coined the term several years ago after reading an article about the importance of linking science concepts to students' everyday experiences. Since that time, I have used EEEPs as a teaching tool in numerous classes and seminars. You'll find many examples of EEEPs—in the Earth, life, and physical sciences—later in this chapter. But first, let's look at the potential value of EEEPs in science teaching.

How Can EEEPs Enhance My Science Lessons?

Most of us would agree that science inquiry is an important goal of science teaching—or, put another way, that helping students inquire into questions, phenomena, and ideas is fundamental to the science curriculum. EEEPs are designed to help us meet this goal.

A good EEEP, first and foremost, creates a look of surprise and fosters an environment in which students might be heard to say such things as, "How did that happen?" or "What caused that?" or "My prediction wasn't even close to what happened!"

For this reason, EEEPs work especially well as the opener for a short cooperative learning activity. By combining them with one of the cooperative learning strategies presented in Chapter 1 (Numbered Heads Together, in the following example), an inquiry environment is established in the context of small cooperative groups. Figure 2.1 is one of my favorite EEEPs.

An EEEP Example: Where Did the Water Go?

Materials: A small bottle of waterlock, also called sodium polyacrylate (this white, powdery substance absorbs a lot of water)[1]; 3 large polystyrene foam cups (large coffee cups work well); a large box (that you will place upside-down on the desk on which you perform the EEEP); bottled water

Procedure:

1. Prior to students entering the classroom, pour about 1 teaspoon of waterlock into one of the large cups. Put the cups on the box (Figure 2.2). Now you are ready to begin.

2. Arrange students in groups of three or four. Tell the students that you are going to conduct an EEEP.

3. Open the bottled water and let the students know that you are going to pour some water into one of the cups. Take the cup containing

Figure 2.1
Sample EEEP Poster

EEEP Poster

- **Number off within each team**
- **Teacher presents the EEEP**
- **Students put their heads together to brainstorm, answer a question, or complete a task—so that everyone knows.**
- **Teacher randomly selects a number and then calls on students in each group having that number.**

[1] Order from Flinn Scientific: http://www.flinnsci.com

Figure 2.2
Where Did the Water Go?

the waterlock, and pour a small amount of water into it. Immediately put the cup back on the box, returning it to its original location.

4. Now, start moving the cups around on the top of the box. As you do so, tell the students to keep their eyes on the cup with the water in it. Move the cups so that you exchange their places one or two times.

5. Now ask students: "Where is the cup with the water?" As students point to a cup, take it and turn it over in front of them (but do not let them look up into the cup). Because the waterlock absorbs water quickly, even the cup with the water in it will appear to be empty when you turn it over. Continue turning the cups over until all three are shown to be empty.

6. Without any class discussion (this is important), tell the students that they have a problem, and the problem is: Where did the water go? Tell the students that they have three minutes to write down, as a group, as many different answers as there are people in their group. (I like to provide small white boards, one for each group, and a dry-erase marker for this activity.) When the three minutes are up, tell the students to take another thirty seconds to review their work and to make sure that everyone in the group knows all of the answers their team generated.

7. Now you are ready to call on students. Do so using the Numbered Heads Together technique. Have the students number off within each group from 1. Then have one student in the class draw a card from a deck of cards numbered the same way. Tell the students that if their number is drawn, they should stand and be ready to represent their group, providing one explanation for the big question (Where did the water go?).

8. Move around the room quickly, asking one student at a time to give one answer. Jot down student replies. When all the students have provided answers, write their replies on chart paper for all to see. You might ask for further opinions at this time.

9. Finally, ask one student to come up to the box holding the large cups. Let the student turn over each cup, one at a time, noting the contents. A look of surprise and delight will emerge when he or she inspects the cup with the mush in it (the water has turned the powder to a gel).

SIDEBAR 2.1

Typical Answers

- It evaporated.
- There was a third cup.
- Something absorbed the water.
- A small bug drank the water.
- There was a hole in the cup.
- It went down your sleeve.
- It's a trick!

When Should I Use EEEPs?

There are a number of situations in science teaching in which you might want to use EEEPs. Here are a few:

- As an introduction to a new chapter or unit of teaching. An EEEP is a wonderful way to begin something new. It helps establish interest and gives the students some idea of what is to come. If you use EEEPs this way, you won't need to use too many more during the course of a year.
- As a pre-assessment activity to ascertain students' prior knowledge. This is a really good use of EEEPs. It lets students hear each other's views, and lets you hear what ideas they bring to the topic.
- As a test of students' ability to:
  - Predict
  - Brainstorm alternative ideas
  - Make observations
  - Hypothesize
  - Work cooperatively
- As a performance assessment

Using the EEEP Activity Sheet

A specially designed (generic) EEEP Activity Sheet (Figure 2.3) helps students consolidate their ideas. Distribute one EEEP sheet to each group. Here, students can make predictions, record their observations, think visually by drawing pictures of their explanations, summarize their findings, and jot down any questions they may have. If you choose, collect the sheets and assess them using the categories on the form as a rubric. They become a powerful learning tool linking instruction and assessment.

Earth Science EEEPs

A Cool Experiment

Wrap a piece of wet cotton around the bulb of one thermometer. Hold another thermometer (with nothing on the bulb) next to the wet-bulb thermometer. Fan both thermometers with a piece of cardboard until there is no further change in their readings. Invite students to explain why the thermometer with the cotton on the bulb has a lower reading than the one without. *Concepts:* evaporation, heat, relative humidity.

Water Evaporation

Pour equal amounts of water into a shallow dish and a test tube. Set the dish and the test tube next to one another and have students observe over a period of several days. Invite students to explain why the water in the dish evaporated faster than the water in the test tube. *Concepts:* surface area, evaporation, heat.

Hot Water Freeze

Put equal amounts of water (about 500 mL) in two metal canisters (labeled 1 and 2). Heat the water in canister 1 to a temperature of about 70 °C. Put both canisters in a refrigerator, and have the students monitor them for the next several hours. Invite students to explain why the water in canister 1 froze before the water in canister 2. *Concepts:* molecular motion, heat energy, freezing point.

Figure 2.3

EEEP Activity Sheet

Exciting Examples of Everyday Phenomena

Prediction: What do you think will happen?

Observations and Data: What did you observe?

Explanation of the EEEP

Explain Your Idea in Words

Illustrate Your Idea

Further Questions

Team Sign-off

The Punctured Can
Puncture three holes at different heights in an empty large juice can or a 2-liter plastic bottle. Set the container in a large pan. Cover each hole with a piece of plastic tape. Now fill the container with water. Ask the students to predict what will happen when the plastic tape is removed from each hole. Students should be encouraged to draw a diagram illustrating their predictions. Now remove the pieces of tape very quickly, one at a time, and have the students observe. Invite students to explain why the water coming from the hole at the bottom of the can streamed out further than the one near the top, comparing their predictions to what they actually observed. *Concepts:* pressure, water pressure.

The Foggy Cloud
Fill a flask with hot water. Pour out most of the water, leaving about an inch of it at the bottom. Sit the bottle in bright light. Hold an ice cube over the opening. Ask students to predict what they think will happen. After water vapor becomes visible, invite students to explain what happened. Some questions: Where did the water vapor come from? What cooled the water vapor? What is water vapor? *Concepts:* evaporation, condensation, cloud.

Breaking Rocks
Show students several pieces of sandstone that you have soaked in water overnight. Tell the students you are going to do something to the rocks before the next class. That night, put the rocks in resealable plastic bags and place them in the freezer. Show the bagged rocks to the students the next day. Invite them to explain what you might have done to cause the change in the rocks. Can they explain why some of the rocks have cracked? Have them make diagrams showing how they think the change may have occurred. *Concepts:* physical weathering, expansion, freezing.

The Mini-Telescope
Show students two lenses (hand lenses will work just fine) (Figure 2.4). Invite students to

Figure 2.4
Mini-telescope: two lenses, one held near your eye, the other at arm's length

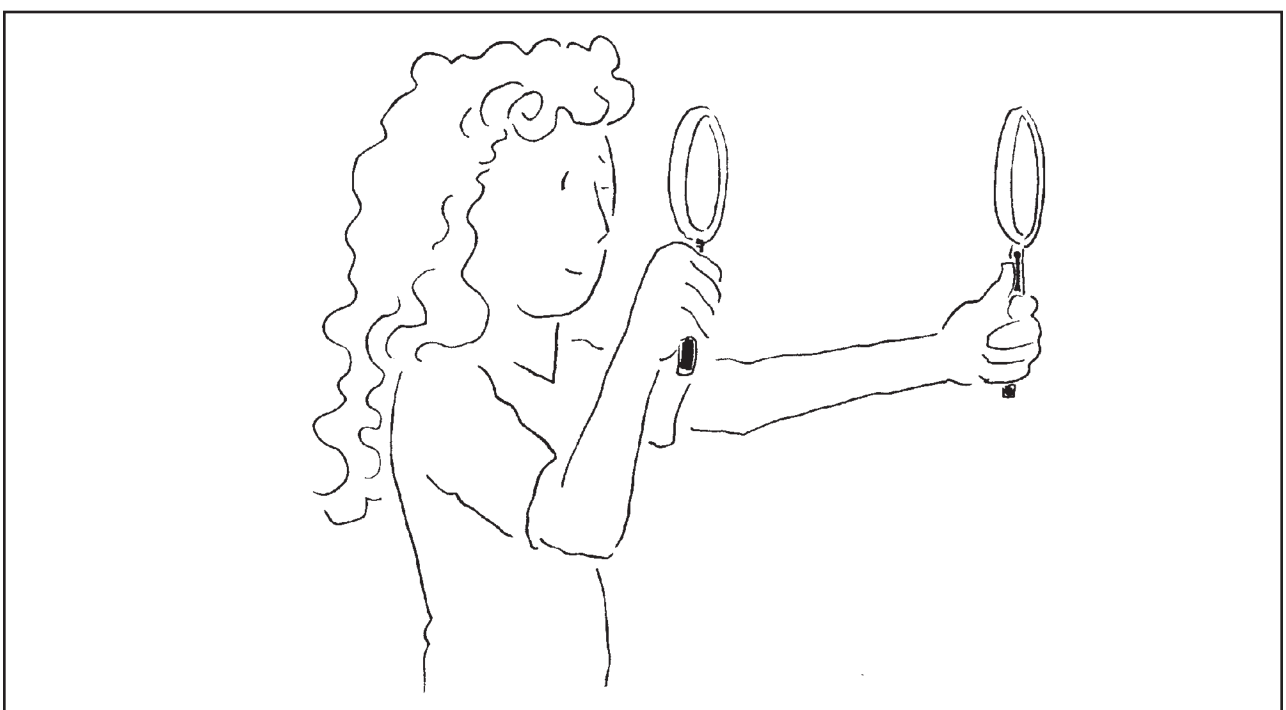
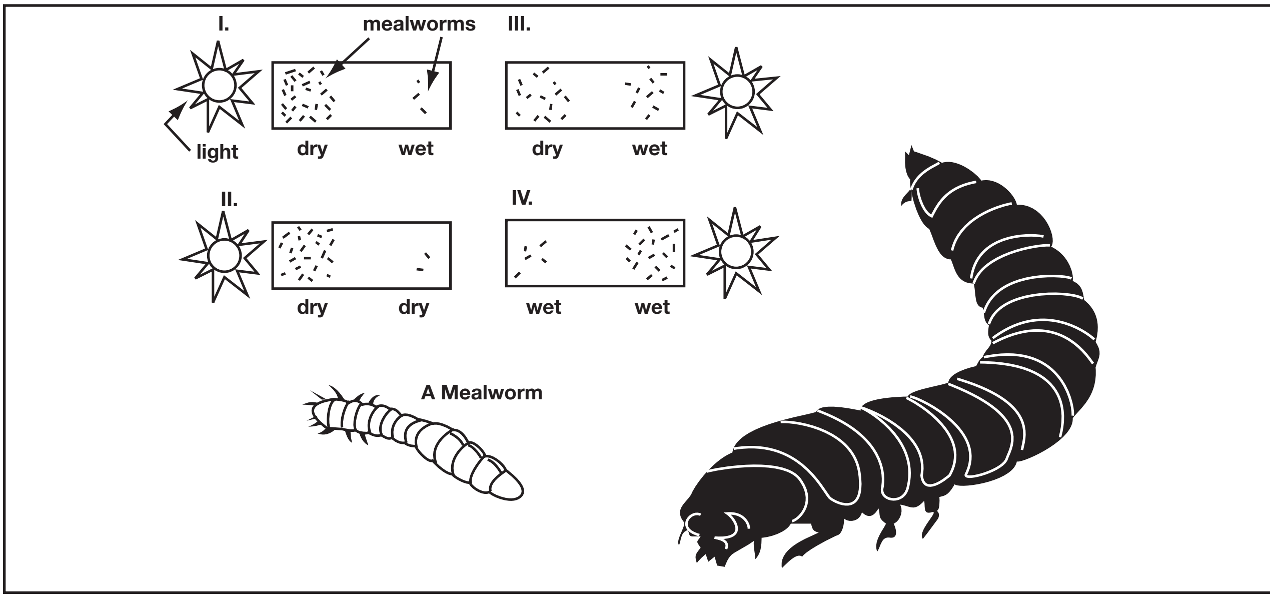


Figure 2.5
The Case of the Mealworms



use the lenses in combination to enable them to see a distant object (a picture or chart on a wall of the classroom, for example). The first challenge is for students to figure out how to hold the lenses in relationship to each other. (Hint: Hold one lens up to one of your eyes; hold the other lens at arm's length out in front of the first lens. Move the lens at arm's length toward and away from the "eyepiece" until objects are focused.) The second challenge is for students to explain why the image they see is upside-down. Invite them to illustrate their explanation of this phenomenon. *Concepts:* refracting telescope, magnification, image.

Life Science EEEPs

Earthworm Investigation

Show students a few earthworms. Invite students to speculate on the interaction of earthworms and changing environmental conditions (e.g., light, temperature, smell, gravity, sound, etc.). Have them formulate their ideas in the form of "If . . . , then . . ." questions. Then have students design simple investigations to answer their questions. *Concepts:* animal behavior, reflexes.

Gravity and Plant Growth

In preparation for this EEEP, begin growing plants in various situations—for example, in a pot on its side, in a pot hanging upside-down, and so on. When the plants have taken hold, show them to students. Invite students to speculate on the relationship between plant growth and the force of gravity. Does gravity affect plant growth? Have students talk about designing an experiment to answer this question. *Concepts:* experimental design, factors affecting plant growth.

The Case of the Mealworms

Show students the diagram of the mealworms (Figure 2.5) As you do so, read them this scenario:

An experimenter wanted to test the response of mealworms to light and moisture. To do this, she set up four boxes as shown here. She used lamps for light sources and constantly watered pieces of paper in the boxes for moisture. In the center of each box she placed twenty mealworms. One day she returned to count the number of mealworms that had crawled to the different ends of the boxes.

Invite students to consider the following proposal: The diagrams show that mealworms respond to (respond to means "to move away or toward"): (a) light but not moisture; (b) moisture but not light; (c) both light and moisture; or (d) neither light nor moisture. Please explain your choice.

Have students work in groups of two, but have them write their responses in their own science log. Here is one student's response: "Boxes I and II show they prefer dry and light to wet and dark. Box IV eliminates dryness as a factor, so they do respond to light only. Box III shows that wetness cancels the effect of the light, so it seems they prefer dry. It would be clearer if one of the boxes were wet-dry with no light."
Concepts: animal responses to environment, reflexes.

Physical Science EEEPs

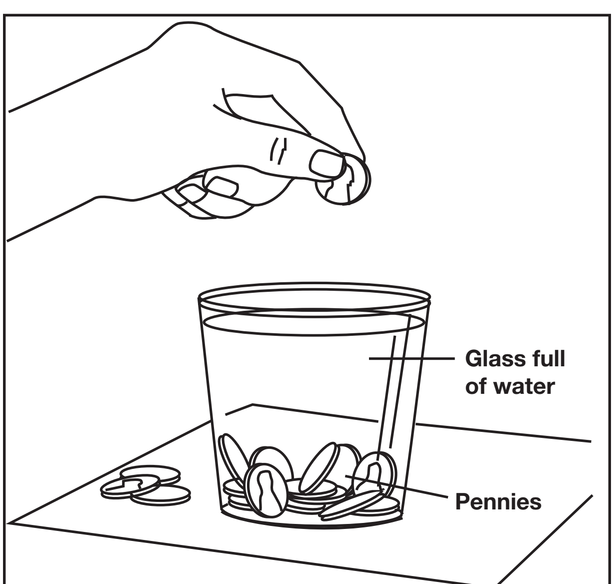
The Penny and a Glass of Water

Present a full glass of water to the class. Ask them to predict how many pennies can be dropped, if done carefully, into the full glass of water without causing it to overflow. Note students' predictions. (If you want to take some extra time, have teams of students work together to talk through their predictions.) In full view, begin dropping one penny at a time into the glass of water (Figure 2.6).

(NOTE: If you hold the penny so that it slides into the water vertically, as opposed to on one of its flat sides, then you should be able to drop between 20 and 50 pennies into a full glass of water.) Invite students to work in small teams to illustrate and describe in their own words what happened on an EEEP Activity Sheet. Figure 2.7 is a sample activity sheet of a student who might have participated in this EEEP.
Concepts: surface tension, properties of water.

The sample EEEP activity sheet is based on "The Penny and a Glass of Water" EEEP that was performed in Alma James's high school science class at the Benjamin Mays High School, Atlanta, Georgia.

Figure 2.6
The Penny and a Glass of Water



Electric Balloons

You'll need a few balloons, some string, and a piece of wool for this EEEP. Inflate two balloons and tie about 50 cm of string to each. Rub one balloon briskly against a piece of wool fabric. Bring the balloon up to a wall in the room and let go. The balloon should stick to the wall. Now, take the second balloon and rub it briskly with the piece of wool. Hold the second balloon close to the first balloon. The balloons should move apart from each other. Have students work in teams to explain both demonstrations. Give each team an EEEP Activity Sheet. On it, students can draw diagrams and use words to help express their ideas.
Concepts: static electricity, charged particles.

Why Does the Water Rise?

Stand a candle (use clay for support) in a pan of water. Light the candle, and then place a small glass jar over the candle (Figure 2.8). The flame will go out very soon after the jar is

Figure 2.7
Sample EEEP Activity Sheet

Prediction: What Do You Think Will Happen?

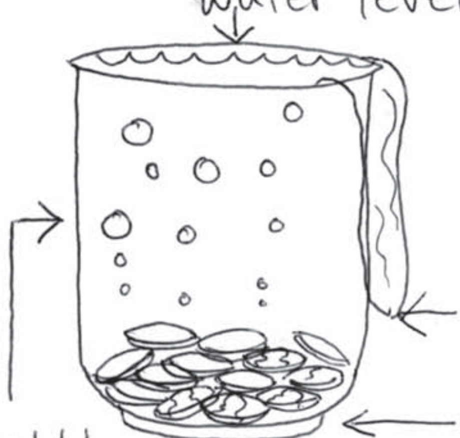
We think that the glass of water will hold 5 pennies.

Observation: What Did You Observe?

After 30 pennies, the water overflowed.

Explanation of the EEEP

Drawing (Visual Pictural)



Team Explanation (words)

We think the weight of the pennies Caused the water to rise.

Team Sign Off

Andrew
Carlos
Melissa
Melinda

Figure 2.8
Why Does the Water Rise?

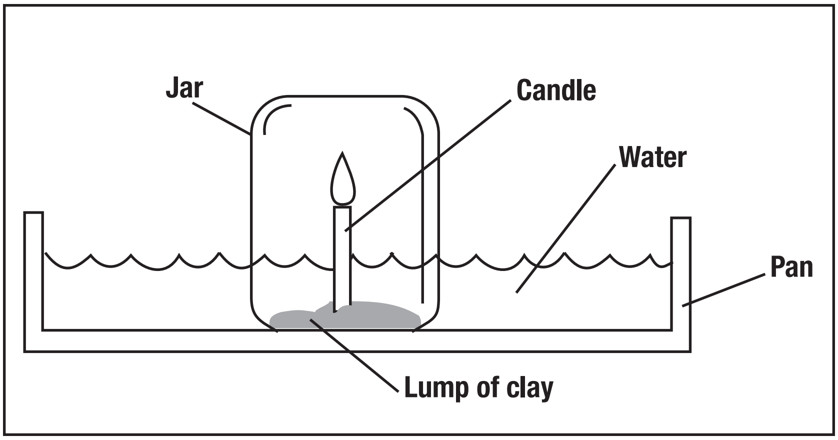
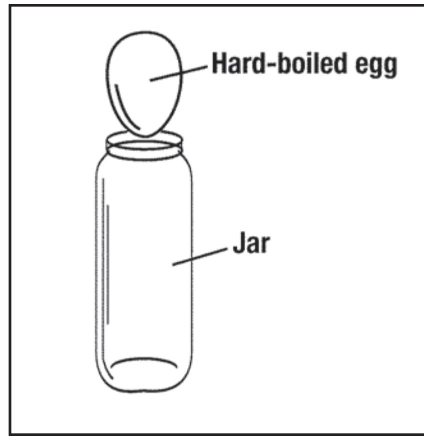


Figure 2.9
The Egg in the Bottle



introduced, and the water will rise into the jar. Invite students to develop explanations that will answer the following two questions: (1) Why did the flame go out? (2) Why did the water rise? *Concepts:* heat, air pressure, molecular model of matter.

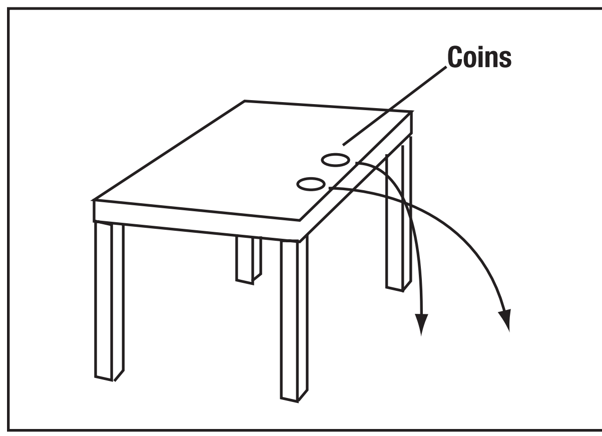
The Egg and the Bottle

Have plenty of hard-boiled eggs on hand for this activity, along with several glass bottles or jugs and matches. Place a peeled hard-boiled egg in the mouth of a bottle (Figure 2.9) and present students with the following problem: How can you get the peeled hard-boiled egg in the bottle without touching the egg? Have students work in teams and propose a methodology for solving the problem. Each team should present you with written details of the proposed procedure before going ahead. Once students have a methodology, they can obtain the material to test out their idea. *Concepts:* air pressure, molecular model of matter.

Fill the Beaker!

Provide students with rubber tubing, a syringe, a beaker, and a pan of water. Tell them to invert the beaker in the pan of water. Challenge them to find a way to fill the beaker with water while leaving it in that position.

Figure 2.10
The Coin Drop and Throw



Have students talk through possible methods. When they have an idea constructed, tell them they can go ahead and test their method. NOTE: Students will discover that removing air, not trying to force water in, will help! *Concepts:* air pressure, molecular model of matter.

The Coin Drop and Throw

Place one coin (a quarter) on the edge of a table; hold another quarter in your hand at the edge of the table. Tell students that, at the same instant, you will flick the coin on the table outward horizontally with your finger while you drop the other coin straight down (Figure 2.10). Invite students to speculate on which coin will hit the floor first. After groups of students come up with their ideas, provide coins for students' use in testing their ideas. Invite students to explain the result. NOTE: In most cases, both coins will hit the floor at the same time. *Concepts:* gravity, Newton's laws of motion.

SUMMARY

EEEPs are science inquiry experiences in which teams of students work together to solve a problem that you have presented. EEEPs from Earth, life, and physical science have been presented in the chapter. An effective EEEP will be one that fosters student inquiry and teamwork. As you try them, think about the many demonstrations that you currently are using, and modify them to reflect the EEEP strategy. How can you use the method presented here to engage your students in inquiry?

There are many sources of EEEPs that you can use to engage your students in inquiry science. Here are some that you might want to visit:
Things to make and do from Exploratorium: http://www.exploratorium.edu/explore/
Lawrence Hall of Science: http://lawrencehallofscience.org/
Zoom Science from PBS: http://pbskids.org/zoom/activities/sci/a

CHAPTER 3 FUZZY SITUATIONS

Oftentimes, science teachers ask students to use their writing skills to answer an essay question about a specific concept in science, at which point students generally slip into a tried-and-true format for answering the question:[1]

- State the question.
- State the answer.
- Give a few explanations or supporting points.
- Summarize the answer.

For this reason, the essay question can become a decidedly tunnel-visioned endeavor. One answer is being sought. The student regurgitates the information presented in class or in the text in direct response to the question.

Writing in science can be more imaginative and constructive than this. Research has shown that creative writing in a subject area can build a sense of discovery, a yearning for explanation, and a need to conceptualize in order to verbally "paint the picture."

What Is a Fuzzy Situation?

Fuzzy situations are stories and scenarios that allow teachers of science to tap into the creative thinking abilities of their students, as well as probe their content knowledge and conceptual understanding. Fuzzy situations dare characterized in the following ways:

- They are told in story form.
- They contain a minimum of facts—the only facts given are the ones needed to set the stage for the story; details are fuzzy.
- There can be as many answers as there are students who answer the fuzzy situation.
- They require a prediction; the student must respond to the fuzzy situation by continuing the storyline and predicting an outcome.
- They ask students to defend their prediction by linking the creative answer they design to facts and terminology from the subject content underlying the situation.
- They address situations in which the self and society are linked to science and technology such that the student can construct a concept of the subject content under study based on personal understanding of the interface of science and society.

Fuzzy situations can take many forms. They may appear in the form of a question, a challenge, a letter to a member of a hypothetical committee, a real or hypothetical activity, or even a news bulletin (Figure 3.1).

Using Fuzzy Situations

Fuzzies lend themselves to many instructional uses in the classroom. Following are four distinct ways to employ them.

Assessing Prior Knowledge

Use fuzzies at the beginning of a unit to assess prior knowledge of a subject area. With a fuzzy, students are engaged in a creative writing assignment centered on the content area, but without the pressure to deliver the "correct" answer. In this manner, students are free to describe their concept of the situation, define terms, and offer their thoughts on the subject. The resulting fuzzy situation answer is authentic, original, conceptual, and delineated by the student's prior knowledge.

From the answer, teachers can determine the depth of students' knowledge, how they conceptualize the topic, what terms they can define, how they associate ideas, how they process and describe scientific explanations, and how they perceive the interface of science and society. The prior knowledge assessment aspect of fuzzies makes them a powerful tool for teachers. Knowledge of "where students are" can assist the teacher in developing lesson plans that will

1 Introductory material prepared by Dr. Nydia Hanna, Assistant Professor of Science Education, Georgia State University. Used with permission.

be appropriate, effective, and challenging.

Ongoing Challenge

Try using a fuzzy situation as an ongoing project, a challenge to be met as the unit progresses. Typically, students identify their initial predictions and then adjust or alter them according to new knowledge they are constructing in the classroom. The ongoing fuzzy project thus documents learning and showcases conceptual construction. Students may keep a "Fuzzy Log" of their thoughts and ideas about their prediction.

By using fuzzies as ongoing projects, teachers foster an understanding of the scientific process of collecting data, the construction of knowledge, the reality of science and society interactions, and the power of prediction. Students' "Fuzzy Logs" will be evidence of their learning.

Assessment

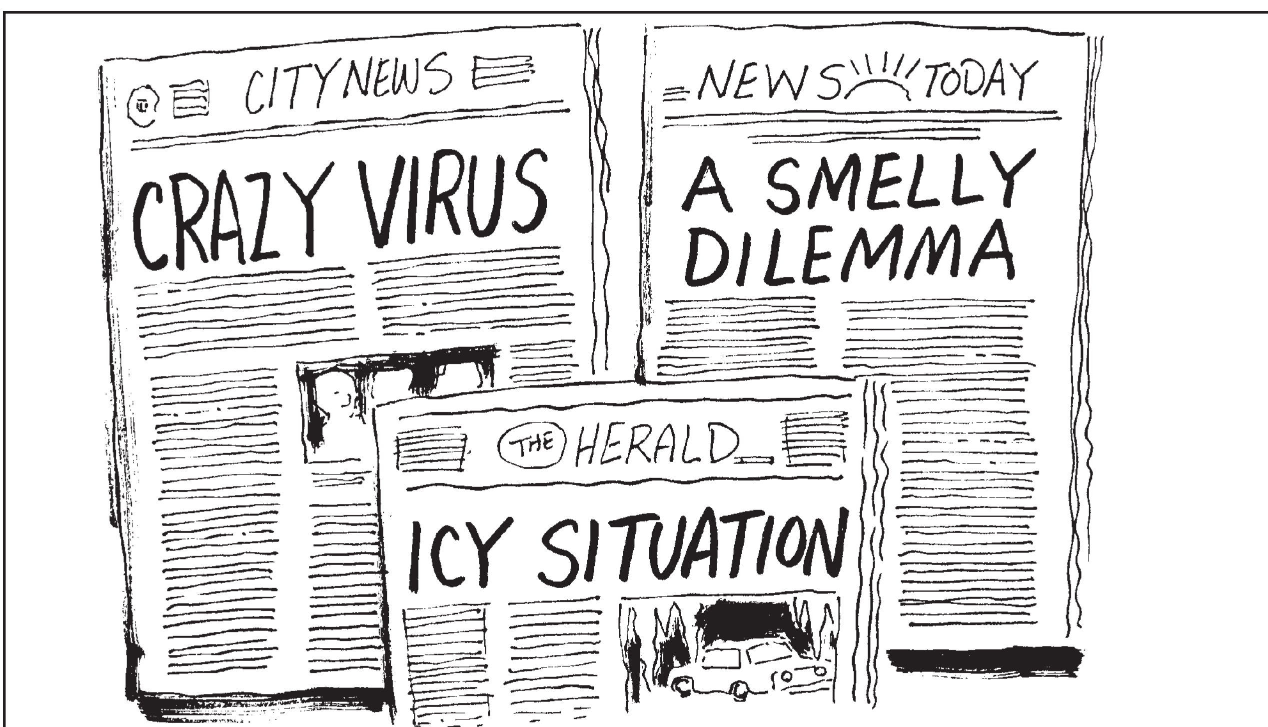
A fuzzy situation also lends itself to a formative or summative assessment. The fuzzy story may be carefully written so as to incorporate all topics covered in the unit. The students make their (unique) predictions and then back them up with the knowledge they have constructed throughout the unit. You may wish to share with students criteria for a successful fuzzy response. This helps to ensure a higher caliber of student response and to clarify your expectations. Criteria may include specifics or broader concepts.

Fuzzy situations used as assessments require assessment tools that examine the depth, breadth, and creativity of the response. This type of assessment can be achieved by using a rubric. Figure 3.2 is an example of a rubric you may want to use to assess fuzzy situations. See Chapter 8 for information about formative & summative assessments.

Taking Action on Social Issues

Use fuzzy situations to empower students to

Figure 3.1
Fuzzy Situation Headlines



take action on a science/technology/society (STS) issue. As the initial or culminating experience in a unit, a fuzzy situation provides opportunities for students to brainstorm possible solutions for or resolutions of societal issues that require scientific understanding. Students might, for example, propose actions to be implemented in their school or community.

In this application, the fuzzy situation becomes a tool used by the teacher to open a window between the classroom and the outside world. It functions as a catalyst, converting theory and book knowledge into practice. You will find that most of the fuzzy situations included below will require students to make scientific and social decisions.

Putting Fuzzy Situations into Action

A fuzzy situation can serve as a tool to facilitate student writing if students are directed to participate in Internet-based discussions or to keep a journal or log of their thinking. Writing-to-learn, a strategy researched by Professor Carolyn Keys [2],helps students construct ideas through writing. In Keys's research, students are encouraged to write their personal views of the laboratory (or, in this case, the Fuzzy Situation) in a journal or on a structured form. Then, working in small groups, students share their thinking and use these sessions to refine their ideas. A Fuzzy

[2] *Keys, Carolyn W.; Hand, Brian; Prain, Vaughn; and Collins, Susan. Using the Science Writing Heuristic as a Tool for Learning from Laboratory Investigations in Secondary Science, Journal of Research in Science Teaching, Vol. 36, No. 10, pp. 1065–1084 (1999).*

Figure 3.2 Rubric

Criteria	Possible Points	Points
Identified social relevance in one area of impact	1	
Identified social relevance in two areas of impact	2	
Identified social relevance in three or more areas of impact	3	
Predicted/discussed pros and cons of one outcome	1	
Predicted/discussed pros and cons of two outcomes	2	
Predicted/discussed pros and cons of three or more outcomes	3	
Creativity	1–3	
Level of logical progression	1–3	
Level and accuracy of science facts to support the positions stated	1–3	
Application to disciplines other than science	2	
Clarity of expression	1	
Suggested action to take	2	
Total	20–26	

Situation can be presented in class, and then students can work alone for a few minutes before coming together as a team to discuss what they wrote.

Another way to implement Fuzzy Situations is by means of an online or Internet discussion. For this you will need to have a Website accessible to all of your students. You can use a blog, a wikispace, or any one of a number of tools such as Google Docs or Zoho Works. Please see Chapter 6 for details on these tools. In each of these cases, your students will be able to post their ideas on the Web, visible to other students, and students can respond to each others' posts. If you make this a homework assignment, discuss the students' responses the next day in class.

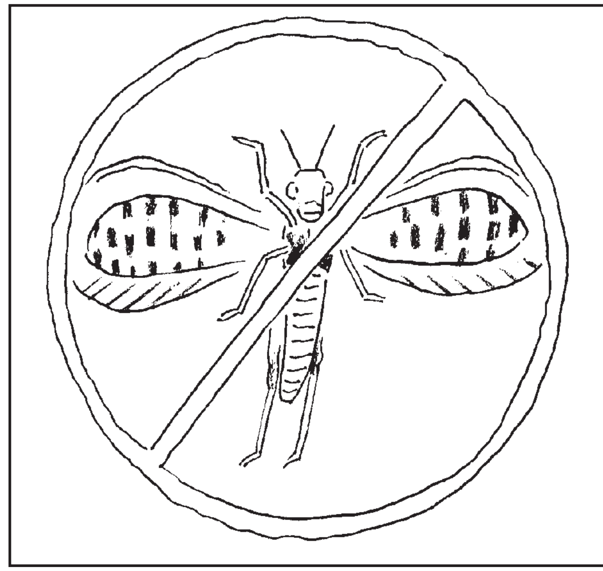
In either method, in class or online, reading the Fuzzy Situation, writing about the Fuzzy, and discussing the Fuzzy are important steps in inquiring into each of the cases that you present them. There are many to choose from in the content areas of Earth science, environmental science, life science, and physical science.

LIFE SCIENCE FUZZIES

No Insects[3]

Wheat and barley farmers in the United States have been experiencing crop failure due to an overpopulation of hungry locusts. Concurrently, scientists from a private European firm have been working on an experimental pesticide that they believe will have the power to eliminate entire populations of locusts and other insect pests. The farmers are desperate to save their crops, so they talk the reluctant scientists into allowing their farms to be the first testing grounds for the experimental pesticide. The European firm prepares the pesticide to be shipped overseas by air. Unfortunately, the plane never reaches the United States. The plane mysteriously explodes mid-flight, releasing all of the pesticide into the atmosphere and contaminating the whole planet. It seems the scientists from the European firm were not aware of how powerful their pesticide was—it not only killed the locusts of the world, but every other insect as well (Figure 3.3).

Figure 3.3
No Insects



- How will the world be different without insects?
- How great an impact do insects have on the day-to-day functioning of the Earth?
- Should the farmers have used the experimental pesticide before it had been fully tested?
- How else might the farmers have eliminated their locust problem?

Human Population Growth[4]

In two years, an International Conference on Human Population Control will be held in

[3] *Written by Julie Jasper while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.*

India, a country in which mass human suffering has resulted from human overpopulation. Due to the gravity of the topic, leaders from every nation will be encouraged to attend this conference. At the conference, leaders will vote on a new International Law. It is to be called the "International Application to Give Birth" (IAGB).

If this vote passes, people all over the world will be required to fill out this application and have it approved according to international standards before having a baby. On the application, prospective parents will have to state how the child's medical, educational, nutritional, child care, and emotional needs will be covered. Parents will also have to reveal whether they have any drug, alcohol, or psychological problems that might interfere with the care of their child. Other information will be asked for on the application, as well, which will help the international committee decide whether the prospective parents are "fit" to reproduce. If parents do not fulfill the requirements, their application will be denied and they will be given three years to change their lifestyle so as to enable them to have a baby and raise it in a healthy manner. The conference points out that as the human population continues to grow exponentially, the effects are felt worldwide.

- Activity 1. Try to think of ten to fifteen problems that our world faces today that you think are caused or worsened by an increasing human population.
- Activity 2. Many countries have tried to implement programs to help curb human population growth. The most famous is China's One Child Law. This law is very controversial; many people think that it is a violation of human rights to impose a ruling of this type. Try to think of at least five possible programs countries could develop to help curb human population growth.
- Activity 3. How do you think the world at large would feel and react if the "International Application to Give Birth" were enforced? Do you think it is a good or bad idea? Do you think it would help curb human population growth? Why or why not?
- Activity 4. Hold a debate. Randomly divide the class into four groups, two pro and two con groups. Provide an environment in which the students can express their opinions in a structured manner. After the debate, have the students (as a class) share their favorite alternative Human Population Control programs. Send these ideas to local, state, and federal politicians. Or, if possible, have the students develop a Web site that presents the results of their research (Figure 3.4).

GENES Committee[5]

You receive a letter today. In it you are asked to be prepared to discuss the implications of an incredible scientific discovery and breakthrough. Here is the letter (Figure 3.5).

Crazy Virus[6]

A horrible virus has been spreading throughout the world. It is similar to AIDS, but it is spread through in other ways than through bodily fluids. At present, it seems to be spreading by floating through the air. It will surely be the end of mankind as we know it, unless something is done quickly.

A biochemist who has been working long hours for many years on AIDS research finds a cure for AIDS that also seems to work on this new virus. But the drug she has discovered requires two chemicals: one from the tiger and one from the humpback whale, both endangered species. The process for retrieving these

[4] Written by Sarah Bexell while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.

[5] Written by Kelli Schuyler while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.

[6] Written by Maggie Hewes while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.

Figure 3.4
Fuzzy situations are opportunities for teachers to engage students in debate and discussion of important science-related social issues.

Figure 3.5
GENES Letter

Dear Colleague,

As the esteemed head of the Global Ethics for New and Experimental Science (GENES), you must contact and meet with the other members of the GENES committee in one week in Helsinki, Finland, to discuss the incredible scientific discovery and application proposed by our revered colleague Dr. Wendell Lipshaw. It is essential that all members of the GENES committee be present, including the scientific, social, cultural, religious, environmental, and economic attachés from the various nations.

Dr. Lipshaw seems to have unlocked the mystery of aging. By using gene therapy, not only is he able to expand the average life expectancy to three times the current average of 76 years of age, but his anti-aging therapy seems to rejuvenate cells, tissues, and organs such that individuals can expect to live well into their second century with smooth skin, firm muscles, clear vision, high energy, and vigorous reproductive capabilities.

It is the job of the GENES committee to discuss when and if we should accept this gene therapy for widespread use. Please predict the outcome of projected widespread use of Dr. Lipshaw's therapy over the next two generations—both its advantages and its disadvantages—and make any recommendations you may have to the committee for implementing the use of this therapy.

Respectfully Yours,
Kelli Schuyler
Chairperson of the Projects for the Advancement of the Human Race
Global Awareness Committee

chemicals requires that the animals be killed. Although the biochemist is sure her fellow organic chemists, if given the time, could make the same compounds in the lab and end this crazy virus, it may take too long. In the meantime, the current process would wipe out the populations of tigers and humpback whales, two wonderful animals. The biochemist must act quickly.

- What should she do? What are her alternatives?
- To whom must she talk in order to solve the problem?
- Do you see humans as the most important species in this world?

Physical Science Fuzzies

Icy Situation[7]

A young scientist, tired of always having to drink around the ice cubes in a glass, devises a solution that, if added to water, would cause the ice to sink to the bottom of the glass. This neat invention is about to go on the market. You, as part of the U. S. Food and Drug Administration, have to either approve or disapprove the manufacturing of this special solution (Figure 3.6).

- What are some questions you would ask the scientist about the special solution?
- How would you explain how the process might work?
- Should we be worried about what implications this invention could have on the world?

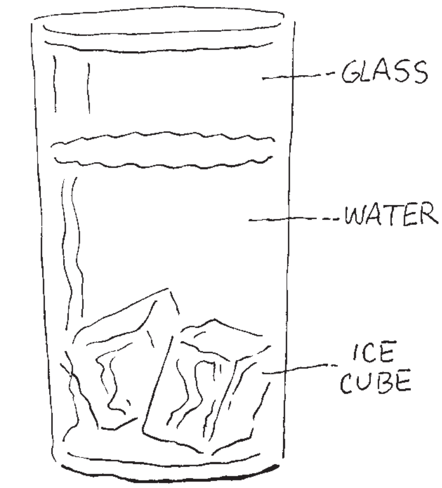
Anonymous Letter[8]

You have been contacted by the United Nations on the basis of your world-renowned problem-solving abilities in the realms of science and society. You will be one of five members of an

[7] Written by Robert Pike while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.

[8] Written by Daniel Whitehair while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.

Figure 3.6
Icy Situation



ad hoc committee that will review an anonymous letter (Figure 3.7) that was received by the United Nations. Your committee will meet according to the following schedule:

- First Meeting: The committee will hold a brainstorming session in which members will discuss all the issues that could be involved in the crisis situation as described in the letter. (Each member of the committee should keep a written copy of the issues discussed in the brainstorming. Each member should research and develop a proposed plan of action for the UN.)
- Second Meeting (one week later): The committee will review and discuss each of the five proposed plans of action. It will then create one Official Plan of Action that will be the committee's recommendation to the UN as to what should be done.
- Third Meeting (two to three days later): In this brief meeting, the committee will finalize its Official Plan of Action and prepare an oral presentation of its plan. (Every committee member should participate in some manner in the presentation.)

Figure 3.7
Anonymous Letter

Dear United Nations,

I write this letter anonymously for my own safety. There is a good chance I may disappear as a result of the enclosed information . . . please look after my cats.

As you are all aware, in 1998, trendy self-made media millionaire Mr. Ed Trunter donated $150 billion to NASA. As you are most likely not aware, the donation contract contained a secret provision that gives Mr. Trunter the right to do private research on 50% of any discoveries made by NASA projects funded by his donation.

Two years after Mr. Trunter's donation, the NASA Sherpa Mission to Venus brought back 120 kg of an unknown substance now known as "CJ" (named for its resemblance to Cracker Jacks™). NASA wasted its 60 kg of CJ on researching space laser weaponry.

Mr. Trunter, however, poured billions into covert research and reached astonishing results. Moreover, he utilized only 20 kg of his 60 kg on research, and thus currently possesses the only 40 kg of CJ that exists!

First, Mr. Trunter developed a cure for AIDS from CJ. The cure, which was tested on mammals and then on third-world humans with only a few casualties resulting, is now 100 percent effective in removing the AIDS virus from a human. The cure, which is a pink liquid that is ingested, has been labeled "PC" or "Pink Cure." One liquid gram of PC is enough to cure one human!

Second, the CJ can also be easily manipulated into a stable gas that could serve as a "patch" over the hole in our ozone layer. For every 10 kg of CJ that is converted to gaseous CJ, one-fourth of the ozone layer could be patched up!

And lastly, the CJ can be converted into a powder known as "NTN" that would be the most explosive substance on Earth. One gram of this powder equals the blast of an atomic bomb.

As you can see, this is powerful, powerful information. As an insider, I can assure you it is still uncertain what exactly Mr. Trunter plans to do with the remaining 40 kg of CJ. It could be used for any one of the above-mentioned possibilities, or it could be used in further research, which could lead to more breakthroughs. You should be aware that Mr. Trunter has spoken with several countries that have made offers to purchase his CJ.

Nevertheless, CJ is in the hands of a commercial omnivore, which can only be DEVASTATING for humanity. You must act for the sake of our existence.

—Anonymous

- Last Meeting (one to two days later): The committee will present its Official Plan of Action before the entire UN (the class) and submit a copy of the plan in written form to the Visiting Observer (teacher).

EARTH SCIENCE FUZZIES

Water or Gas[9]

The largest oil and water pipeline in the United States runs from Texas to New Jersey. The route takes it through your county. The government has just released a report on the status of the pipeline. The walls are

[9] Written by Karen Stewart-Tolmich while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.

deteriorating and there is an 85 percent chance that the contents of the pipeline will begin leaking into the ground. Since the pipeline crosses major rivers in the area, there is a 90 percent chance that it will begin leaking into the water that your city uses as its drinking water. The company that owns the pipeline says that if it rebuilds the pipeline to meet government standards, the company will have to quadruple the price it charges for transporting the oil and gas. That will result in the price of gas at the pump rising from $1.00 to $6.00 a gallon.

- Should the government force the pipeline company to repair the pipeline?
- If so, what effects will that have on the city and the people in it?
- What will happen if the company is not forced to repair the pipeline?

Aqua City[10]

It's the year 2150. Scientists and architects have designed an undersea city in response to a constantly increasing population on Earth. The construction of Aqua City may, however, cause unnatural changes in the ocean's environment. The prototype, built five years earlier, has been a success in the sense that humans can safely inhabit the city without complications. However, the number of waste products in the water has increased. There also have been reports of an increased number of shark attacks and whales beaching within 10 miles of the prototype city. Because of the growing need for inhabitable spaces, the actual city would have to be ten to twenty times larger than the prototype. Researchers cannot say for certain what will happen to the ocean's ability to support life in the next ten years if the project is approved.

- Should the city be built? Why or why not?
- Where should it be built?
- What are some alternatives to an undersea city?

A Smelly Dilemma[11]

Following are the minutes from a local town meeting:

The local citizens are totally opposed to the proposed landfill. The site would serve as a dumping ground at least until the year 2118, at which time other sites will be available to serve as landfills. The citizens insist that the government should find alternative methods for the disposal of trash. Moreover, the homes in the neighborhood are at most five years old, and the city council has just approved the construction of 500 additional single-family-home units.

You are a member of a task force that has been commissioned by the city to examine the way in which garbage disposal can be handled. During this examination, you are to consider the accumulation of solid waste due to the growth of the community, the cost and feasibility of potential handling plans, and the effectiveness of past initiatives (Figure 3.8).

- Part One: Brainstorming Possible Problems. Do not begin this section until you have carefully considered the above situation and thought about it or discussed it. When you feel you understand the situation, brainstorm as many problems associated with the disposal of solid waste as you can. List only your five best ideas and number each one.
- Part Two: Identifying the Underlying Problem. Select one of the problems you have just listed and write it below. It should begin with the words "In what ways might . . ." or "How might. . . ." Your problem should be written as clearly and specifically as possible.

[10] Written by Nedeidre Smith while an intern in the TEEMS Science Education program at Georgia State University. Used with permission.

[11] Written by Arlethea Williams while an intern in the TEEMS Science Education program at Georgia State University.

Figure 3.8
In the "Smelly Dilemma" fuzzy situation students become members of the City Council to discuss and decide upon ways in which garbage disposal can be handled.

- Part Three: Alternative Solutions. Brainstorm as many possible solutions as you can to the problem as you have defined it above. Record only ten of your solutions below, numbering them in order of feasibility.
- Part Four: Scenario. If Solutions Are Enacted. Each member of your group should choose a different solution and describe how it would be implemented, along with any possible drawbacks.

ENVIRONMENTAL SCIENCE FUZZIES

Should We Make the Plunge?[12]

You live in a lovely country setting, with a forest surrounding your house and a beautiful crystal-clear river running near your home. You've always enjoyed having the river nearby as a resource for swimming and fishing in the summer months and for watching the wild animals drink and play by the water year-round.

To make a public lake and social meeting place, the local government is suggesting damming the river about a mile upriver from your house. They plan to create a wonderful playground and picnic area for the surrounding community. The town developers doing research on the dam report that little or no change should occur to the river community. They believe they can build the new lake and allow much of the river to continue flowing. A private citizens' group also has been doing some research on this topic and does not believe the developers' findings. The group's findings suggest that diverting the river flow will greatly alter the surrounding neighborhoods.

As a concerned citizen yourself, you want to do some research on the topic of water diversion and dams. Discuss the situation with your peers and brainstorm some questions or issues that

[12] Written by Kirsten Mixter while an intern in the TEEMS Science Education program at Georgia State University.

you would raise with the developers and/or the citizens' group. Consider the following:

- What do you think would be the effect of changing the flow of water?
- Construct a list of pros and cons for and against the construction of the dam and lake.
- Would you support the construction of the dam and lake? Why?
- What could you do to support or protest its construction?

Summary

Fuzzy Situations are a way to engage your students in discussions in which they have to make decisions and consider the consequences of human actions. They enable your students to explore science-related social issues, ethical situations in science, the role of writing and discussion in an inquiry approach to science teaching. Once you start using the Fuzzy Situations presented here, you will be in a good position to write and create your own. For more ideas on Fuzzy-like scenarios, please visit the National Center for Case Study Teaching in Science:
http://sciencecases.lib.buffalo.edu/cs/

Chapter 4 Active Learning Strategies

This chapter focuses on a collection of six active learning strategies that build on the cooperative learning strategies, EEEPs, and Fuzzy Situations presented in Chapters 1, 2, and 3. In each case, the strategies have been shown to improve students' motivation, attitudes, and conceptual learning in science.

- Pre-Assessment Strategies
- The Collaborative Questioning Strategy
- The Q-M-S Strategy
- The Active Reading Strategy
- Visualization: Guided Imagery
- Games

Pre-Assessment Strategies

The goal of a pre-assessment strategy is to assess students' prior knowledge, ideas, beliefs, and attitudes. Research studies in science education have linked the use of pre-assessment strategies with improved student concept learning. By having students participate in an activity designed to identify their existing ideas about a topic, we add a powerful active learning strategy to our lesson planning. Following are five strategies you can use to identify students' prior knowledge.

T-charts

In this strategy, teams of students answer two questions about a science topic:

(1) What have you heard about . . . ozone (or dinosaur extinction, or the Big Bang Theory, The Laws of Motion, etc.)?

(2) What questions do you have about this topic?

The T-chart on ozone (Figure 4.1) is an example of the type of work created by four seventh-grade students working together as a small team. As you read the listings under the "What we have heard about ozone" column, note the misconceptions that are included. These should not be corrected immediately; rather, they should be revisited later in the unit of study and reconsidered by the students.

Figure 4.1
Sample T-chart—what we might expect from middle-school students

Ozone

What we have heard about ozone	What questions do we have about ozone?
• It makes us burn up.	• What causes ozone?
• It's smog and it's harmful to us.	• How can we tell if there is ozone in the air?
• Makes the earth heat up.	• Is it different in the center of a city compared to the suburbs?
• Air pollution can cause ozone.	• What effect does it have on humans?
• It's caused by chemicals in the air.	• Is it caused by cars?
• It can be dangerous to people with breathing problems.	• What will happen if the ozone in the air is all gone?
• There is good and bad ozone.	

Procedure: Provide sheets of chart paper and pens, and instruct the student teams to make a T-chart similar to the one shown in Figure 4.2, which happens to be about rocks.

1. Tell the students they will have about 6 minutes to brainstorm and write their ideas on the chart. At the end of 6 minutes, tell the students to finish the thought they are currently writing.

2. Then tell the students to look over their lists and select one very interesting idea and question and to be ready to share it. At this stage, you should have a master T-chart on a piece of chart paper.

3. Have one student from each group write the group's idea and question on the class chart.

4. Hang the student-produced T-charts and the master T-chart in the classroom. As students study the topic further, have them evaluate their ideas, crossing off those they can refute and discussing the questions they posed.

Surveys

This strategy can help you identify any "alternative views" students might have on a particular science concept or topic. Cards with pictures and diagrams on them, classroom demonstrations, open-ended questions, and even multiple-choice questions can be used. The goal is to find out what students really think about a topic.[1]

Procedure: Give each student a copy of a survey such as the one that appears in Figure 4.3. This Living Things Survey is designed to help determine students' understanding of the statement "An animal is a living thing." Tell students to look over the list and place a check mark next to those items they consider to be animals, and another check mark alongside those they consider to be living. Have the students total the number of check marks in each column. By a show of hands, you can see the range of responses in your class. The important point here is that we all construct meanings for the words we see and hear.

Interviews

Although interviewing students is a time-consuming process, it, like surveying, can help us find out what students really think about the concepts we are teaching. When interviewing, you might use pictures, cards, and other props that will help students express their ideas.[2]

Procedure: Interview students individually. Following is a set of interview questions for the word animal. Use it as a basis for constructing your own interviews about key topics you are introducing to your students.

1. **Introduction.** "I would like to talk to you about your understanding of the word animal. First, I'll show you some drawings and then we'll have a little talk about them."

2. **Question for each card.** "Given your understanding of the word animal, would you consider this to be an animal?"

3. **Follow-up for each card (choose one).** "Why did you say that?" or "Can you explain to me why you think that?" or "Can you tell me more about that?"

4. **A final question.** "Thank you for telling me about your understanding of the word animal. Just to finish, I wonder if you could describe to me, in your own words, what you think an animal is."

NOTE: A good set of interview cards can be created from the survey example on animals.

[1] *The following idea comes from Roger Osborne and Peter Freyberg in Learning in Science (Portsmouth, NH: Heinemann, 1985).*

[2] *Adaptation of Appendix D2: Interview questions from Learning In Science: the Implications of Children's Science by Roger Osborne and Peter Freyberg, with Beverley Bell et al., p. 177. Copyright © 1985 by Roger Osborne and Peter Freyberg. Reprinted by permission of Reed Publishing Ltd.*

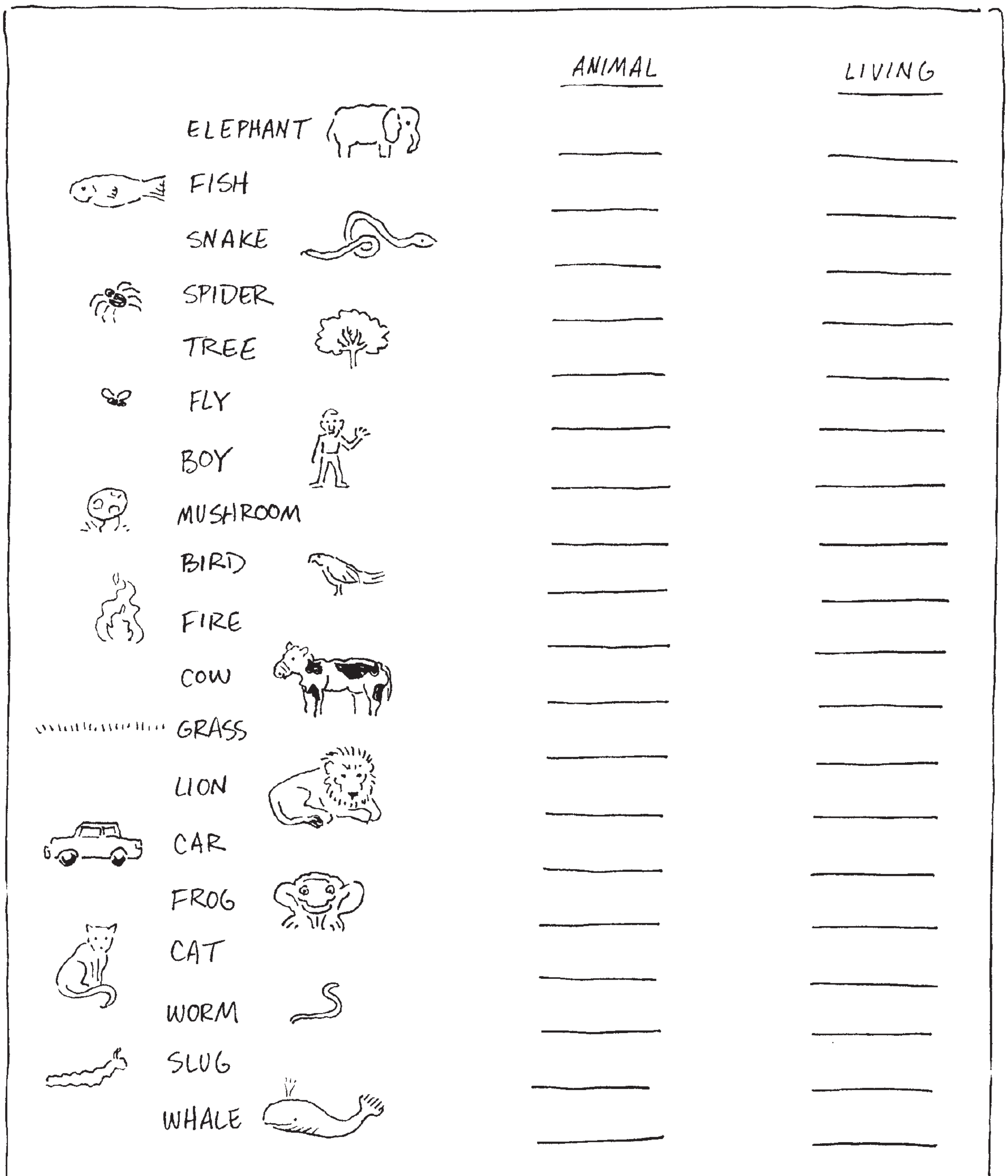
Figure 4.2
T-chart Template

Rocks

What have you heard about rocks?	What questions do you have about rocks?
Most interesting idea	**Most interesting question**

Figure 4.3
Living Things Survey

Adaptation of Figure 12.2: Exploring teachers' meanings for 'animal' and 'living' from *Learning in Science: The Implication of Children's Science* by Roger Osborne and Peter Freyberg, with Beverley Bell et al., p. 140. Copyright © by Roger Osborne and Peter Freyberg. Reprinted by permission of Reed Publishing Ltd.



Cushioning/Underexplaining

In Inspiring Active Learning, Merrill Harmin points out that cushioning and/or underexplaining a new idea will tend to create a climate of openness and thus increase the chances that students will talk about the idea. This, in turn, will help teachers find out what students really believe, and, in the case of a skill, what they are able to do.

Procedure:

Cushioning. When we introduce new material, it is often a good idea to minimize anxiety and maximize a relaxed, open-minded focus. So we might start off by saying, "We will talk about something new today. Do not assume you need to understand it completely right now. We will review and help each other later, so relax, and let's just see what happens today."

Underexplaining, using learning pairs: Present the concept or principle to be learned—for example, using a balance (Figure 4.4). You might begin by saying something like this: "There are lots of ways to get a scale like this to balance. You can move this center point or the position of the weights, as I am doing here. You can invent your own system, but one general rule to follow is. . . ." Continue your brief, cursory explanation, so perhaps only half the class understands it. Then say: "Now get together in pairs. Help each other figure out how to do this. When you both get it, work some practice problems. If you're both stuck, ask another pair for help."

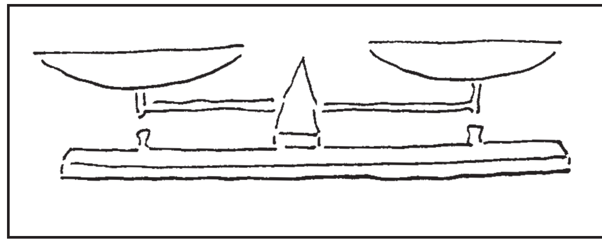
Attentive lecture/discussion. Ask the class: "How did we do? What did you figure out? What questions remain?" Continue discussion or explanation as appropriate, but no longer than whole-class involvement and attention are maintained.

Ask a friend/individual work. Have students complete their worksheets. Tell them: "Practice good thinking. If you get stuck, ask a friend for help."

Concept Mapping

Concept mapping is a strategy aimed at getting at the connections our brains make between the ideas that we think about and use. As such, it is a powerful tool for pre-assessing knowledge (or, naturally, for assessing learners at any stage of the learning cycle). (See Figure 4.5.)[3]

Figure 4.4
Swing Balance



Procedure: Begin by giving students marking pens, small index cards or self-stick writing pads, and chart paper. Choose a key word or topic for the concept map—e.g., food chain, plate tectonics. Then lead students through these steps:

1. Think of as many words as you can that relate to the key word. Write these words on scratch paper. (Encourage brainstorming, with little discussion.)

2. Look over the words on your scratch paper and throw out any words that remain.

3. Write each of the words, including the key word, on individual index cards or self-stick removable notes.

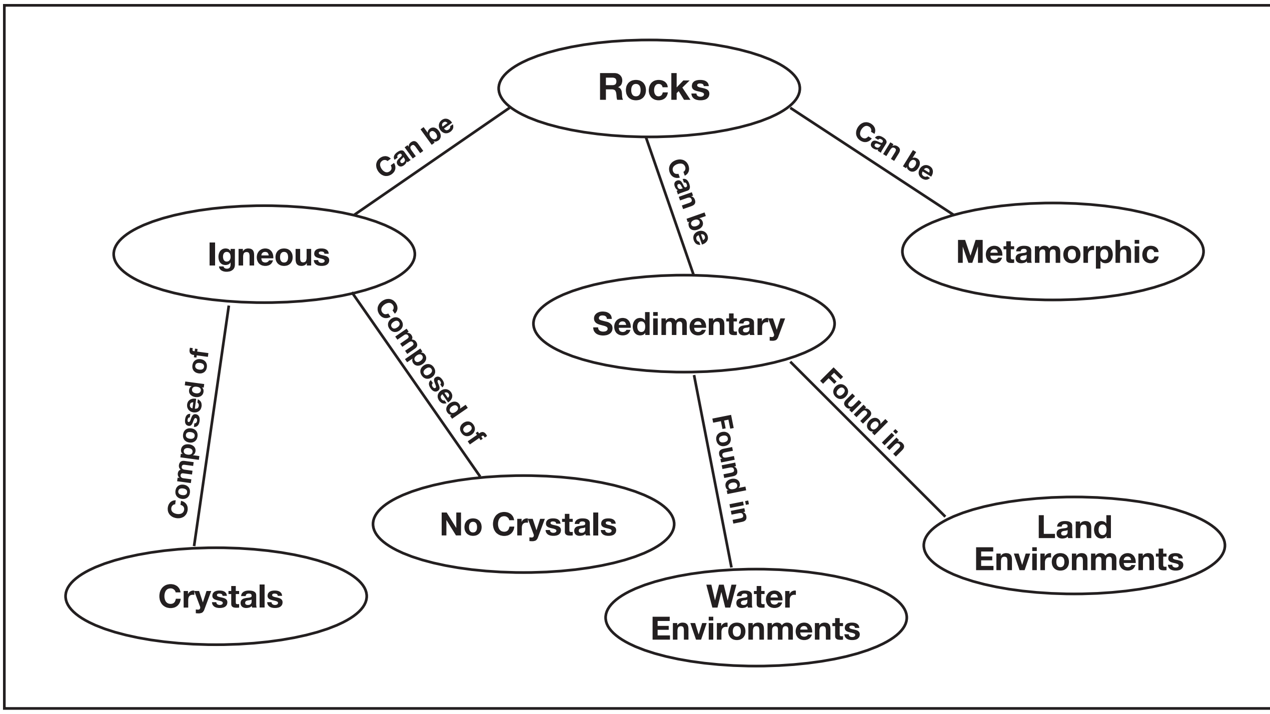
4. Rank the concepts from most inclusive to most specific.

5. Group the concepts into clusters. Add more specific concepts (on cards) if necessary.

6. Arrange concepts (using the cards or self-stick writing pads) in a two-dimensional array.

[3] *The ideas presented here are based on the work of Joseph D. Novak and D. Bob Gowin, Learning to Learn. Cambridge, England: Cambridge University Press, 1984, pp. 32–33.*

Figure 4.5
Concept Map for Rocks



7. Write the concepts on the sheet of chart paper exactly as they appear in the two-dimensional array, or simply attach the cards to the chart paper.

8. Link the concepts and label each link.

Collaborative Questioning

When we ask students questions in the course of our lessons, quite often the question is presented to the whole class, and then we use one of several methods to get ONE student to reply. What about the rest of the class? Collaborative questioning is a strategy designed to involve the entire class in discussing the questions we pose. This is important, because there is evidence that the more students have an opportunity to talk about science, the more they will learn.

Collaborative questioning can be used in a number of different contexts and for a variety of purposes, including:

- As a pre-assessment tool
- As a brainstorming tool
- As an inquiry session strategy
- As a way to encourage talking aloud within the safety of small groups
- As a cooperative group review strategy

Procedure:

1. **Students number off into cooperative groups.** Organize your class into cooperative learning groups of four students each. Although your goal is to have equal numbers of students within each group, this may not be possible if your class is not divisible by four. In that case, organize one or two groups of three students each. Have students number off within their groups from one to three or four.

2. **Teacher poses an inquiry question.** Inquiry questions can be either convergent or divergent. Low inquiry questions tend to be closed or convergent, whereas high inquiry questions tend to be open and divergent. Each

Figure 4.6
Collaborative questioning engages cooperative teams of students in answering important questions, as well as completing challenging problems as a team.

type is appropriate, depending on your objective(s). Suggestions for both types of questions appear in Figure 4.7.

3. **Students put their heads together to collaborate on and discuss the question.** Try allotting students just a few minutes to discuss the question; that way, they will immediately focus their attention on the task. Give each team either a small white board and dry-erase pens, or a sheet of newsprint, to record their answers. Appoint one student to be the team recorder.

4. **Teacher randomly calls a number.** If you wish, in lieu of calling a number, try using numbered cards and typically asking a student to draw the card. (Refer to Numbered Heads Together strategy in Chapter 1.) The student whose number is called "represents" the team by standing and answering the question, by

Figure 4.7 Inquiry Chart

Low and High Inquiry Questions Chart

Type of Question	Student Responses	Type of Response	Examples
Low inquiry (convergent)	• Recall, memorize • Describe in own words • Summarize • Classify on basis of known criteria • Give an example of something	Closed	How many . . . Define . . . In your own words . . . state similarities and differences. . . What is the evidence . . . ? What is an example . . . ?
High inquiry (divergent)	• Create unique or original design, report, inference, prediction • Judge scientific credibility • Give an opinion or state an attitude • Make value judgments about issues	Open	Design an experiment . . . What do you predict . . . ? What do you think about . . . ? Design a plan that would solve. . . . What evidence can you cite to support . . . ?

going to a designated space on a class board to write the team's answer, or by holding up the small white board presenting the team's work.

THE Q-M-S STRATEGY

The Q-M-S strategy is designed to help us rethink how we structure hands-on laboratory activities and reorient them so that they emphasize problem solving and inquiry, both of which are central to the reform of science education. Whenever students are faced with experiments or activities in the lab or on the classroom tabletop, they should be presented with challenging situations that encourage them to use inquiry and problem-solving approaches. In the Q-M-S strategy:[4]

Q stands for **Question** or problem situation
M stands for the possible **Means** to finding the solution or alternative solutions
S stands for the **Solution**

In classroom situations (laboratory, small-group discussion, assessment), one or more of the three components of the strategy can be left "open." The table in Figure 4.8 shows many variations on the Q-M-S strategy. The engaging science classroom will generally make use of different variations at different times, depending on teaching objectives, student abilities, subject matter, and the like.

Q question given	**"Q"** question not given
M means given	**"M"** means not given
S solution given	**"S"** solution not given

Following are some activities that you can use with your students that make use of the Q-M-S strategy.

Task 1. The Onion Lab

Examine the following activity (Figure 4.9) and classify it in terms of the Q-M-S strategy. Then modify the activity to satisfy one of the other inquiry and problem-solving types.

Activity: Looking at Onions
Onion cells are easy to see through a microscope. Following are the materials you will need for this investigation and the procedure you should follow.

Materials: Part of an onion, microscope, one slide with coverslip, one toothpick, one dropper with water, transparencies of onion skin cells, methylene blue solution, blotting paper or filter paper

Procedure:
1. Squeeze a drop of water onto the center of the slide.

2. Peel off a small piece of the thin onion skin.

3. Float the skin on the drop of water on the slide.

4. Cover with the coverslip. Put your slide in a safe place.

5. Look at the transparency of onion skin cells. You will see something like this when you look at your slide.

6. When you know what you are looking for, examine your slide through the microscope. Use the lowest magnification first. Later, you may be able to view the cells by using a higher magnification. Draw some of the onion cells in your science log.

7. Stain the cells. Look at them through the microscope again, and check what you see.

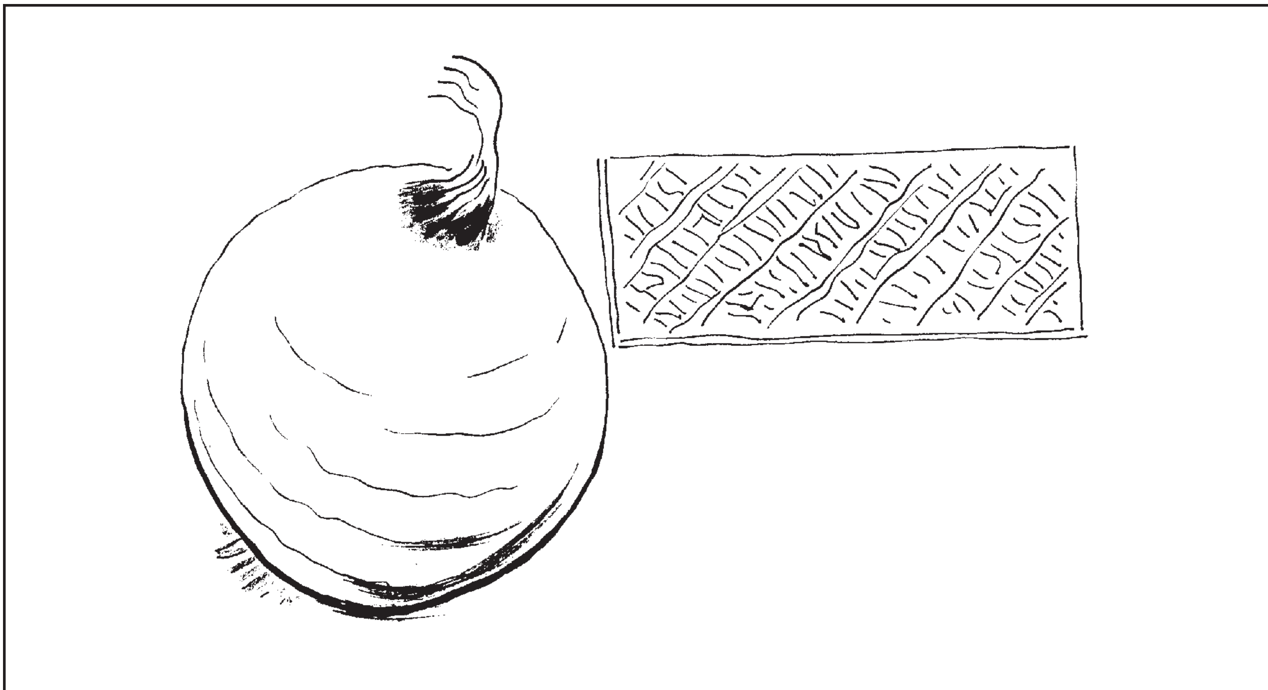
8. Draw some of the stained onion cells in your science log.

[4] *From the Do-It-Yourself Curriculum Guide published by the Education Department of South Australia, by Roger Cross, La Trobe University, Melbourne, Australia.*

Figure 4.8 Q-M-S Chart

Variation	Example	Type of Activity
"Q" "M" "S"	Students are asked to think of new questions to ask, to investigate them, and to arrive at conclusions. This may be appropriate as a follow-up exercise after a project or laboratory investigation. You might also elect to work from student questions, in which case, you might say, "Work out and do an investigation to find possible solutions to that question."	Asking question, inquiry
Q M S	A complete presentation of a scientific explanation or an historical account of a scientific investigation (e.g., Rutherford Gold Foil Investigation) is given.	Historical
Q "M" "S"	Given a question or hypothesis, students are asked to design their own investigation. This works very nicely after doing a demonstration or an EEEP. Students might also generate a hypothesis based upon the observation of the EEEP and then design an investigation.	Given this . . . then . . .
Q M "S"	In this standard laboratory exercise, the question is stated and a method is suggested that the students then follow to arrive at a solution. This variation has often been called the "cookbook" approach to lab activities.	Cookbook lab
"Q" M "S"	Students are given a means or technique (e.g., measuring water loss in plants) and are asked to think of questions and then use the means to answer them.	Using techniques to solve problems
Q "M" S	You might begin this way: "The text says that molds grow best in dark, warm conditions. What kinds of experiments could scientists do or have they done to show that?"	Investigating a method
"Q" M S	Students are given an account of an experimental procedure, with data collected and results obtained, and are asked: "What hypothesis was being tested?"	Working backward

Figure 4.9
The Onion Lab



Task 2. The Drifting Continents

Examine the maps of the Earth (Figure 4.10) showing the movement of continents over the past 210 million years. Using the Q-M-S strategy, design two inquiry activities that make use of the cards in Figure 4.10.

Task 3. The Geoblock

The Geoblock is a technique designed to help students understand the structures in rocks such as the folds shown in Figure 4.11. The students can cut out the block, fold the edges, and examine it from different angles. Using the Q-M-S strategy, design as many variations as you can using the Geoblock to help students understand ideas related to rock formations and geological maps.

THE K-W-L STRATEGY

One active reading strategy that is worth exploring is the K-W-L strategy. An active reading strategy prepares students to make predictions about what they will be reading, as well as engaging them with other students in a discussion of the content of the topic. The procedure consists of three steps:

K = Assessing what we know or have heard
W= Determining what we want to learn
L = Recalling and discussing what we did learn

In step K, students do two things. First, they brainstorm what they know or what they have heard about a topic. Using the K-W-L Strategy Data Sheet (Figure 4.12), students work in small groups and begin to record their ideas. The focus should be specific. In the sample lesson plan that follows, for example, students would talk about what they know or have heard about earthquakes, not what they know about natural disasters. The second part of step K is to categorize the information students have generated. In the sample case that follows, the teacher might suggest these categories: causes of earthquakes, how earthquakes are measured, and damage caused by earthquakes.

Step W helps students anticipate the

Figure 4.10
The Continents

National Association of Geology Teachers. *Journal of Geological Education,* Vol. 23, No. 5, pp. 169–170 in *Continental Drift,* by Scotese and Baker. Copyright © 1962 by C. Scotese.

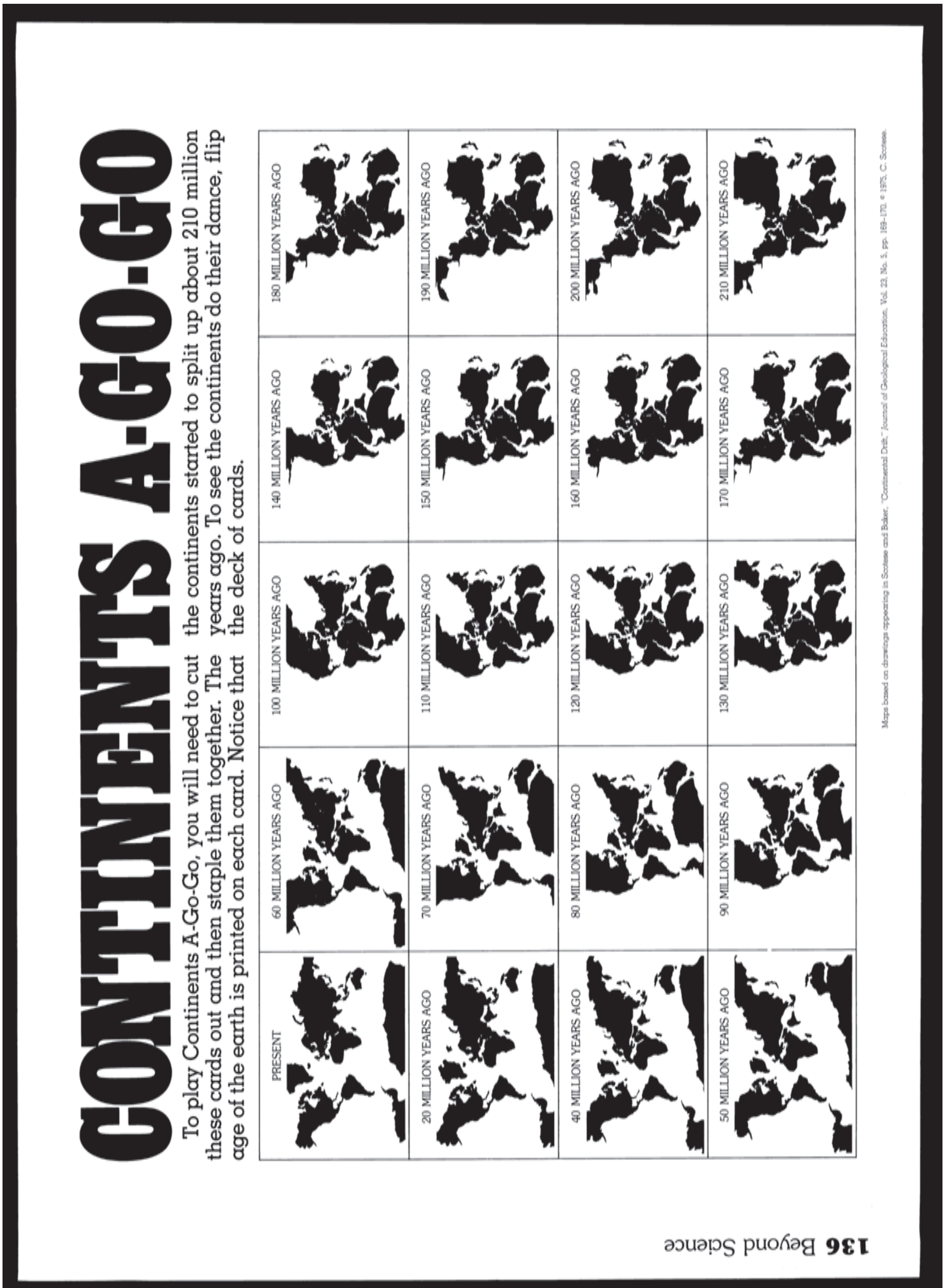


Figure 4.11
Geoblock

From *Adventures in Geology* by Jack Hassard. © 1989 American Geological Institute.

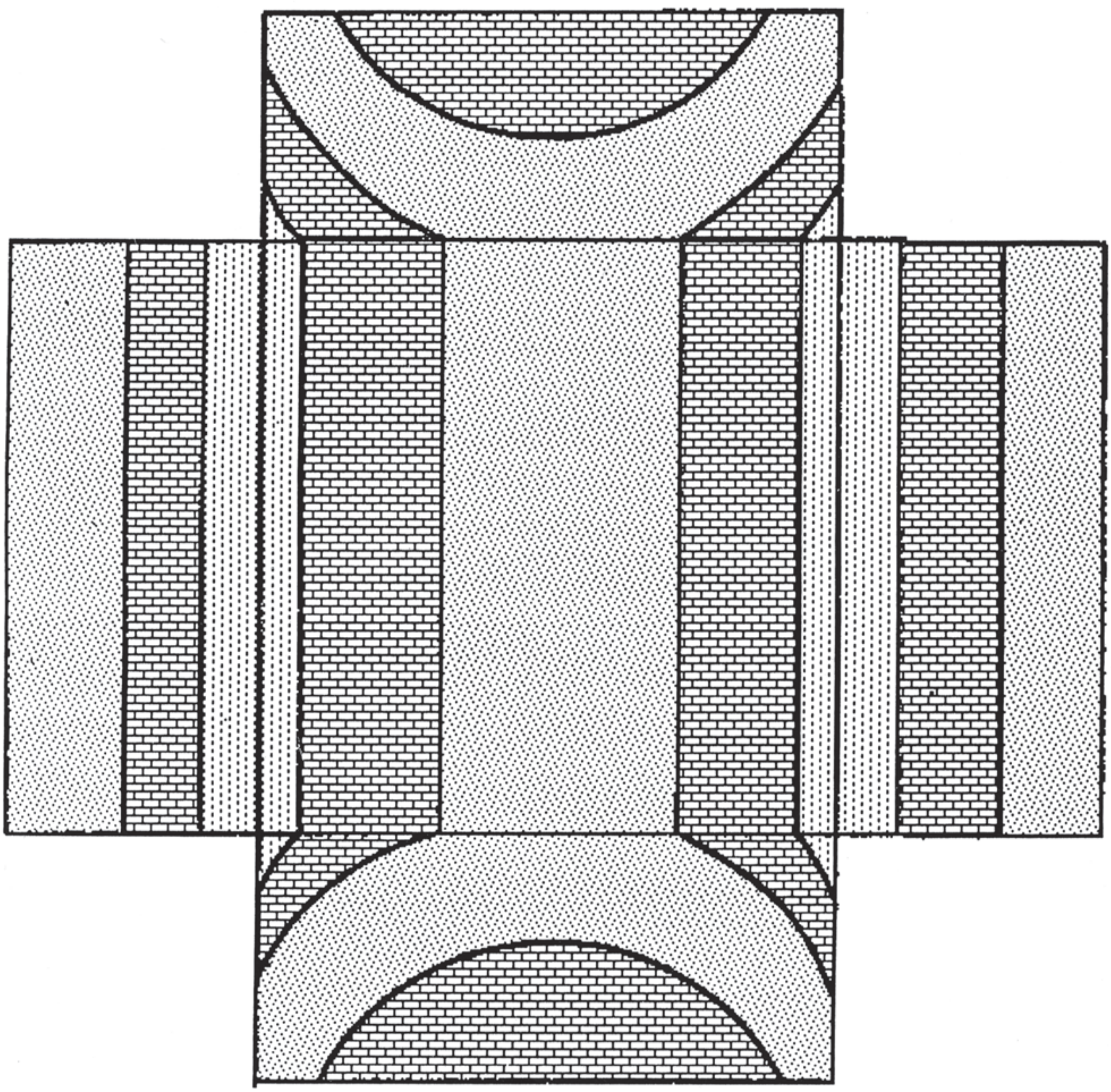


Figure 4.12
"K-W-L Strategy Sheet" from *Minds-on Science* for Figure 8.14, "K-W-L: A Teaching Model That Develops Active Reading of Expository Text" by Donna M. Ogle from *The Reading Teacher,* February 1986, pp. 564–570. Reprinted with permission of the author.

K-W-L STRATEGY DATA SHEET

K—What we know	W—What we want to find out	L—What we learned and questions we still have

Categories of information we expect to use:

(Categorize the information from the K step.)

A. ______________________ E. ______________________

B. ______________________ F. ______________________

C. ______________________ G. ______________________

D. ______________________ H. ______________________

reading that is to come and helps the students focus on what they want to learn from the reading. The teacher directs the groups to write on the data sheet several questions they are most interested in having answered, based on their prior discussion and brainstorming.

Step L, which follows the reading of the text passages, focuses the students on recalling what they learned from the reading. As a group they should brainstorm a list of ideas representing things they learned in the reading. They can also try and answer the questions they posed.

LESSON PLAN: EARTHQUAKES

This lesson plan is appropriate for any chapter on earthquakes in a middle-level science textbook.

Objectives:

- To describe how earthquakes are caused
- To predict the effects of an earthquake

K: What do students already know about the topic?

NOTE: This is a brainstorming session in which students describe what they know about earthquakes—your role is to pose a specific problem or task in order to help students focus on the reading yet to come.

1. Pose the question: "What do you know about earthquakes?" Pairs of students brainstorm and record what they know about earthquakes.
2. Pairs of pairs (groups of four) share lists and prepare composite list.
3. Groups of four share with the whole class by taping composite lists on the walls of the classroom. Focus on the lists, and ask groups of four to categorize the information—topics might include causes of earthquakes, damage caused by earthquakes, earthquake waves, and how earthquakes are measured.
4. Ask students how they got their information about earthquakes. This final substep personalizes student knowledge and recognizes the sources of students' prior knowledge.

W: What do students want to know about the topic?

NOTE: This step helps students anticipate the reading that is to come, and helps the students focus on what they want to learn from the reading. This step should be carried out as a group activity.

1. Each group of four develops four questions about the topic.
2. Teacher records these questions on the board. Teacher can elaborate on the questions, perhaps selecting two or more that seem especially interesting to the students.

L: What did students learn about the topic?

NOTE: Students read the assigned text material. Students write what they learned on the K-W-L Strategy Data Sheet. They also check to see if their questions were answered, and if some of their prior knowledge was confirmed. Students work in small groups to discuss their questions.

1. Group circles information on the master list that was taped to the wall that the text confirmed.
2. Group crosses off information that the text refuted.
3. Students contribute to the final column of the list: What we learned!
4. Teacher goes around the class and asks each student to indicate (by thumbs-up or thumbs-down) if his of her question(s) was(were) answered.
5. Teacher asks each group to make a concept map of the main ideas and supporting secondary categories of what they learned from the reading.

VISUALIZATIONS: GUIDED IMAGERY

Close your eyes and try to recreate the most beautiful rock you have ever seen in the natural world . . . .

The teacher who gave her students these instructions was using an active learning strategy called guided imagery, which is a visualization technique. Some cite guided imagery as an example of a right-brain activity.

Guided imagery is a powerful tool well worth incorporating into science lessons. Some science teachers see the power of guided imagery as giving students insight into concepts by drawing on the students' own experiences, thereby personalizing the learning of science. Science has many recorded instances of reverie, insight, and/or dream experiences leading to the central insight in a scientist's theory.

In science teaching, guided imagery functions much like a story; the teacher guides the students on a journey, encouraging them to create images and form ideas. Imagery experiences should take place in a quiet, relaxed atmosphere. Some teachers dim the lights or play music and have students sit quietly at their desks. Follow-up activities after the guided imagery are an important part of the experience. These can include making something (perhaps with clay or other manipulatives), writing in a journal, or pairing off and discussing the experience.

Using Guided Imagery in Science Teaching

The following exercise helps to show how guided imagery can enhance science learning. The example is based on a mini-unit focusing on rocks.[5]

Objectives:

- To describe how rocks are formed
- To use imagery to explore the processes that affect rocks
- To classify rocks
- To invent a rock

[5] *Adapted from 4Mat And Science Toward Wholeness in Science Education by Bob Samples, Bill Hammond, and Bernice McCarthy, pp. 86–87. Reprinted by permission of Excel, Inc.*

Materials: Index cards, marking pens, large samples of granite, sandstone, and marble, collection of rocks for each group that should include granite, sandstone, shale, marble, limestone, gneiss, slate, and obsidian

Procedure:

Phase I. Introduction/Prior Knowledge/ Personal Meaning

1. **Guided Imagery Experience.** "Close your eyes and try to re-create the most beautiful rock you have ever seen in the natural world. . . . Try to remember everything you can about the setting. . . . Note the colors and smells. . . . Imagine what the rock feels like. . . . Pretend the rock can talk and tell you about its history. . . . Listen carefully to its story so you can remember it. . . . You will have two full minutes, starting now."

2. **Cooperative Group Activity.** Have students form groups of four students each and have them tell each other all they can about their rocks and the stories of their rocks. After the discussion have them write their description of their rock on a 3"   5" card. Remind them that the descriptions should include color, shape, weight (heavy or light), and texture (bumpy, smooth, jagged, etc.). Have them save the descriptions for later.

Phase II. Some Information, Please!

3. **Guided Imagery Experience.** "We are going to use guided imagery again to continue our exploration of rocks. This time we will explore some of the ways rocks are formed. Close your eyes and relax. . . . Some rocks form in the waters of oceans or lakes. . . . Most often they are made of particles of mud or sand that drift to the bottom of the water. . . . Try to visualize this process. After long periods of time, they may become crushed and fastened together by different materials. . . . Think back and see if this is how you think your rock

Figure 4.13
Granite, Sandstone, and Gneiss

formed.

"Other rocks formed deep within the Earth and were once melted or molten. . . . Sometimes these rocks come to the surface in volcanoes. . . . Try to imagine rocks pouring out of the Earth. . . . Some never make it to the surface and end up cooling down deep in the Earth. These rocks often have crystals and large grains of different materials. . . . Try to imagine them forming.

"Some rocks lie near the deep heat sources of the volcanoes. These rocks are baked and even remelted by the heat. . . . Try to visualize rocks being melted and twisted by other molten rocks flowing by.

"Keep your eyes closed and review the three kinds of rocks: those formed in the water . . . those formed by molten rock inside the Earth and at its surface . . . and those formed by being crushed, twisted, and melted by other rocks. . . ."

At the end of the visualization, have your students open their eyes, and then show them a video on the origin of rocks. (A variety of videos are available. You might want to try focusing on volcanic rocks or sedimentary rocks.)

4. **Mini-Lecture (10/5) Strategy.** Prepare a mini-lecture (about 10 minutes long) on the origin of rocks. Show students examples of igneous, metamorphic, and sedimentary rocks. You might try giving formal definitions of the types of rocks, and then (for about 5 minutes) have students work in small groups to write out their own definitions on index cards while they handle and observe rock samples.

Phase III. Analysis

5. **Quiz/Worksheet.** Provide a quiz or worksheet on rock formations and how they are classified. Have students work in small groups to complete them. Also, have the groups refer back to the descriptions they wrote on 3" 5" cards (Phase 1) and use the cards to reclassify their original rock descriptions based on the classification system they have now learned.

6. **Laboratory Activity.** Give groups of students a collection of rock specimens and have them classify the rocks according to origin. Have the students try to match up the rocks with the descriptions of rocks on their cards. For a homework assignment, you might give each student a small plastic bag of sand and have students try to make a synthetic rock at home (Figure 4.14). Allow at least 2 days for this activity. Tell the students the "fake" rock is intended to approximate some of the same processes that are involved in the formation of rocks in nature.

Phase IV. Synthesis and Application

7. **Synthesize.** In this phase, students present their "fake" rocks to the class in the form of a display and discuss the effort that went into making the "fake" rock. Connections should be drawn between what the students did to make "fake" rocks and processes in nature that make "real" rocks.

8. **To the Field.** The final activity in this guided imagery example is a short field trip into nature, which can be anywhere in nature

Figure 4.14
Recipe for a fake rock: 1/2 cup sand, 1/4 cup gravel, 1/2 cup water, 1/2 cup plaster of Paris. Mix ingredients in a quart-size milk carton and let the mix harden. Remove the carton to reveal the "fake" rock.

or in the community. The goal is to look for and identify real and fake rocks, and discuss the way in which they were formed.

Creating Your Own Visualizations

Visualizations are easy to create, which is nice since you'll find many opportunities for their use during the course of the year. Some teachers make up visualizations and record them on audiocassette tapes for future use by individual students or small groups of students. Figure 4.15 provides suggestions for creating visualizations.

GAMES

Not only do games promote active learning in the science classroom, but they serve as powerful motivators for your students. Games can be used to introduce new science concepts, to help students apply concepts already explored, and, in many cases, to review for quizzes and tests. Finally, games can be used as an alternative form of assessment.

Included here is a complete description of one game, the Disaster Game, followed by descriptions of several other games.

The Disaster Game

Objective: To get each system on your disaster board to balance by placing exactly 200 Earth balance points in each space.

Materials: One set of cards (disaster cards, response cards, Earth balance point cards), 1 Disaster game board (Figures 4.16 and 4.17)

Number of players: 2

Game Rules: One player deals the disaster cards, one at a time, until each player has seven cards. The dealer puts the next card face up between the players to form a discard pile. The other player starts by picking a card from the top of the discard pile. After drawing one card, the player can do one of the following:

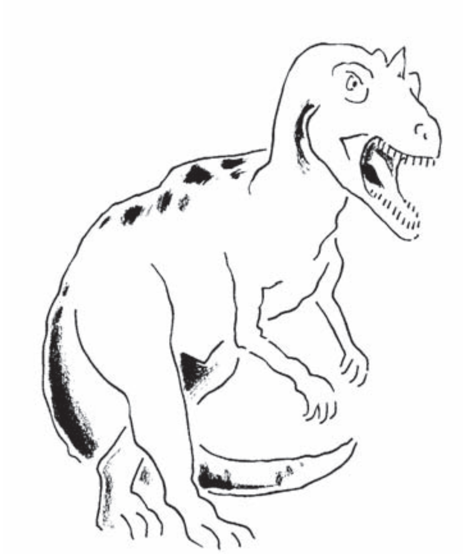
- Place a disaster card on any earth system on the opponent's game board, draw another card, and then discard one card.
- Place an Earth balance points card on any Earth system on the player's own game board, draw as many cards as were placed on the game board, and then discard one card.
- Discard one card.

A player who has a disaster occurring in any system cannot continue to play until the correct response card is placed on top of the disaster. Thus the only move open to this player is to draw and discard cards.

Exactly 200 Earth balance points secure a system from disaster. Any value on the system less than 200 does not. If a disaster card is placed on a system that has less than 200 points, the player loses whatever earth points are on that system.

End of Game: Play ends when one player has exactly 200 earth balance points on four of the six systems on his or her game board.

Figure 4.15
Visualization chart. What visualizations do these images help you create for your students?



Paleontology

Idea: Living with dinosaurs

Question: *Which one is the largest?*
Which one do you fear the most?
Do dinosaurs live in families?
How do dinosaurs eat?

Glaciers

Idea: Being a piece of frozen water in a moving glacier

Question: *What sounds might you hear?*
What effect might you and the rest of the glacier have on the rocks and land you pass over?
What might you leave behind?

Hurricanes

Idea: Being a cloud traveling near the eye of a hurricane

Question: *How fast are you going?*
In what direction do you move?
How predictable are you?
What damage do you do?

Rocks

Idea: Being a rock tossed along a streambed

Question: *How might this experience change your appearance?*
Where might you end up?
What sights might you see along the way?

Figure 4.16
Disaster Game

"Disaster Game" from *Earthpeople Activity Book* by Joe Abruscato and Jack Hassard, pp. 158–162. Copyright © 1978 by Goodyear Publishing Company, Inc.

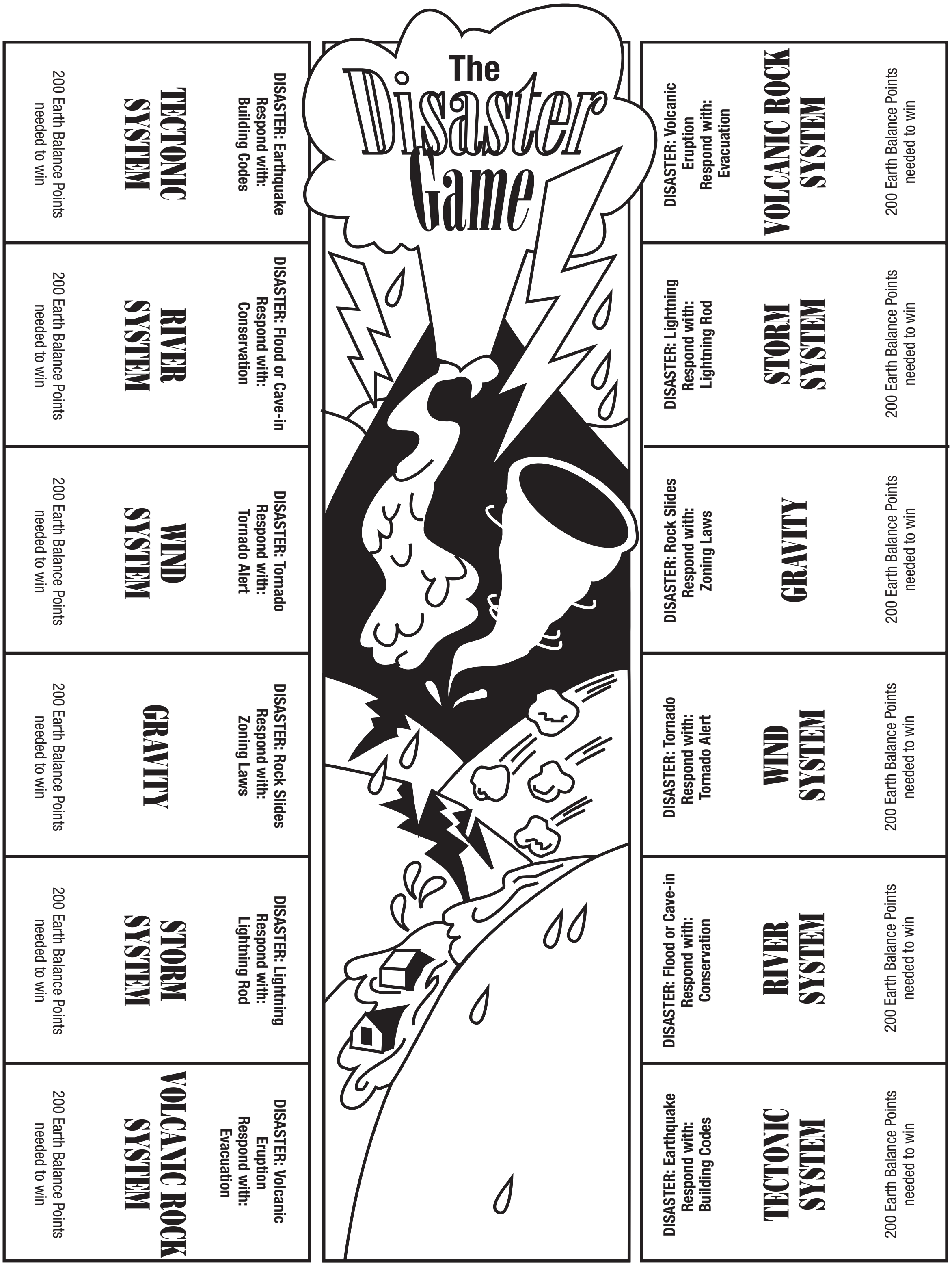


Figure 4.17
Disaster Game Cards

"Disaster Game" from *Earthpeople Activity Book* by Joe Abruscato and Jack Hassard, pp. 158–162. Copyright © 1978 by Goodyear Publishing Company, Inc.

How to Play

Objective: To get each system on your disaster board in balance by placing exactly 200 earth balance points in each space. *Materials:* One set of Disaster cards. 1 disaster gameboard (each player to use half). *Number of players:* two.

Game rules: One player deals the Disaster cards, one at a time, until each player has seven cards. The dealer puts the next card face up between the players to form a discard pile. The other player starts by picking a card from the top of the face-down stack or from the top of the discard pile. After drawing one card, the player can then do one of the following:

1. Place a disaster card on any earth system on the opponent's gameboard, draw another card, and then discard one card.
2. Place an Earth Balance Points card on any of his or her earth systems, draw as many cards as were placed on the gameboard, and then discard one card.
3. Discard one card.

A player who has a disaster occurring in any system cannot continue play until the correct Response card is placed on top of the disaster. The only move open to this player is to draw and discard cards.

Exactly 200 Earth Balance points secure a system from disaster. Any value on the system less than 200 does not. If a Disaster card is placed on a system that has less than 200 points, the player loses whatever eath balance points are on that system.

End of Game: Play ends when one player has exactly 200 earth balance points on four systems on his or her gameboard.

Rock Slide

Wet earth, soil, and rocks slide down a hillside, destroying vegetation and buildings.

Place over a *Gravity* card to stop. Respond with a *Zoning Laws* card to continue.

Lightning

Severe thunderstorm hits home. Potential fire and electrical damage.

Place over *Storm System* card to stop. Respond with a *Lightning Rod* card to continue.

Evacuation

This is the best response if a volcano erupts. This action will keep you alive!

Place over a *Volcano* card before continuing.

Tornado Alert

Open windows, go to center of building, and take cover. This card will protect you and tell you what to do in case of a tornado.

Place over a *Tornado* card before continuing.

Rock Slide

Wet earth, soil, and rocks slide down a hillside, destroying vegetation and buildings.

Place over a *Gravity* card to stop. Respond with a *Zoning Laws* card to continue.

Lightning

Severe thunderstorm hits home. Potential fire and electrical damage.

Place over *Storm System* card to stop. Respond with a *Lightning Rod* card to continue.

Evacuation

This is the best response if a volcano erupts. This action will keep you alive!

Place over a *Volcano* card before continuing.

Tornado Alert

Open windows, go to center of building, and take cover. This card will protect you and tell you what to do in case of a tornado.

Place over a *Tornado* card before continuing.

Rock Slide

Wet earth, soil, and rocks slide down a hillside, destroying vegetation and buildings.

Place over a *Gravity* card to stop. Respond with a *Zoning Laws* card to continue.

Lightning

Severe thunderstorm hits home. Potential fire and electrical damage.

Place over *Storm System* card to stop. Respond with a *Lightning Rod* card to continue.

Evacuation

This is the best response if a volcano erupts. This action will keep you alive!

Place over a *Volcano* card before continuing.

Tornado Alert

Open windows, go to center of building, and take cover. This card will protect you and tell you what to do in case of a tornado.

Place over a *Tornado* card before continuing.

Volcano

A volcano has erupted, spilling hot lava on the earth's surface.

Place above a *Volcanic Rock System* card to stop. Respond with an *Evacuation* card to continue.

Flood

A river has flooded beyond its flood plain. Erosion increases: buildings and homes are destroyed.

Place above a *River System* card to stop. Respond with a *Conservation* card to continue.

Tornado

A tornado has been sighted and reported by the weather bureau.

Place over a *Wind System* card to stop.

Respond with *Tornado Alert* card to continue.

Earthquake

The earth begins to shake and roll: buildings begin to collapse.

Place over a *Tectonic System* card to stop.

Respond with *Building Codes* card to continue.

Conservation

Conservation techniques such as terracing, building higher levees, and revegetation can help control erosion by flooding.

Place over a *Flood* card before continuing.

Zoning Laws

Better zoning laws would prohibit construction in areas of weak rocks.

Place over a *Rock Slide* card before continuing.

Volcano

A volcano has erupted, spilling hot lava on the earth's surface.

Place above a *Volcanic Rock System* card to stop. Respond with an *Evacuation* card to continue.

Flood

A river has flooded beyond its flood plain. Erosion increases: buildings and homes are destroyed.

Place above a *River System* card to stop. Respond with a *Conservation* card to continue.

Tornado

A tornado has been sighted and reported by the weather bureau.

Place over a *Wind System* card to stop.

Respond with *Tornado Alert* card to continue.

Earthquake

The earth begins to shake and roll: buildings begin to collapse.

Place over a *Tectonic System* card to stop.

Respond with *Building Codes* card to continue.

Conservation

Conservation techniques such as terracing, building higher levees, and revegetation can help control erosion by flooding.

Place over a *Flood* card before continuing.

Zoning Laws

Better zoning laws would prohibit construction in areas of weak rocks.

Place over a *Rock Slide* card before continuing.

Volcano

A volcano has erupted, spilling hot lava on the earth's surface.

Place above a *Volcanic Rock System* card to stop. Respond with an *Evacuation* card to continue.

Flood

A river has flooded beyond its flood plain. Erosion increases: buildings and homes are destroyed.

Place above a *River System* card to stop. Respond with a *Conservation* card to continue.

Tornado

A tornado has been sighted and reported by the weather bureau.

Place over a *Wind System* card to stop.

Respond with *Tornado Alert* card to continue.

Earthquake

The earth begins to shake and roll: buildings begin to collapse.

Place over a *Tectonic System* card to stop.

Respond with *Building Codes* card to continue.

Conservation

Conservation techniques such as terracing, building higher levees, and revegetation can help control erosion by flooding.

Place over a *Flood* card before continuing.

Zoning Laws

Better zoning laws would prohibit construction in areas of weak rocks.

Place over a *Rock Slide* card before continuing.

Figure 4.17
Disaster Game Cards

"Disaster Game" from *Earthpeople Activity Book* by Joe Abruscato and Jack Hassard, pp. 158–162. Copyright © 1978 by Goodyear Publishing Company, Inc.

Lightning Rod This card will ground you and the structure you are in. It will save your life. Place over a *Lightning* card before continuing.	**50** Earth Balance Points	**50** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points
Lightning Rod This card will ground you and the structure you are in. It will save your life. Place over a *Lightning* card before continuing.	**50** Earth Balance Points	**50** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**150** Earth Balance Points
Lightning Rod This card will ground you and the structure you are in. It will save your life. Place over a *Lightning* card before continuing.	**50** Earth Balance Points	**50** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**150** Earth Balance Points
Building Codes Designing and locating buildings to withstand earthquakes is possible. This card will do it. Place over an *Earthquake* card before continuing.	**50** Earth Balance Points	**50** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**150** Earth Balance Points
Building Codes Designing and locating buildings to withstand earthquakes is possible. This card will do it. Place over an *Earthquake* card before continuing.	**50** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**150** Earth Balance Points
Building Codes Designing and locating buildings to withstand earthquakes is possible. This card will do it. Place over an *Earthquake* card before continuing.	**50** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**100** Earth Balance Points	**150** Earth Balance Points

Earth Science Games

The Disaster Game. A challenge game in which students learn about various natural disasters and ways to protect themselves. (See preceding description.)

Dinosaur Games: A collection of eight online games in which students learn about geologic time and dinosaurs.
http://www.kidsdinos.com/

Environmental Science Games

Endangered Species Board Game. The purpose of the game is to save endangered animals from extinction by moving them to their natural habitat while confronting a number of environmental conservation issues.
http://www.abifol.com/

Predator: The Food Web Game. Students study the food relationships found in a temperate forest. Available from Carolina Biolagical Supply:
http://www.carolina.com

Food Web Game. Introduces basic ecological and wildlife topics. Players choose an animal—predator or prey—and try to survive in the American North.Available from Carolina Biolagical Supply:
http://www.carolina.com

Life Science Games

The Cell Game. Players explore either a plant or an animal cell, carrying out such processes as synthesis, parasitism, respiration, and photosynthesis.Available from Carolina Biolagical Supply:
http://www.carolina.com

Codon: The DNA Game. Student "scientists" identify amino acid sequences for key proteins in 5 common human diseases Available from Carolina Biolagical Supply:
http://www.carolina.com

Wild Animalopoly. All the fun of a traditional property-trading game with some wild animal twists! Players become caretakers of animals and pay meal fees when landing on animal spaces. Available from Carolina Biolagical Supply:
http://www.carolina.com

Bug-Opoly. A creepy, crawly game about the fascinating world of insects, starting with ants and moving to the praying mantis. Available from Carolina Biolagical Supply:
http://www.carolina.com

Gene Rummy Game: Players compete with each other to manipulate the 4 bases of the genetic code, select codons for the 20 amino acids, and genetically engineer proteins. Available from Carolina Biolagical Supply:
http://www.carolina.com

Physical Science Games

Chem Cubes: Elements. Teaches the names and chemical symbols of common metallic and nonmetallic elements, use of the periodic table, and writing of simple chemical equations. Available from Carolina Biolagical Supply:
http://www.carolina.com

The Electric Circuit Game. Teaches basic electrical circuitry. Players try to be the first to complete a circuit without being shocked or shorted out.Available from Science Kit & Boreal Laboratories:
http://sciencekit.com

Element-O. Introduces many basic chemistry concepts, such as the configuration of the periodic table and physical characteristics of elements.Available from Lewis Educational Games:
http://elementogames.net

Summary

This chapter brought together several strategies that expand our notion of science inquiry. Exploring students' initial ideas on a topic, as was presented in the section on pre-assessment strategies, honors student ideas. To recognize the value of student ideas, it is important to begin instruction by soliciting their views. Questioning and active reading strategies explore the importance of language and writing in science and show how students can be encouraged to talk about their ideas and to express them in writing as well. Finally, we saw the value of visualization in helping students explore, in their mind's eye, the nature of science.The chapter ended with an exploration of how games can be used in the science classroom to engage students in a variety of actions.

Chapter 5 Project-Based Teaching

When science teachers are asked why they teach science, many of them say they want to inspire and encourage the love of learning. They explain that they want to encourage inquiry and innovative thinking in their classrooms. A compelling way to achieve this goal is to use project-based activities. The purpose of this chapter is to provide ideas and resources for implementing project-based activities in science teaching.

What Is a Science Project?

Greg Lockett, a science teacher from Cottonwood, California, provides this conception of a science project:

> *Children learn by doing. If you want students to learn physics, they must "do" physics. From this view, the goal of the teacher is to re-create the process and experience of working in a physics laboratory. As experimenting is central in physics, experimenting takes a central role in the project classroom. Several features are important in this approach. Students are free to choose a research problem. They do not know the solution to their problem at the outset of their project. While students must work within the constraints of time, resources, and their current knowledge, they are given considerable time and freedom to attack their problem as they see fit. Collaboration is acceptable and desirable. The end product of student work can vary widely (reports, papers, equipment, experiments, constructions, models, etc.). Student success is not easily measured by objective tests.*
>
> *In this process, the goal of the teacher is not the efficient transfer of large amounts of information and mathematical problem-solving skills. The goal is to give the student an immediate and compelling "inside" view of science (physics). The teacher functions primarily as a facilitator. In many respects, she or he is like a research director in a laboratory. She or he familiarizes new researchers with the laboratory, obtains needed resources or suggests alternatives, resolves disputes—from equipment scheduling to squabbling among the researchers, and in general attempts to maximize the creation of new ideas and technology within the laboratory. At all points, the teacher is guided by the current practice of physics and the goal of re-creating that practice within the classroom.*
>
> *The goals of the project paradigm are broader and deeper than those of the basal-text paradigm. At the highest level, they include firsthand knowledge of what science is, how it works, and its limits. Mathematical problem-solving skills are encompassed within a broader structure that includes research skills (using libraries), motor skills (building*

Figure 5.1
Students working on a project

apparatus and operating it), cooperative social skills (collaborating on projects), communication skills (oral reports during informal lab meetings, writing science papers), and thinking skills (logic, induction, deduction, analysis, synthesis). Skills are learned as needed. Motivation is rarely a problem since the context makes the need for the skill obvious to the student.[1]

RATIONALE FOR USING PROJECTS

Project-based teaching supports the active learning paradigm developed in this book. Project-based science teaching, although not a new concept, has enjoyed something of a renaissance during the past 10 years. The merger of new technologies, especially microcomputer-based labs (MBLs) and the Internet, with reform efforts in science education that emphasize science as inquiry, have led to greater interest in project-based teaching. Four shifts in perspective (Figure 5.2) provide a rationale for using project-based teaching in science.

TYPES OF PROJECTS

Although projects can be done individually, those completed by teams of students generally prove more valuable. Not only do group projects reduce the workload for the teacher, but, more significantly, they emphasize the importance of group work in the learning, understanding, and doing of science. To help you decide what projects to use in a unit of science teaching and when to use them, consider the three categories of projects that follow. Note that it is quite possible to combine the categories in the development of a project. For example, you might have students build something (an airplane) and then design an experiment to study the effects of one or more variables on its motion.

[1] From Labnet: Toward a Community of Practice by Richard Ruopp et al., p. 35. Copyright © 1993 by Lawrence Erlbaum Associates, Inc. Reprinted by permission of Lawrence Erlbaum Associates, Inc.

Construction or Engineering Projects

Students build something (a cell, volcano, racing car, musical instrument). They focus on what they learned, demonstrate how the product works, and explain how they would improve on their product the next time.

Experimental/Research/Measurement Projects

Students design an experiment to study the effects of one or more variables on an object. Students model scientific procedures by presenting their results in a group report that should include these headings: "Problem Studied," "Purpose of the Study," "Method Used," "Results Obtained," and "Conclusion Reached."

Search and Find Projects

Students select a topic (global warming, mission to planet Mars, the FLU) or a scientist, and use primary and secondary resources to build a presentation board summarizing their findings. Students make use of a variety of resources, including the Internet.

USING THE GROUP INVESTIGATION METHOD

Projects can be carried out by student teams in a variety of ways. One approach that you might want to consider using is the Group Investigation Method developed by Yael and Shlomo Sharan. By means of a series of steps, students work through the various stages of their project as shown in Figure 5.3. This method places more responsibility on the student (rather than the teacher) for thinking through what has to be learned, and then figuring out how to gather the information, analyze and interpret it, and share it with others.

EVALUATING PROJECTS AND PRESENTATIONS

The best method for evaluating projects combines peer review, self-evaluation, and teacher

Figure 5.2
Project-Based Teaching: Shifting Paradigms

From an Older View	Perspective	To a Contemporary View
• Information is learned by listening to lectures from teachers, reading from texts, and answering questions.	• Nature of learning and learner	• The development of intelligence, in general, and subject matter understanding in science, in particular, is actively constructed by the individual. New knowledge is acquired in relation to previous knowledge, building on intuitive, informal experiences.
• Learning occurs individually, with little regard to context or communities.	• How learning occurs	• Learning occurs in communities of practice wherein students engage in authentic tasks in which real meaning is derived from immersion in, and conversation about, the task.
• Textbook-oriented curricula	• Materials for learning	• Subject matter presented in texts is not an end in itself but rather a means to engaging in authentic tasks and solving real problems.
• Teachers transmit subject matter through well-crafted lectures, demonstrations and other presentations.	• Role of teacher	• Teachers provide leadership in building a short-term community of learning. They promote meaningful conversation, encourage talking aloud on problems, and invite students to work collaboratively on problems and issues in science.

Richard Ruopp et al., LabNet: Toward a Community of Practice. Hillsdale, New Jersey: Lawrence Erlbaum Associates, Inc., 1993, pp. 55–56.

Figure 5.3
Steps for Projects

Stage	Teacher's Role	Student's Role
• Determine subtopics to be investigated and organize into groups.	• Introduce general topic of investigation; lead groups in discussion of topic and subtopics.	• Generate questions of interest for an environmental project; sort questions into categories; form project groups.
• Plan project.	• Help groups formulate plans; meet with groups; help find resources; and provide equipment and materials.	• Plan what to study; choose resources; assign roles; send e-mail report describing plans.
• Carry out project.	• Help with study and research skills; check with groups to monitor progress.	• Seek answers to questions; locate information; collect data; interview people; integrate findings; and summarize.
• Plan presentation.	• Discuss with class plans for presentations; organize the process.	• Determine the main thrust of the presentation; plan how to make presentation; and prepare materials for presentation (poster, video, etc.).
• Make presentation.	• Coordinate presentations.	• Present project; offer feedback to classmates.
• Evaluate.	• Evaluate learning and summarize the project findings.	• Reflect on work as group members; reflect on impact of project on understanding of science.

Figure 5.4 Rubric for the Paper Tower Project

Response	Criteria	Rating
Outstanding	Complete freestanding tower; clearly demonstrated need for base and support	4
Competent	Complete freestanding tower	3
Nearly Satisfactory	Tower has inadequate base/support	2
Assignment Not Completed	Concepts unclear; work attempted	1
Off Task	Tower not constructed	0

Figure 5.5 Holistic Rubric

Response	Criteria	Rating
Outstanding	Shows expanded thinking and clear understanding of task; clear evidence of testing models and cooperative effort	4
Very good	Completed task; acceptable conclusions; completed models; cooperative effort apparent	3
Satisfactory	Task nearly completed; conclusion incomplete	2
Fails to Complete	Failure to communicate understanding of task; task attempted	1
No Attempt	No project constructed; little cooperation	0

evaluation. Projects can be effectively assessed by means of rubrics, devices that identify evaluation criteria. Take, for example, one of the projects described in the physical science section of this chapter, called The Paper Tower. Students build a freestanding tower out of one sheet of paper. The teacher and/or other students assess the tower using the rubric shown in Figure 5.4.

See, too, the Whirlybird project described in Chapter 1, in which two rubrics were presented for use in assessing student work. The rubric shown in Figure 5.5 is a holistic rubric. This means that a single score is given for the project. The rubric shown in Figure 5.6, by contrast, is an analytic rubric, meaning that several specific criteria are developed for the project and each criterion is scored.

Figure 5.6 Analytic Rubric

Response	Criteria	Rating
Cooperative	To what extent did group members cooperate with each other to help solve the problem?	0 1 2 3 4
Content	To what extent is there evidence that the team understands the (physics) concepts behind the task?	0 1 2 3 4
Completion	To what extent did the team use the allocated time wisely?	0 1 2 3 4

PROJECTS FOR THE ACTIVE SCIENCE CLASS

The projects that follow have been organized into three categories—Earth science, life science, and physical science. These should help you to incorporate the projects into your course curriculum. In addition, detailed project descriptions have been provided so that you can present the projects clearly to your students, who can then tailor them to their own goals and learning interests. As you look over the projects, keep in mind that they are intended for small teams of "student scientists." The emphasis here is on "doing science" and on "student-directed learning." Be aware, too, that projects lend themselves to final presentations, which can take many forms in the classroom. It's best to think about the form(s) you want the presentations to take, and discuss these with students in advance. Here are some options to consider:

- Commercials
- Plays
- Debates
- Science Fair-type Presentations
- Videos
- Computer simulations
- Digital slide shows
- Web publishing: blogs, podcasts, and social networks like Facebook, Twitter, and MySpace

Earth Science Projects

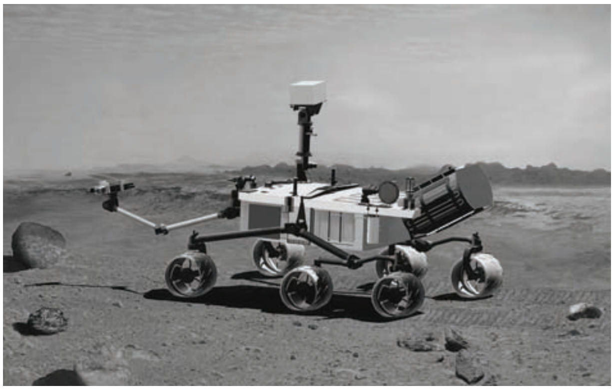
The Mars Egg Drop

The goal of this project is to design a cargo system that can safely transport an egg dropped from a high place. A drop of 3 meters to 10 meters is recommended. Provide a variety of materials, such as aluminum foil, string, polystyrene foam packing peanuts, cereal boxes, cups, tape, cardboard, and paper. Encourage students to bring in and share additional materials. Use either raw eggs or hard-boiled eggs. Students' responsibilities: Record their ideas in a journal or log; make drawings of their designs and, as they test them out, record the results; and provide explanations of the results. Be sure to establish a time period for the construction of the containers, as well as for the day of competition.

On the day of competition, each team will drop their cargo system. Assemble the students at the site from which the systems will be dropped. You should have only one team at a time present their system. They should explain their system, and why they constructed it as they did. After they drop their cargo system, they should open it in front of everyone for inspection. The egg systems that survive should compete in a second round of drops from a slightly higher elevation.

You may want to relate this project to NASA's Mars Pathfinder mission. Sojourner, NASA's Mars rover, withstood a crash landing on Mars. Packed inside a protective shield of

Figure 5.7a
Mars Science Laboratory mobile lab, rover Curiosity, can drill and analyze Martian rocks and soil. It is the newest Mars rover, and lands on the moon much like the Space Shuttle, but with a parachute and retro-rockets.



balloons, the vehicle bounced more than ten times after a free-fall final descent to the planet. Despite the rough beginning, Sojourner was able to navigate the surface of the planet for several months, sending to Earth valuable data from and dramatic images of Mars. Have students visit NASA's Mars Explorations Program Web site (Figure 5.7b) at http://mpfwww.jpl.nasa.gov
NASA's newest Mars project includes a much larger rover—Curiosity **(Figure 5.7a).**

The Erathosthenes Project

This project is named for the Greek astronomer (Figure 5.8) who accurately estimated the

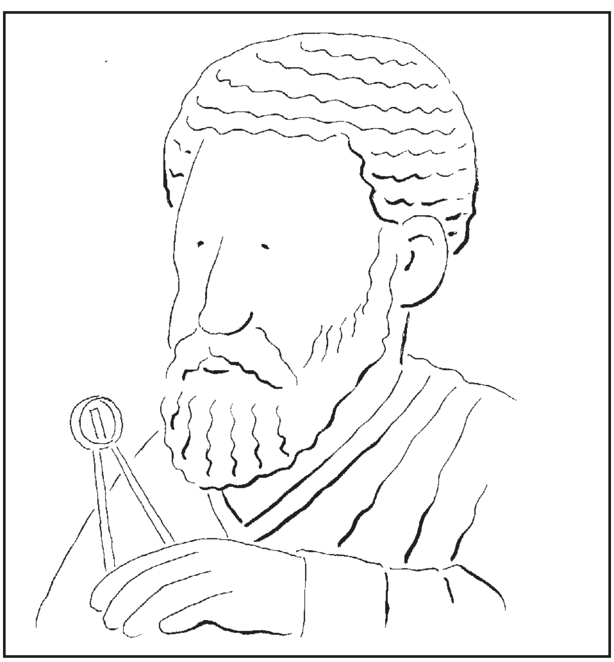
Figure 5.7b
Mars Exploration Program

This NASA program is a long term effort to explore the planet Mars. Visit the web site at http://mpfwww.jpl.nasa.gov circumference of the Earth. It is described in LabNet: Toward a Community of Practice as an Internet-based project shared by several science classes across the country.[3]

By measuring the length of an object's shadow and comparing this to the actual length of the object, students can determine the angle at which the sun's rays strike the Earth in their particular area of the world at a given time of the year. Data collected in places that are separated by at least 10° latitude can be used to calculate the circumference of the Earth. The idea is to contact, via the Internet, other science classes and then collaborate with them to try to solve this problem.

In the original experiment, conducted in 200 B.C., Erathosthenes assumed that the Earth was round and that the sun's rays were parallel. He set up a stick in Alexandria, Egypt, and measured the angle of the sun's shadow when a well at Syene (a city many miles away from Alexandria) was completely sunlit. He knew from geometry that this angle represented the angle of the Earth's center between Alexandria and Syene. He also knew that the distance between the two cities was 5,000 stadia (1 stadium = about 200 meters). From the distance and the angle he measured, Erathosthenes calculated the Earth's circumference to be 250,000 stadia, which is equal to about 46,250 km (the actual circumference is about 40,000 km).

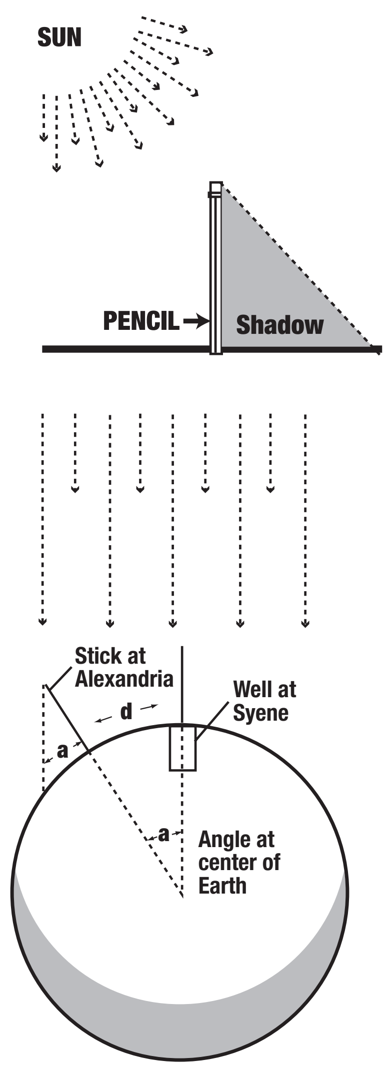
Figure 5.8
Erathosthenes



Shadows

Another interesting Internet-based project is to have classes from different locations across the globe measure the length of the shadow cast by a meter stick on specified days of the year (Figure 5.9). For a long-term project,

Figure 5.9
Shadows



[3] From LabNet: Toward a Community of Practice by Richard Ruopp et al., pp. 116– 118. Copyright © 1993 by Lawrence Erlbaum Associates, Inc. Reprinted by permission of Laurence Erlbaum Associates, Inc.

students might measure shadow lengths at 12:00 noon on September 21, December 21, March 21, and June 21. Courtesy of the Internet, schools in the Northern Hemisphere can collaborate with those in the Southern Hemisphere to compare results.

Lunar Settlement
Students design a lunar settlement out of cardboard, pipe cleaners, cotton, sand, construction paper, plastic, tape, and paint. Students need to consider the environment of the Moon and what alterations need to be made to sustain a human colony on the Moon.

Planetary Travel Brochure
Using both fact and fantasy, students design a travel brochure about one of the planets of our solar system. Students also design a transportation system used to shuttle people back and forth between the destination planet and Earth.

National Park Project
Students design a national park to demonstrate their knowledge of the environmental impact of these natural treasures. Their project should include a topographic map of the park and a description of how the park impacts the area in and around the park. Finally, students design a brochure for the park, describing its general operation.

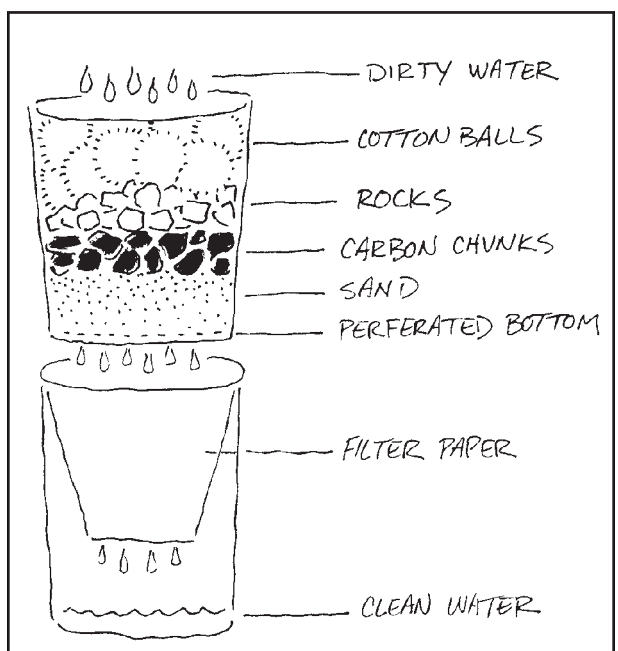
Testing the Waters
Combining local monitoring and the Internet, students set up a project where they investigate the quality of the water in a stream or river close to their home or school, then communicate with another group of students carrying out the same investigation elsewhere. Using simple monitoring equipment, students monitor the water for temperature, flow, pH, and dissolved oxygen. Students should also make qualitative observations of land use near the stream, surrounding ground cover, the odor of the stream, the color of the bed bottom, and any erosion near the stream. Students then organize their information in chart or map form. Using the Internet, students locate at least one group of students from another school (in another town, state, or country) and compare findings.

Life Science Projects

The Biodrama Project
Students write a play about the parts of a cell and the life process of a cell. The "director" selects a cast of students, who rehearse and then present the play to other groups in the school. Students might wish to explore such cell-related topics as cancer, sickle-cell anemia, or cell division.

The Dirty Water Project
In this project, students are challenged to design a method to clean up dirty water (Figure 5.10). Provide students with small samples of the following materials, which they will use to make a large container of water dirty: wood chips, sand, grass, shells, potting soil, baking soda, vinegar, pieces of newspaper, polystyrene foam. Have student teams place

Figure 5.10
Water Filter System



these materials in a large container of tap water. This done, challenge students to come up with a method to clean up the water. Provide the following materials and tell students they can use any of them to design a water treatment system: small plastic cups, beakers, sand, activated charcoal, cotton balls, filter paper. Allow students to add other materials pending your approval. Be sure students understand that they must document their work by recording their ideas in a journal.

The Insect Project
Student teams select an insect that they would like to study. Next, the students search for information about the insect, including its characteristics and habitat, traits beneficial and harmful to man, and literature about the insect. Students then create a model of their insect using any materials they wish. The model can be scaled up in size, but the various parts of the insect must remain proportional. Finally students present the results of their research to the class or another group (Figure 5.11).

The Design-an-Organism Project
Students use any materials they wish to design an organism that they think would be able to survive in a specified environment. You specify an actual environment, such as a forest or wooded area near your school, a meadow, a city park, a playground. Be sure students understand that they should be prepared to explain why they think their organism will survive. What characteristics does it have to protect it from predators, for example? What will it find to eat?

Figure 5.11
The Insect Project

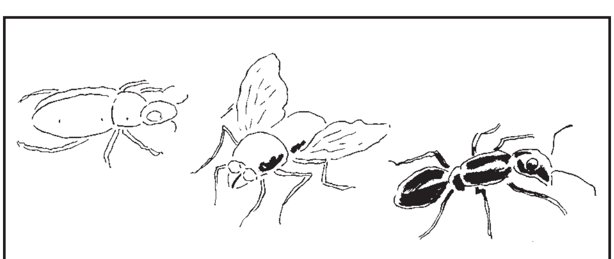
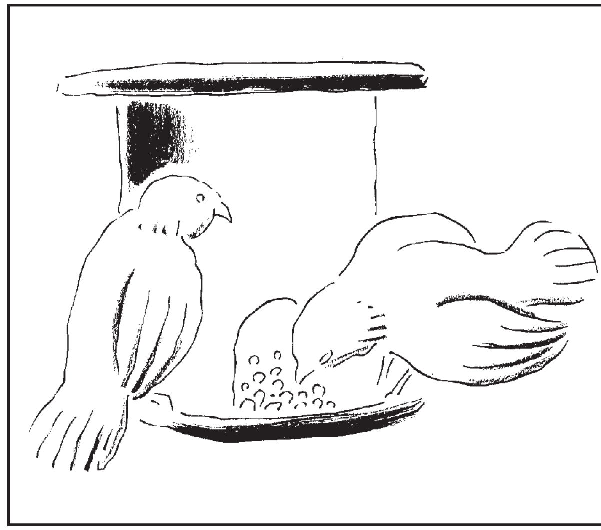


Figure 5.12
Project Feederwatch



Project Feederwatch
Backyard or schoolyard birding provides a powerful way for students to investigate the behavior and characteristics of birds in their region (Figure 5.12.) To begin, have students build a birdfeeder by consulting references on professional feeder designs. Set the feeder in an area that is convenient for observation and study. Using their observation skills, students study the characteristics and behavior of the birds at the feeder, and the environmental factors that may affect them. Students then design research questions to investigate various aspects of what they've observed. Students may wish to consult an online project called Classroom FeederWatch at http://www.birds.cornell.edu/pfw.
This project involves students in monitoring and data analysis of birds in North America.

Physical Science Projects

The Paper Tower
This project challenges collaborative teams to construct the tallest possible structure using one sheet of paper (8 1/2" 11") and 50 cm of cellophane tape (see Figure 5.13). (Each team will also need a pair of scissors.) Allow students one or two days to complete the project.

Figure 5.13
Students collaborate to build the tallest possible structure using only paper and tape in the "Paper Tower" Project.

If a one-day project, give the students about 20 minutes to experiment with various designs, testing them out as they talk aloud. Then provide fresh materials and give the students 30 minutes to build the paper tower. If a two-day project, use the first day for talking aloud and testing out designs, and the second day for the challenge contest.

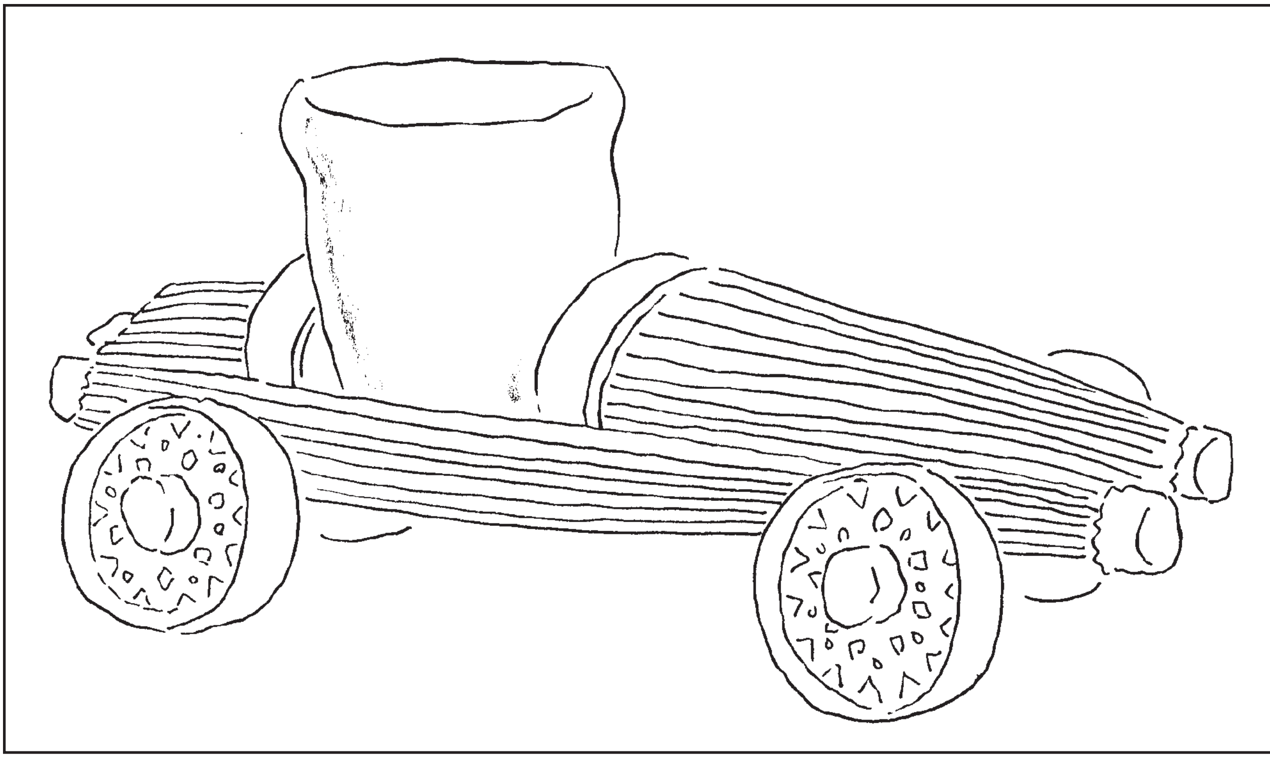
Wind-Powered Vehicles

In this project, students design and build (using household materials) a vehicle that harnesses wind energy. The entire vehicle must fit inside a 1-cubic-foot space. Any common household materials may be used, including aluminum foil, plastic wrap, milk containers, tin cans, paper bags, cardboard, toothpicks, string, paper clips, shoe boxes, cereal boxes, and straws. Parts from dismantled toys are not allowed. Materials not listed here require teacher's approval. Each team member keeps a log documenting his or her team's ideas and designs. As students work together and talk, they record and illustrate their ideas. On the actual day of construction, team members bring in all their materials. Give them 30 minutes to build their vehicle. On the next day, arrange for head-to-head matches to determine the fastest vehicle to traverse 3 feet. During the matches, each team has 30 seconds to place its vehicle in the starting block before the fan is turned on. Use rounds of single (or double) elimination to determine the winners. Award teams for neatest construction, most innovative design, and honorable mention, in addition. All entries should receive a certificate of merit.

Clay Boats

Students' challenge in this project is to design a boat that will float in water and hold the greatest number of paper clips (or any other weight you decide upon). Give students a measured amount of clay (50 grams), a container of water, and paper clips. Allow students 30 minutes to work with the clay and test out their designs. Tell students to record their ideas and

Figure 5.14
Spaghetti Car



designs in their logs, and to be ready to re-create their design during the next class session. On the appointed day, give students 10 minutes to build the boat and then demonstrate in front of the class the number of "weights" the boat can hold. As with the Wind-powered Vehicles project, give out awards for a variety of "bests," such as longest boat, most innovative design, etc. Note: If you prefer, substitute aluminum foil for the clay. Give each team an equal amount of foil.

Spaghetti Cars
Students build cars out of spaghetti and small marshmallows (Figure 5.14). They then calculate how fast the car rolls down an incline. Give students 6 pasta wheels, 25 spaghetti strands, and 10 small marshmallows with which to work. Students' goal is to build a car that rolls and can hold one large marshmallow. Set up a "downhill track" and have students test and measure how fast their cars roll.

SUMMARY

This chapter underscores the importance of "learning by doing." Project-based learning is a compelling strategy that engages teams of students to solve real problems. There are many projects in the chapter from which to choose, and you should experiment with the ones included here. Start with one that relates directly to the content of the topic that you are currently teaching. Make use of the information in Chapter 1 on cooperative learning and help your students work together as a team on the project or projects that you assign. Projects can help you attain a variety of goals and objectives. Some of them can be used to help students build models (of a cell or an atom). Others can help them learn how to design scientific investigations and make use of the Internet by assigning projects that require students to find information on current topics.

Part II Using the Internet to Enhance Science Inquiry

Chapter 6 The Online Science Classroom

This chapter will explore how the Internet can be used as an active learning tool, how to establish an online science classroom, and how the Internet can enhance science inquiry. The ideas in this chapter are based on personal experiences using the Internet with teachers and students starting nearly 20 years ago. The ideas are also based on the research that has been done over the past 20 years by a cadre of pioneer teachers and science education researchers.

Early Experiences with the Net

In the early 1990s, a team of science educators and classroom teachers from different countries collaborated and worked on a pioneering Internet-based environmental science project, the Global Thinking Project[1] (GTP). Initially, teachers from Australia, the Czech Republic, Russia, Spain, and the United States used materials developed by the GTP to enable students to use telecommunications, computers, and the Internet to observe and monitor various environmental elements (ground-level ozone, river water, soil, and solid waste), to post data, and to access all the data put online by all the participating schools. When we started the project, e-mail and bulletin boards were the Internet tools that we used to establish collaboration among students and schools around the world. Although primitive by comparison with today's Web 2.0 tools (to be discussed in detail below), the Internet brought people together from distant places around the globe to work together on global environmental issues. When the first Web browser came "online" we created the GTP Project Web site, and through it, students and teachers from the participating countries could access all of the GTP projects, post data, retrieve data, and post messages on project bulletin boards. We used video tools to conduct online conferences. Using WebCT, we held real-time chat with students from different countries. Our research showed that network science (a term used by the researchers at TERC in the Global Lab Project) was a powerful way to help students work cooperatively with each other on issues important to themselves and their communities.

We learned a lot from these early experiences, and over the years, teachers conducted workshops with colleagues to help newcomers to online learning work through the issues and problems inherent in using the Internet as a teaching tool.

Teachers in the GTP Project reported and discussed reasons for creating an online classroom and going "online." One very powerful reason is that Internet access supported teachers' existing activities and enabled them to implement new, even more authentic learning activities in the classroom. For example, students were able to ask experts in the field questions about science, and were able to search university sites for current information on almost any topic in the science curriculum In our case, students were able to carry out collaborative projects with students in other schools—schools in other states and other countries. We also found that going online resulted in finding colleagues out there on the Net who supported and encouraged the work teachers were trying to implement. This became a two-way street, enabling teachers not only to get support, but also to lend their expertise to others. In summary, when teachers hook up to the Internet they can bring a vast array of information—databases, libraries, and world class experts—into their classrooms at the speed of light.

Some Problems with the Internet

For teaching in general and for science learning in particular, the Internet has the potential for being a transformative technology. The growth of Internet-related technologies has been breathtaking, and advances appear to grow at warp speed. Some educators are concerned that these technologies have not made the rapid growth in schools that is seen in institutions outside of school. Indeed, some

[1] *http://www.artofteachingscience.org/gtp/*

Figure 6.1
Tag Cloud Presenting the Web 2.0 Elements in Chapter 6. Created using Wordle: http://www.wordle.net

educational researchers have criticized how technology has been used in schools, explaining that teachers in general use computers only occasionally, and mostly for uses limited to preparing assignments, writing reports, and searching the Internet. There is also the suggestion that technologies such as computers are used to sustain the typical pattern of teaching, and not used to make fundamental changes in learning that take into account the importance of collaboration and inquiry.

According to some researchers[2], the present "age of technology" has little effect on mainstream education. Allan Collins and Richard Halverson point out that even though lots of money has been spent on educational technology, the technology remains on the periphery of learning, and has not fully been utilized to help students learn. They suggest that even though the world outside of school has embraced technology, our schools have not yet made full use of these remarkable tools that have been shown to promote learning and intellectual growth, and that could propel schools in a new direction.

Despite this criticism of technology and science teaching, much of this chapter reports on uses of new technology that has been successfully incorporated in classroom learning environments in the context of an inquiry approach to learning. My approach in this chapter and the next is to present concrete ideas that have worked, and to suggest specific activities and projects that you can use with your students. In particular, I am interested in providing this material in a way that you can adapt to your own style of teaching, and to your own level of interest in computers, the Internet, and technology. These technologies are no panacea, but new technology is an integral part of our culture. It is here to stay, and it will continue to develop in innovative ways. This ought to suggest that these technologies should become a fundamental part of science teaching and learning, as well.

Classroom teachers, working in teams with colleagues and university science educators and

[2]*See Rethinking Education in the Age of Technology, by Allan Collins and Richard Halverson. New York: Teachers College Press, 2009*

researchers, have developed much of what is presented here. Indeed, the growth that we see in the application of the Web-based technologies has been the result of this collaborative work among different groups of professionals. I'll point out some of the pioneers, and reference their works for you to use with your own students.

Web 2.0 Tools for Science Teaching

Tim Berners-Lee, the inventor of the World Wide Web had a dream for the Web and he put it this way: "When I proposed the Web in 1989, the driving force I had in mind was communication through shared knowledge, and the driving 'market' for it was collaboration among people at work and at home."[3] Berners-Lee's dream of the Web was to link people "mind to mind," and it's a powerful mantra for how the Web could be used in the classroom. Surely in the second decade of the 21st Century, Berners-Lee dream has come true. Simply the presence of Facebook and Twitter has transformed the way people communicate with each other, and for teachers, pioneer educators and researchers have laid a path inventing tools and projects that will form the substance of the rest of this chapter.

In the recent past, with the emergence of new Web applications, a form of interaction and learning has emerged on the Internet that involves students and teachers in participatory information sharing, student-centered activity and design, and collaboration. This phenomenon has been called Web 2.0, and you will find many teachers who have incorporated Web 2.0 tools to create classrooms, and experiences that involve students in their class in collaborative work, research, and design. This Chapter introduces you three emerging pedagogical teaching practices, and a collection Web-based innovative teaching strategies that integrate various Web 2.0 applications and tools that allow teachers to connect, collaborate, and share content with their students, and teachers and students elsewhere. We start first by answering the question: What are Web 2.0 tools, and how can they be applied to the science classroom

Web 2.0 refers to using the Web in a more interactive, and social way where students can create, share, publish and work together in collaborative groups. This is a far cry from the early days when Web surfing was the main attraction of the Web.

In a groundbreaking book[4], Pam Berger and Sally Trexler have provided the research and the practical examples of how Web 2.0 tools can transform and be applied to classroom teaching. Their book is exciting, and offers an in-depth look at how Web 2.0 tools are being used by students and teachers to implement a new, more inquiry-oriented view of learning and teaching.

If you have not used or are just beginning to use Web 2.0 tools with your students, I have designed this section of the chapter with you in mind. The tools identified here are connected to the constructivist and inquiry model of teaching that you will find in all of the activities included in Part IV of the book (Chapters 9–12). Table 6.1 provides an overview of these sequences of learning, and the correlation to some of the Web 2.0 technology tools that have emerged in the last few years.

There are numerous Web 2.0 tools that you might want to consider and implement in your science course. Please refer to Sidebars 6.1 and 6.2 for brief descriptions of these tools, and links to provide further information.

The Pedagogies That Emerged From Practice

Web-based classrooms afford teachers and students the potential to think differently about their interactions with science and society. In Web-based classrooms students have ready access to the resources and people

[3] *Berners-Lee, T. Weaving the Web: the Past, Present and Future of the World Wide Web by its Inventor, London: Orion business books, 1999.*

[4] *Berger, Pam and Trexler, Sally. Choosing Web 2.0 Tools for Learning and Teaching in a Digital World, Santa Barbara, CA: Libraries Unlimited, 2010*

Learning Phase	Inquiry Teaching Strategies	Web 2.0 Technology Tools	Example of How to Use in Science Teaching
Inviting students to learn	Finding out about students' prior knowledge: EEEPs, T-Charts, Interviews, Challenges, Mapping	Edublogs, Wikispaces, blogs, Google Docs, MindMeister, Zoho Docs	Using a blog, wikispace, or Google Docs, students can post their ideas about a new topic, telling teachers what they have heard about this idea. Students can also set up an online journal using Zoho Writer.
Exploration	Exploring and researching a phenomenon, concept, or theory: inquiry, hands-on, observation, data collection, data sharing, data analysis, asking questions, constructing explanations, communicating ideas	Google, blogs, EduBlogs, Wikispaces, Google Reader, Google Docs, e-mail, project Web sites	Students monitor a local phenomenon (smog, water pollution, soil acidity), use a blog, wikispace, e-mail, or a project Web site to post their results. See http://science-as-inquiry.org and click on Projects to see examples.
Explanation	Students propose and compare ideas: discussion, debate, presentation, displays of work, model building, journaling, explaining ideas, defending models	Blogs, Google Docs, Animoto, Wikispaces, Edublogs, e-mail, project Web sites	Using a Blog, Wikispace, or Google Docs, have teams of students post the results of their research project, as well as their conclusions. Conduct an online debate using the Web 2.0 tool you have chosen.
Taking Action	Students apply their knowledge: sharing knowledge, journaling, mapping, asking new questions, taking action on science-related social issues, letter writing, posting research results	Blogs, EduBlogs, Wikispaces, Google Docs, Google, Podcast	Using a blog or a Web site developed on Wikispaces, have students design a campaign to widen the scope of the research they have done and maximize how it affects citizens in their community.

Table 6.1.
How Web 2.0 Technology Tools Can Be Applied to Inquiry and Constructivist Science Teaching.

SIDEBAR 6.1

- **Animoto**: Turns photos, video clips, and music into outstanding video productions to share via links from your wiki or blog. http://animoto.com
- **Blogs**: Diary-like interactive Web sites in which your students can post regular entries about the content in the form of text, images, and video.
- **Delicious**: This is a social bookmarking site where you can easily create an account and post all your bookmarks, and then you can link from your Web site to your Delicious bookmarks. http://www.delicious.com
- **EduBlogs**: A free blogging service for educators, enabling you to manage teacher and student blogs. http://edublogs.org
- **E-mail**: A way to exchange messages.
- **Google**: Initially a Web search program, now morphed into an array of products including Google Books, Google Earth, Google Maps, Google Images, Google Blogger, Google Docs, Google Mail, Google Reader, iGoogle (your own home page), the Chrome Web browser, and more. http://www.google.com
- **Google Docs**: You can create and share all of your documents, presentations, and spreadsheets online, and then invite others to collaborate on your "docs."

SIDEBAR 6.2

- **Google Reader**: Enables you to set up a page on Google, accessible anywhere, to track favorite sites and recommend articles to colleagues and students.
- **MindMeister**: Online collaborative mind mapping. You can see examples in this book on pages 3 and 4. http://www.mindmeister.com
- **Podcast**: A digital audio or video file that occurs in episodes, is downloadable, and can be set up as an automated feed. Many sites support podcasts. Here is a URL for Apple's iTunes Podcast site: http://www.apple.com/itunes/podcasts
- **Skype**: A software application that enables you to make voice calls and chats over the Internet, including video conferencing. http://www.skype.com
- **Wikispaces**: Web pages on which you can post, publish, and share text, presentations, projects, assignments, images, and other files. You can also set up student accounts where pupils can develop their own individual or group wikis connected to your course. http://www.wikispaces.com
- **Wordpress**: A free publishing platform where you can easily set up a beautiful Web site or blog. The Web site science-as-inquiry.org is published in Wordpress. http://wordpress.org
- **Zoho**: A suite of free tools for collaboration (chat, wiki, mail, projects) and productivity (notebook, calendar, docs, writer). All of your documents are stored online. Zoho is similar to Google Docs, and other Google tools. http://www.zoho.com

connected to the Internet. For many teachers, however, access is one of the serious challenges that can curtail the dream that Berners-Lee envisioned. Access not only means having easy technical connections to the Internet, but also knowing how to use the resources of the Internet in ways that put the student in the center of the learning process.

Teachers around the world have developed significant experience using information and communication technologies, and in this section of the chapter we'll explore some methods (pedagogies) that teachers have created. We'll call them "emerging pedagogical practices." Out of these practices, three overarching ideas emerged, and they will not only help you understand how the Internet can be a valuable resource, but will also open doors to new ways of thinking about how to use these technologies. Introduced here are three ideas:

- Computer-mediated communication (CMC)
- Computer-supported collaborative learning (CSCL)
- Mobile/wireless computing (MWC)

COMPUTER-MEDIATED COMMUNICATION (CMC)

Computer-mediated-communication (CMC) is communication between people that occurs through a variety of tools including e-mail, instant messages, and newsgroups. CMC is further enhanced with video, audio, Weblogs, and wikis. For example, teachers who use wikis[5] with their students enable them to work together to generate text online, and with a wiki's "open editing" function students can generate, modify, and change any page in a wiki Web site. Teachers use wikis to create an interactive class resource center where students can engage in discussions related to the current topic, and can seek help from their teacher or their peers. Teachers and researchers who use CMC in the classroom are able to engage their students in authentic activities that have real-life consequences.

There are many projects that use the CMC approach. In this approach, students collaborate to solve problems, often working with students around the world. One project that exemplifies CMC is WISE, the Web-Based Inquiry Science Environment within which students examine real-world evidence and analyze current scientific controversies. Access to WISE is free. A simple form is filled out, and then you have access to the WISE Web portal. One of the major sections of the site that drives home the CMC approach is the Communities page, which serves as a headquarters for teachers to team up with colleagues around the world to create or join existing WISE projects.

There are a wide range of CMC projects that you can access through WISE, and a sampling is shown below[6].

- Antibiotics: Will They Work?
- Benchmark for CLEAR Project
- Benchmark Projects for TELS
- California Earthquakes!
- Drink or Swim
- Earth Team: Something in the Air
- Genetically Modified Foods
- Heat & Temperature
- Houses in the Desert
- Plate Tectonics
- Rainforest Interactions
- Scientific Controversy
- The American Physiological Society
- What Makes Plants Grow?

COMPUTER SUPPORTED COLLABORATIVE LEARNING (CSCL)

Computer-supported collaborative learning is concerned with how students learn together with the help of computers by guiding students through ongoing interaction, with a sense of social presence, and therefore purpose. The collaborative learning approach of CSCL is similar to the collaborative inquiry strategy explored in Chapter 1.

There are many examples of projects that helped define the CSCL strategy. Project Ozone, discussed in Chapter 7, is a CSCL project drawn from one of the earlier CSCL efforts, the Global Thinking Project[7]. Global Lab, developed by TERC, was one of the earlier projects that used computers to help students collaborate on important scientific problems.

To illustrate how CSCL works, we'll use the the Globe Program[8], which has a long history (since 1994) of engaging teachers and their students doing collaborative science work over the Internet. GLOBE, which stands for "Global Learning and Observations to Benefit the Environment," has designed inquiry-based

[5] *Wikis: http://www.wikispaces.com/ Create a free K-12 wiki at Wikispaces.*

[6] *Go to this website to access these projects:http:// wise.berkeley,edu/teacher/projects/library.php*

[7] *http://www.artofteachingscience.org/gtp*

[8] *http://globe.gov*

Figure 6.2
A page from the GLOBE Web site illustrating the science explored in the program. Source: the GLOBE Program, http://globe.gov/science. Used with permission of the GLOBE Project.

investigations of the environment and the Earth system in collaboration with NASA, NOAA, and NSF's Earth System Science Projects. Figure 6.2, a screen shot from the GLOBE Web site, shows the science topics that are explored in GLOBE.

Student investigations are focused on an inquiry (or essential question). The GLOBE Student Climate Research Campaign (SCRC)[9] is an example of the scope and importance of the GLOBE projects. In this project, students will be involved in monitoring activities, events, and research activities that are inquiry-based and involve collaboration with students and scientists.

Mobile/Wireless Computing (MWC)

PDAs, smart phones such Apple's iPhone, iPads, MP3 players, digital cameras, and handheld probes together have made it possible to develop teaching strategies that enable learning to take place anytime, anywhere.

[9] *http://globe.gov/scrc*

Table 6.2
Summaries of Emerging Pedagogical Practices, Definitions, and Examples

Emerging Pedagogical Strategies		
Strategy	**Description**	**Examples in Practice**
Computer-Mediated Communication (CMC)	Communication between people using a variety of tools including e-mail, instant messaging, wiki's, blogs, Facebook, Twitter	WISE: The Web-Based Inquiry Science Environment (http://wise.berkeley.edu)
Computer-Supported Collaborative Learning (CSCL)	In CSCL teachers are concerned with how students can learn together with the help of computers	The GLOBE Program: Connecting the Next Generation of Scientists (http://globe.gov)
Mobile/Wireless Computing (MWC)	Here, interaction can occur anywhere, anytime using small handheld mobile devices that are connected to the Internet wirelessly	LabQuest: A handheld by Vernier: (http://www.vernier.com) Concord Consortium: a leader in the development of probeware and mobile computing. (http://www.concord.org/projects)

Wireless interactive network learning is due to the development of these devices. The leader in this approach to teaching has been the Concord Consortium, which has developed the technology and the inquiry-science approach that enables teachers to integrate wireless computing into their ongoing science program.

Teachers can access a wide-range of activities suitable to mobile/wireless computing. Link to http://www.concord.org/activities and you will have access to online activities by subject or grade level. An especially powerful tool for wireless computing is the iPad. With iPads or smartphones and access to wireless networks, students can be involved in inquiry-science investigations in the classroom and in the field.

Web 2.0 Science Innovations & Tools

In this section of the chapter you will find a number of Web 2.0 science innovations that support student-centered inquiry and authentic learning. In each case, I have provided specific examples, lessons, or projects that you can apply to your classroom. You will also find links to important sites that exemplify each of the innovations and tools. Table 6.3 provides an overview of all of the Web-based innovations and Internet tools that are explored in the last part of this chapter.

Mind-to-Mind Activities—Interpersonal Tools

Mind-to-mind activities are interactive and interpersonal experiences that make use of Internet hardware such as wireless computers, smart phones, and iPads, enabling multiple forms of interaction with e-mail, Wikispaces, blogs, Skype, and interactive Web sites. The reach of these activities extends from the local to the global, and can not only show students that science is inquiry but also engage them in problems that have personal and social significance.

Keypals and the Global Classroom

The electronic equivalent of pen pals, keypals interact with each other over the Internet. In the context of collaboration among two or more classrooms, teachers in many instances

Web 2.0 Science Innovations & Tools			
Category of Learning	**Innovation**	**Web 2.0 Tools**	**Curriculum Examples**
Mind-to-Mind	Keypals & Global Classrooms In the context of collaboration among two or more classrooms, keypals is a method of structuring "talk" over the Net.	e-mail, edublogs, blogs, Skype, Google Docs, Zoho Writer	ePals.com
	Telementoring and Question and Answer Sessions A way to bring students in contact with people who can serve as mentors, provide expertise, and answer student questions.	e-mail, Google, blogs	*Scientific American's* "Ask the Expert"
Information Exchanges and Virtual Learning	Network Science: Pooled Data Analysis Students research, share, and analyze data on problems of local and global significance	Google, blogs, project Web sites, Adobe Forms Central, Google Docs, Zoho Writer	Project Feederwatch BioKids Project Ozone Project Green Classroom Project River Watch
	Virtual Field Trips Students use e-mail, videoconferencing, and Web site communication to communicate with another community or with experts	Google, blogs, Wikispaces, Skype, e-mail	Journey North Antarctica Journey virtual experiences in science museums
	Virtual Classroom Course offered over the Network	Google, blog, wikispaces, Google Docs, Nicenet course management system	Virtual High School
Problem Solving	Social Action Projects Involving students in environmental, social, and ethical issues over the Internet	Google, Wikispaces, Podcast, e-mail lists, Skype, Google Docs	Salt Flats Project Flat Classrooms Project iEarn Projects

Table 6.3 Web 2.0 Science Innovations and Tools

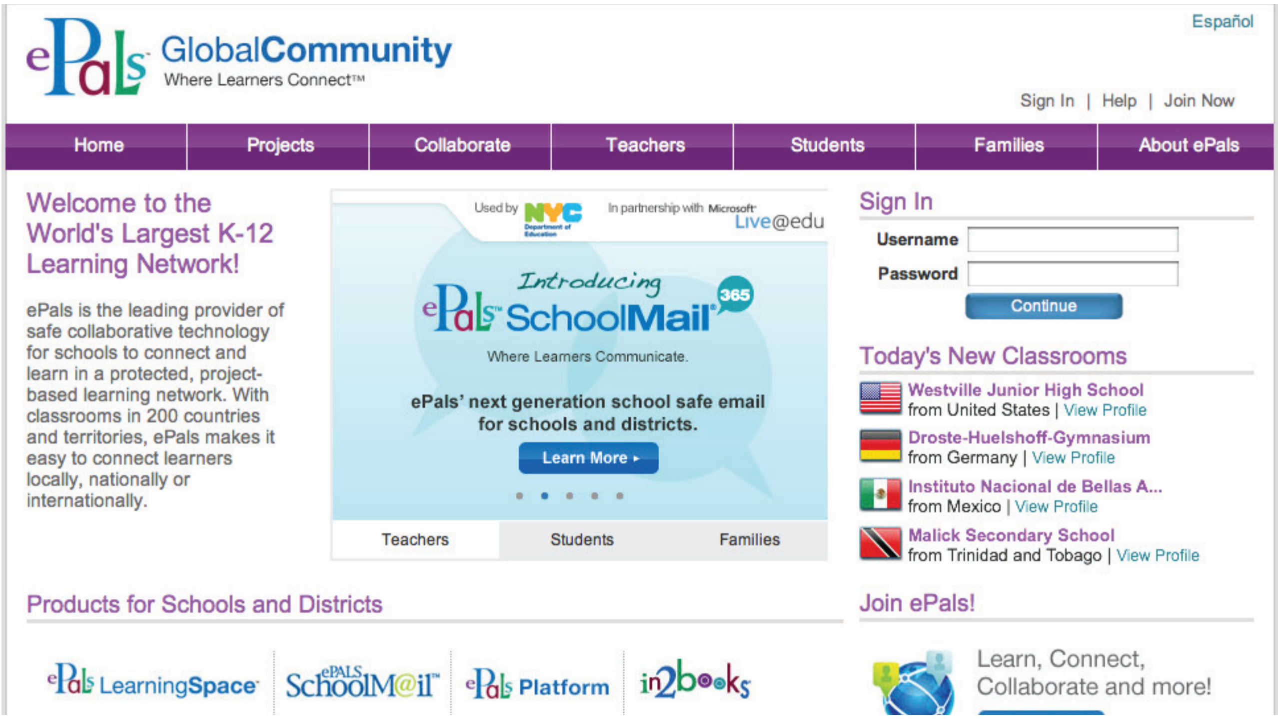


Figure 6.3
EPals enables teachers around the world to connect and participate in inquiry-based projects. Used with permission of ePals, Inc.

organize students into keypals groups, and thus use the group as the unit of collaboration. Each group can send e-mail directly to another group, or send their e-mail to a list. More powerfully, using Wikispaces, blogs, and Google Docs enables students not only to interact with each other, but also to participate in the collaborative creation of products.

As shown in Figure 6.3, ePals[10] is a global community that you can join to participate in a variety of online activities. EPals supports many activities that would be relevant to middle and high school science. Here are a few:

- The planet is heating up
- Habitats and the plants and animals that live within
- Why in the world do we need different types of maps?
- A worldwide look at natural disasters
- Water, water everywhere, or is it?
- Forecasting the future: How weather works

The ePals Web site includes all of the information, objectives, protocols, and e-mail calendars needed to join and participate in activities relevant to your curriculum.

EPals-type tools enable science teachers to involve their students with students at a distance, thus transforming their classrooms into a global classroom. For example, if you go to ePals Facebook page (http://www.facebook.com/ePals), you can click on any spot on the map shown here (Figure 6.4) to find ePals classrooms.

[10] *http://www.epals.com*

Figure 6.4.
EPals in Europe on Facebook. (http://www.epals.com/search/maps/europe) Used with permission of ePals, Inc.

Telementoring and Question and Answer Sessions

Telementoring is a way to bring students in contact with people who can serve as mentors, provide expertise, and answer student questions. One way of making use of this Web-tool is to create a task in which students interview a person you identified as a mentor or expert. For example, if you are teaching a biology class, the assignment might be to find how this person uses biology in his or her "line of work." After you have identified a list of experts and assigned them to respective groups in your class, each group needs to make contact through a series of e-mail interviews (no more than three) with their "expert." The information students obtain from their expert can be used in a presentation to the entire class. You should refer to the "Ask an Expert" site listed below to access hundreds of experts on the net. In the early days of the Net, this type of project would be carried out using e-mail or an electronic bulletin board. Today we can use blogs, Wikispaces, Google Docs, Skype, Facebook, and Twitter to engage students with experts.

NETWORK SCIENCE CYCLE AND CLASSROOM ACTIVITIES	
Data Collection at Local Site	Teachers introduce the network project; schedule of local observations is established.
Data Sharing	Observational data is submitted via Web forms.
Data Analysis	Teachers work with students to analyze local data as well as data available on the network Web site. In most cases, the data on the project's Web site can be downloaded into Excel or similar programs to create graphs and charts to help students with their analyses.
Taking Action	The final step is for students to take action on their analyses. At one level, students can publish/share their findings and conclusions by posting them on a Web site that they design. At another level, students can take action locally by sharing their findings and conclusions with the community by means of a conference, presentation, or fair.

Table 6.4
Network Science Cycle and Classroom Activities as a Way to Organize Pooled Data Analysis Projects

Experts may be closer to your classroom than you think. Starting with the local community is a good way to bring your students in contact with the human resources that are close to their homes. For example, you could do the "expert" activity described above by lining up people in your community. A more specific example is the "college students as mentors" project. In this activity, college students are assigned to groups of about four students. Each college student can be used as an online mentor to help the students with science projects.

Scientific American has an online resource, "Ask the Expert."[11] The topics that are discussed as timely and related to current events in various topical areas include energy & sustainability, mind & brain, technology, and health.

Information Exchanges and Virtual Learning

Information exchanges and virtual learning engage students in activities in which information is gathered, shared, and analyzed, often within a social context. Three approaches are presented here: network science, virtual field trips, and virtual classrooms.

Network Science: Pooled Data Analysis

Pooled data analysis activities on the Internet have a long history in science teaching. It was one of the first uses of the Internet that was embraced by science teachers. In this approach, students focus on problems that are relevant to them and their community by asking questions and seeking to answer those questions by collecting real data themselves. Often students generate a research project and then, to answer their research questions, they set up monitoring activities to collect data on an important phenomenon that is driving their inquiry. Through the process of inquiry connected to the Internet, students can participate in a pooled data analysis project, often at a global level. They collect data locally and pool their results with other participating schools. Some teachers and researchers refer to this kind of activity as "network science," implying that a community of practice in which students research, share, and analyze data is established over the Internet. The pioneers of this approach saw network science as a valuable way to get students involved in social constructivism in the context of real problems and issues, and witness the application of new technologies to science education.[12]

These collaborative research projects typically involve, first, identifying a phenomenon to investigate (the topic might be set by a project entity or agreed upon by collaborating schools) and then, second, organizing the work of participating students and schools through a "project Web site" that is interactive. Phenomena investigated could include acid rain, cloud coverage, or stream or river investigations; the possibilities are endless. At the project Web site, students can post data, retrieve data from other schools, participate in blogging, and share their thinking via related wikis or Google Docs. See Table 6.4

Many teachers use these pooled data analysis projects to involve students in socially useful Science and Technology for Sustainability (STS) projects suggested by the National Academy of Sciences, or in Science, Technology, and Society projects as suggested by the National Science Foundation (also STS). As students investigate the impact of a science phenomenon at the local level, but add their research to that of other schools across the network, their small efforts contribute to nationally significant research. Students involved in network science learn science by participating in a cycle of learning as shown in Figure 6.5.

One of the powerful understandings that emerges with students who participate in such projects is a deeper understanding of the nature of science: how science works, and how questions are not only answered, but also

[11] *http://www.scientificamerican.com/section.cfm?id=ask-the-experts*

Figure 6.5.
Network Science (Pooled Data Analysis) Internet Innovation Learning Cycle.

approached. Students learn that science is not simply the result of four or five steps, but involves messy thinking in the sense that they have to think about the validity and reliability of the data they have collected, and whether or not the data from other students can be used to help answer their questions.

One example of network science is Project FeederWatch (see Figure 6.6), a winter-long survey of birds that visit feeders at backyards, nature centers, community areas, and other locales in North America. FeederWatchers count the birds they see at their feeders from November through early April and send their counts to Project FeederWatch. Data is sent to the Cornell Lab of Ornithology and to Bird Studies of Canada. As you can tell by looking at the Project FeederWatch Web site, participants are walked through instructions for making bird observations, and then are able to enter data online as shown on the site. Running for 21 weeks beginning in November of each year, observations use a sampling technique in which participants choose three days a week to observe birds at their feeder at the top of each hour available, or perhaps for one hour in the day. Data can be entered online after each observation day.

You can then "explore data" that has been collected and uploaded to the Feederwatch Web site. You can work with your students to examine and analyze bird count summaries. Figure 6.7 shows a map of FeedWatch observation sites, and Figure 6.8 shows a sample from Bird Summary Data. Project Feederwatch is a compelling Network science project.

Another example of network science is BioKids (http://www.biokids.umich.edu), a life science inquiry program in which students collect data on animal distribution in their schoolyard using Palm Pilots and software originally used by African animal trackers. Students participate in online discussions and are able to compare their findings with those of other students. See Figure 6.9.

[12] For a full analysis of Network Science, see Feldman, A., Konold, C. & Coulter, B. Network Science A Decade later: The Internet and Classroom Learning, Mahwah, NJ: Lawrence Erlbaum Associates, Publishers, 2000

Figure 6.6
Project FeederWatch Web site. Participants observe birds at their feeder during the winter months and send their counts to Project Feederwatch. Data is available for analysis and review. Used with permission of Project FeederWatch.

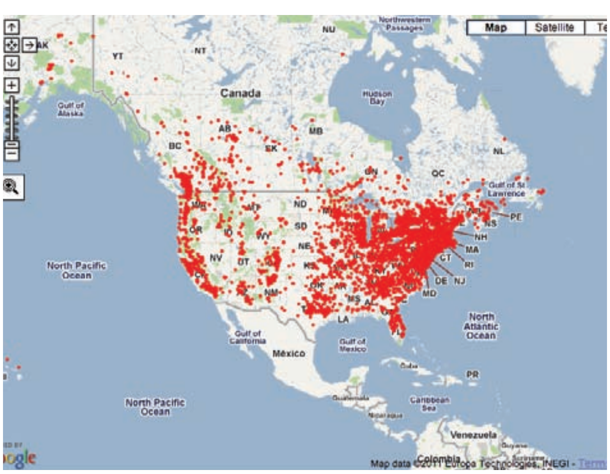


Figure 6.7
Maps are available for each season, and show the vast range of count sites in North America. Used with permission of Project FeederWatch.

The BioKids Web site provides teachers with a rich diversity of resources including a "Critter Catalog," field guides, links to general biology topics and multimedia sources, and resources for the classroom. Figure 6.10 shows the online critter catalog that you can access to help students with their observations and monitoring. Figure 6.11 shows one of the online field guides that students can use to identify organisms by tracks, marks, things animals build, and things they leave behind. BioKids is another powerful example of network science.

There are many other examples of network science.[13] Chapter 7 is devoted to a network science project, Project Ozone, which you and your students can use in your curriculum. Students learn not only about stratospheric ozone and how this ozone protects us by absorbing UV light, but also about ground-level ozone by monitoring the ozone in their own locality.

---

[13] *We have developed three network science projects that are available by going to the Science-As-Inquiry website: http://www.science-as-inquiry.org, and clicking on Projects. You will find links there to Project Ozone, Project Green Classroom, and Project River Watch.*

Bird Summaries by State or Province

2010-2011 | Colorado | Go!

Bird Count Summary for Colorado: 2010-2011

Species	Percent sites visited during count period										Average group size when seen
Alphabetic Taxonomic	Nov 13- Nov 26	Nov 27- Dec 10	Dec 11- Dec 24	Dec 25- Jan 07	Jan 08- Jan 22	Jan 22- Feb 04	Feb 05- Feb 18	Feb 19- Mar 04	Mar 05- Mar 18	Mar 19- Apr 08	
Brown-capped Rosy-Finch	< 1	< 1	1	1	1	1	0	1	0	-	77.0
rosy-finch sp.	< 1	2	3	4	3	2	2	4	2	-	39.9
Pinyon Jay	7	5	3	1	4	3	3	3	2	-	32.2
Black Rosy-Finch	0	0	0	1	0	0	0	0	0	-	15.0
Wild Turkey	< 1	3	1	3	2	0	1	1	0	-	15.0
Evening Grosbeak	11	12	12	10	9	8	12	13	12	-	11.5
Gray Partridge	0	0	0	0	0	0	1	0	0	-	11.0
Canada Goose	0	< 1	0	2	0	0	1	1	0	-	10.2
Red-winged Blackbird	21	16	16	17	14	14	20	29	32	-	9.3
House Finch	79	85	78	82	79	78	83	79	68	-	8.3
Gambel's Quail	< 1	2	2	1	1	1	0	0	0	-	7.6
Bushtit	12	14	13	16	13	13	12	16	10	-	7.1
House Sparrow	49	51	47	48	47	41	43	43	37	-	6.9
Pine Siskin	25	30	24	25	21	20	23	23	27	-	6.5
European Starling	16	27	26	35	34	36	44	44	41	-	6.0

Figure 6.8
You can access bird count data going back to the 1988-89 counting season. The table shows only part of the data for Colorado during the 2010—11 season. Used with permission of Project FeederWatch

They then pool their data with other participants in the project by posting their results on the project's Web site. Two other network science projects available through the Science-As-Inquiry Web site are Project Green Classroom and Project River Watch. To participate in any of these projects, please visit http://science-as-inquiry.org and click on "projects."

Researchers suggest that most virtual field trips are networked communities within which students in your class can use e-mail, video-conferencing, or a Web site to communicate with other community members, other communities, or experts. One example is Journey North,[14] a global study of seasonal change and wildlife migration. Students not only participate in making observations, but they also can visit a virtual field to view sightings of migrating animals that other participants have made and shared with Journey North (see Figure 6.12).

Another example of a virtual field trip is one created by teachers in a Norway eighth grade in which students followed the progress of two female explorers crossing Antarctica. More than

[14] *http://www.learner.org/jnorth*

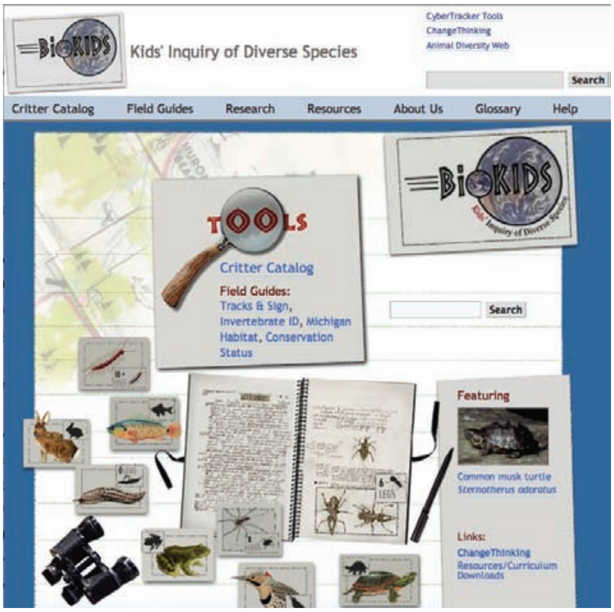


Figure 6.9
BioKids Web site (http://www.biokids.umich.edu). Copyright ©2002–11, the Regents of the University of Michigan. All rights reserved. Used with permission.

Figure 6.10
The Critter Catalog start page from the BioKids Project. Used with permission: Copyright © 2002-2011, The Regents of the University of Michigan. All rights reserved.

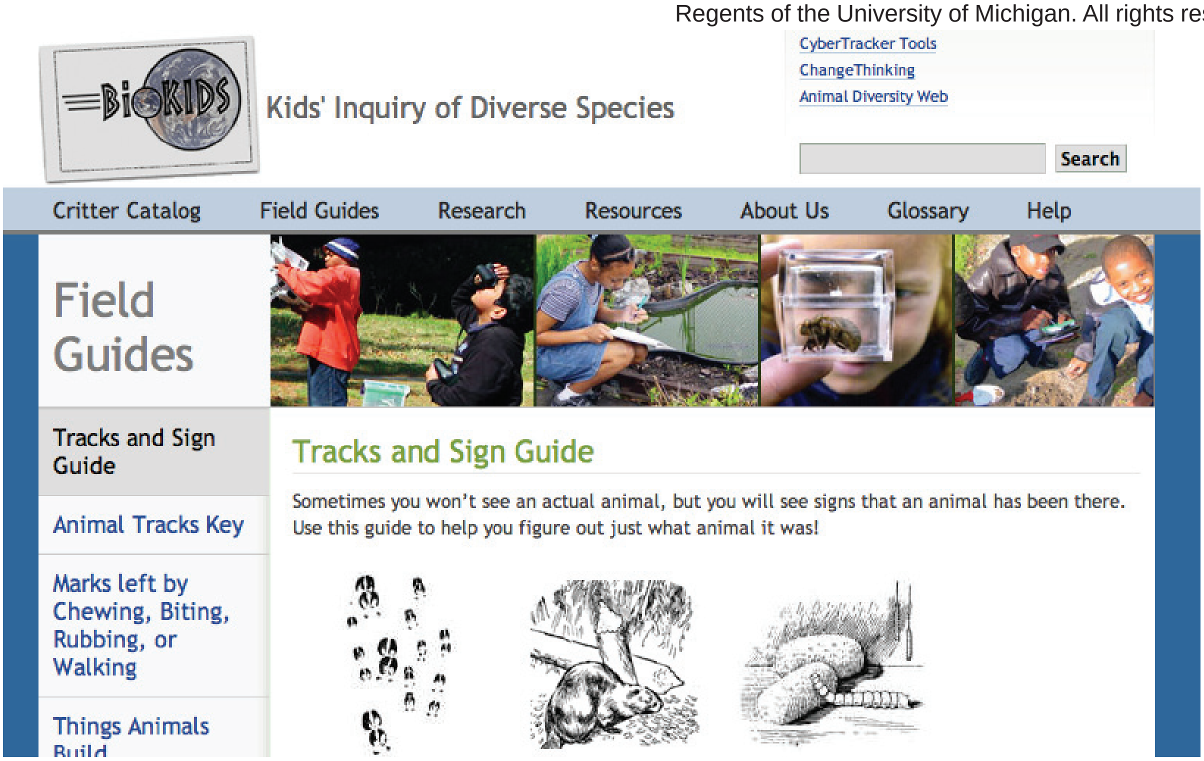


Figure 6.11
One of the Field Guides' pages from BioKids. This guide helps students make observations of animal tracks, marks, and other observations indicative of animal life. Used with permission: Copyright © 2002–2011, The Regents of the University of Michigan. All rights reserved.

SIDEBAR 6.3

Project Ozone

- A pooled data analysis project located on the science-as-inquiry.org Web site.

Project Green Classroom

- An environmental science research investigation into the "ecology" of your classroom. Web site: science-as-inquiry.org.

Project River Watch

- A network science project monitoring a local body of water. Data is pooled and retrieved from the River Watch site on science-as-inquiry.org.

Virtual Field Trips

- By visiting museums virtually, or by participating in virtual field trips sponsored by a project or a notable scientist, teachers can involve their students in real scientific experiences not otherwise available to nonprofessionals.

315 students using 20 computers connected to the Web followed a 2000–01 expedition, with the Internet giving students direct access to the explorers before, during and after the expedition. Access to the explorers was used to support student inquiry. Students in the Norway school produced a Web site of their work and, according to Anderson, during the project their site received more than 3000 visitors per week.

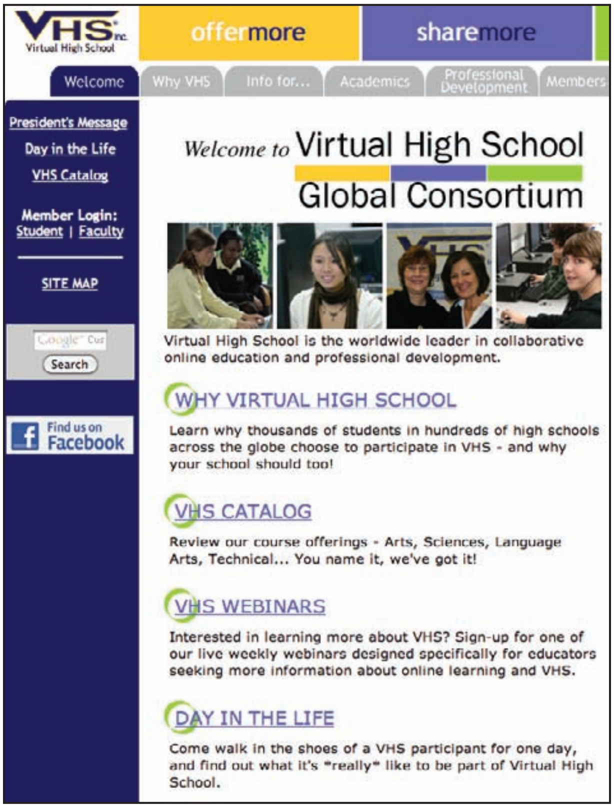
Museums of science around the world also provide access to a world of "virtual" experiences including dissections, labs, and field trips. Visit the Access Excellence Resource Center[15] to find links to a range of virtual experiences including:

- The Cell Visualization Project: http://www.kenneth-eward.com/cvp/cvpindex.html
- Virtual Courseware for Earth and Environmental Sciences: http://www.sciencecourseware.org/eecindex.php
- The Human Heart: http://www.fi.edu/learn/heart
- Microbe Zoo: http://commtechlab.msu.edu/sites/dlc-me/zoo

[15] *http://www.accessexcellence.org/RC/virtual.php*

Figure 6.12
Journey North, a global study of wildlife migration and seasonal change. ©1997–2011. Used with permission of Journey North.

Figure 6.13
Virtual High School home page. Copyright 1996—2011. Used with permission of Virtual High School.



THE VIRTUAL CLASSROOM

The virtual classroom can be used to teach courses entirely online or in hybrid form. Over the past several years, a number of local school districts, consortiums, and states have created their own virtual schools. Virtual courses allow interactive learning for any student anywhere at any time. Virtual courses have been developed for elementary, middle and high school students. You might want to visit the Virtual High School (See Figure 6.13 or visit http://www.govhs.org/Website.nsf), one of the first virtual school projects, developed in collaboration between the Concord Consortium (http://www.concord.org)and Hudson Public Schools of Massachusetts.

For the individual teacher, however, the hybrid approach is a very practical alternative in which the teacher combines online and face-to-face activities. Thousands of teachers are using this approach by creating their own interactive Web sites which have aspects of the course syllabus, activities, projects, and evaluation. Interactive Web sites can be easily created using free software. Blog software such as WordPress[16] or Blogger,[17] or wiki software such as Wikispaces[18] are easy to use and have features that enable you to create powerful interactive Web sites for your courses. You can also use Google Docs or Zoho Docs to manage your own files, and you can also make these available to your students and colleagues.

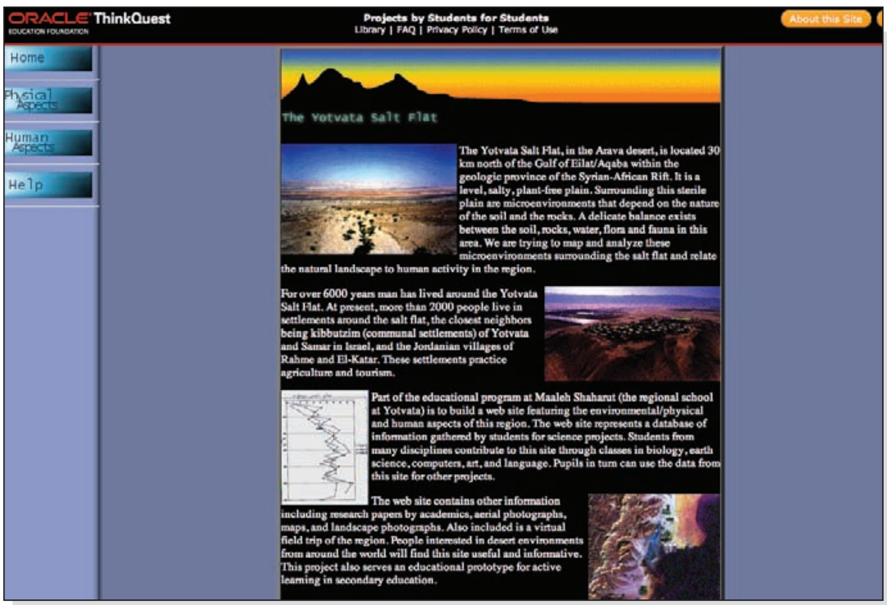
By building a Web site, you can use the resources of the Web as an assistant in your approach to teaching. This enables you to implement Web-based teaching strategies in a seamless manner. Your website becomes a learning hub that organizes the work of your course for your students. You can place links to your syllabus, an online bulletin board, and links to an assignment page, activities, and collaborative projects.

But probably more significant here is the fact that your students can be great agents and co-collaborators in the development of websites, digital video of class projects, creators of Wikispaces, participants in Google docs, generate Google Readers and Delicious links, perhaps for the benefit of younger students that might indeed teach.

The author, using either WordPress or Sandvox,[19] designed all of the webpages associated with *Science As Inquiry*. WordPress is a tool for building websites (for free) that is powerful, and easy to use. The *Science-As-Inquiry* website was built using Wordpress. I used Sandvox to develop the Network science projects (Project Ozone, Project Green Classroom, and Project Water Watch). For theNetwrok projects developed for the book, I used the Adobe Form Center[20] to create web

[16] *Wordpress, a blog or publishing platform. You can establish free, hosted websites at http://wordpress.org*
[17] *http://google.com/Blogger*
[18] *http://www.wikispaces.com/*
[19] *Sandvox is website creating software program for hte Mac. You can find it at http://karelia.com/sandvox*
[20] *http://formscentral.acrobat.com*
[21] *http://www.mindmeister.com*

Figure 6.14
The Yotvata Salt Flat Web site developed by students in the project. You can visit their Web site at http://library.thinkquest.org/C004132/plain/indexE.html.



fillable forms, and access data sites for students to download to their computers for analysis. most of these tools are free, or available at a very low cost. All of the charts and maps were made using MindMeister[21] and Word.

Creating projects on the Web is an important part of one's approach to Web-based teaching. Now that it is easy to create Web pages and put them on the Web, teachers can use Web pages to communicate with their students, students can publish the results of their work, and parents can see directly the work that goes on in your classroom. An interactive Web site organizes instruction, facilitates communication with students and parents, and motivates student effort as they realize their work will be published for the entire world to see. More and more students already have their own Web sites, so teachers can capitalize on their students' expertise. The Web's publishing capacity allows students to share their work in projects and activities, do reflective writing, design pages, write up experiments, publish the results of research projects, and even become peer teachers to their fellow students.

Problem-Solving Projects

Problem-solving projects involve students in a variety of investigations that can lead to some form of social action. Some of the earliest projects on the Web brought students together to collaborate on science-related social topics such pollution, acid rain, endangered species, hunger, and poverty. In a sense, these Internet-based projects provided the experiences and the research data for teachers to develop reliable projects that are now offered as virtual courses. To illustrate how problem-solving projects can contribute to science inquiry, we'll explore several Web-based social action projects.

One powerful use of the Web is to involve students in Science-Technology-Society (STS) projects. Social aspects of science and science-related social issues provide the basis for such activities. Social action projects can involve students in environmental issues related to endangered species, air, and water and soil pollution. Social action projects typically involve students with networked cultures and communities. In these innovations the Web is used to network disparate communities, which could include different cultures, and schools.

An example of a social action project is the Salt Flats Project (Figure 6.14), a project developed in the context of environmental studies, and involved middle and high school students (grades 7 -12) from a school located in the Southern Negev desert. The focal point of the project was the development of a major Web site, which served as a "dynamic learning center" for the whole school, and schools along the boarder between Israel and Jordon. Students developed projects on geography and geology, wrote historical texts and created visuals, designed learning activities, and provided links

Figure 6.15
The Flat Classroom Projects: http://www.flatchassroom-project.net/. Used with permission of Vicki Davis and Julie Lindsay.

relevant to the Salt Flats. Students were involved in interdisciplinary study involving, biology, chemistry, geology, computers, art and language. The project also led to collaboration of students on each side of the Israeli and Jordanian boarder involving the students in cultural aspects of the project.

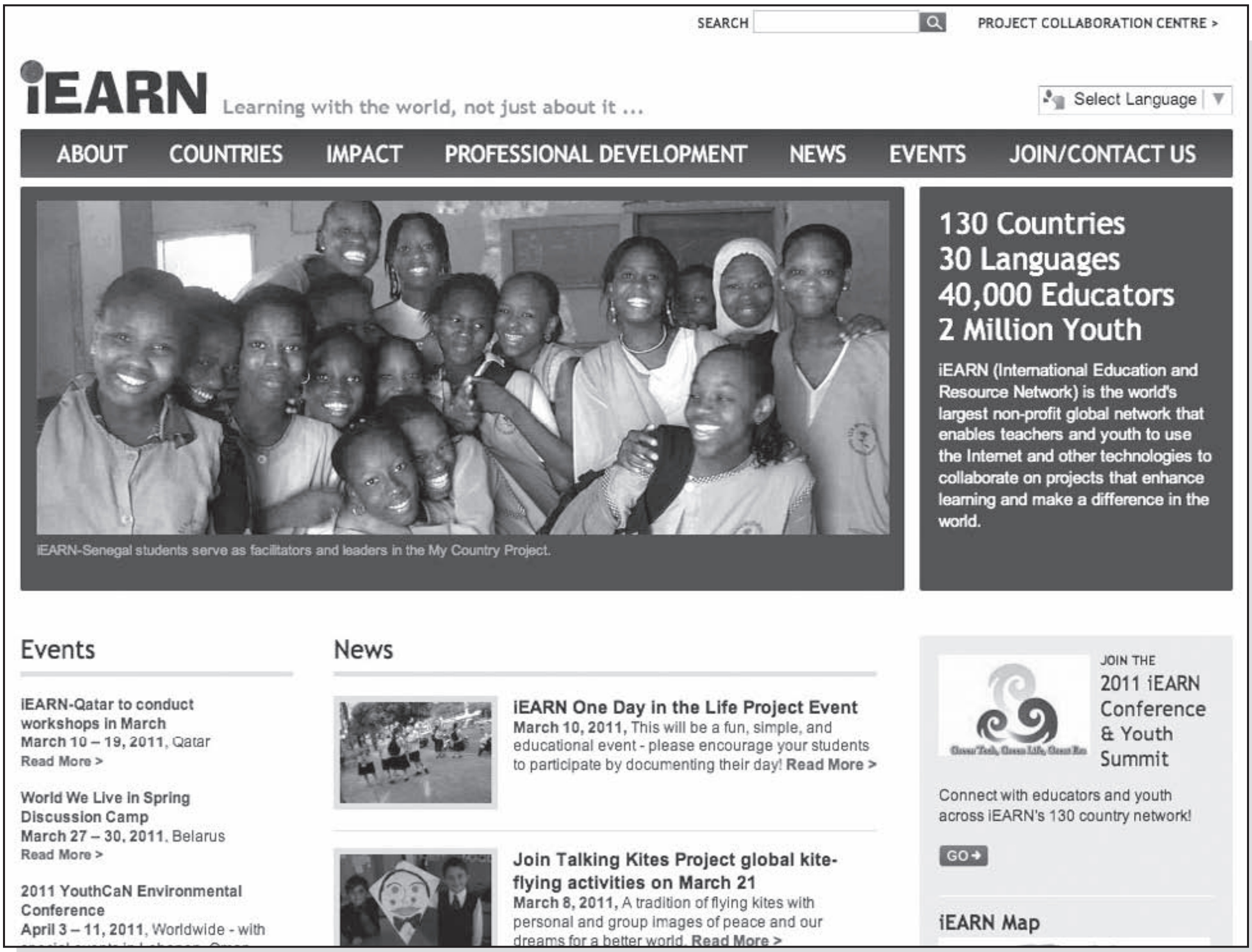
Another social action project that you might want to explore is The Flatclassroom Project developed by teachers Vicki Davis[22], and Julie Lindsay.[23] The Flatclassroom supports and encourages global collaboration. Davis and Lindsay are on the cutting edge in terms of the use of Internet-based technologies in teaching, and this project brings together teachers from around the world to share, and collaborate on classroom projects.

Many of the Network science projects introduced earlier in the Chapter focus on global problems, and encourage students to inquire into important science-related social problems. In our own work with the Global Thinking Project, we used the term "citizen-scientist" to describe the how students were engaged in searching for answers to significant science-related social questions.

One of the groups that led the way in bringing together teachers and students around the world to collaborate on various problems and issues was iEarn (International Education and Resource Network). As seen in the two figures (Figures 6.16 and 6.17) that follow, iEarn promotes interactive projects conducted in local classrooms using the Internet as the medium of global collaboration.

22 A computer science teacher in Georgia. http://coolcatteacher.blogspot.com
23 Then a teacher in Dhaka, Bangladesh, now Information Technology and E-Learning Coordinator at Beijing (BISS) International School, China. http://julielindsay.wikispaces.com

Figure 6.16
The iEarn Home Page. iEarn promotes social action projects, and brings together teachers from around the world. Used with permission of iEARN. http://www.iearn.org/



Summary

The Internet is a dynamic tool that is constantly changing. As you look back on this chapter, keep in mind that the information presented about the Internet together represents a range of tools to enhance your science teaching. The Internet is much more than a place to surf. It is a place to invent, to create, to communicate, and publish. The array of Web 2.0 tools, and Science Innovations and tools described should provide you with teaching strategies to apply to your classroom. All of the links, and projects in this chapter can found online at http://science-as-inquiry.org.

Figure 6.17
iEARN project collaboration center. Used with permission of iEARN. http://www.iearn.org/

Chapter 7 Project Ozone: A Web-Assisted Science Unit

Figure 7.1
The air that surrounds Earth is becoming increasingly polluted. In this chapter you and your students will research ground-level ozone, the principal component of smog, and try to do something about the problem.

Project Ozone is a Web-based science inquiry unit that uses the Internet to engage students in a science inquiry investigation. It consists of five interrelated activities. It was originally developed for the Global Thinking Project and is presented here as a stand-alone Internet project because it provides a good example of many of the activity structures covered in Chapter 6. The following structures will be an integral part of Project Ozone:

- **Keypals:** Students will be able to correspond with other students who are working on Project Ozone.
- **Global Classroom:** Your school will be part of a group of schools that are using the Global Classroom structure to study ozone.
- **Question-and-Answer Services:** Students will be prompted to go to "Ask-a-Scientist" sites so that, if they have questions, they can seek out the expertise of professional scientists.
- **Virtual Field Trips:** Students will be prompted to visit one or more sites on the World Wide Web that function as "virtual field trips."
- **Pooled Data Analysis:** Your students will use Web forms to pool data with other students; the data then can be analyzed and conclusions drawn.
- **Social Action Projects:** Your students will be encouraged to take action on the basis of the results of their research, connecting the work they are doing in school to social action in their local, state, and national communities.

Introduction to Project Ozone

Several summers ago, more than 200 scientists gathered in Atlanta to study how smog forms. As a newspaper article at the time pointed out, most people try to avoid dirty air, but for the researchers conducting studies of urban smog, the best environment is dirty air!

In another newspaper's editorial column, a letter urged that "the world must move faster to stop making chemicals that destroy the Earth's protective *ozone shield*."

Ozone (O3) is a gas that is found concentrated in a small layer in the upper atmosphere, and near the ground in urban areas, especially on hot days. It is a highly reactive gas with a pungent (sharp and biting) smell. It can cause serious damage to plants, and can adversely affect the human respiratory system. High concentrations of ozone pose a serious health threat not only to people with respiratory disorders, but to children and adults, especially if engaged in vigorous activity.

On the positive side, ozone absorbs ultraviolet light. The concentration of ozone in the upper atmosphere acts as a planetary shield, preventing most of the sun's ultraviolet radiation from reaching the Earth's surface. In humans, most skin cancers are associated with exposure to ultraviolet radiation. There is evidence that

SIDEBAR 7.1

Smog

A dense, discolored fog containing large quantities of soot, ash, and gaseous pollutants.

SIDEBAR 7.2

Ozone

A highly reactive gas comprising three oxygen atoms. Ozone is produced by the recombination of oxygen in the presence of ultraviolet radiation from the sun

Ultraviolet Light

Short wavelengths of light

Ozone Shield

Not really a layer, it is, however, the ozone in the atmosphere that forms a shield protecting life by filtering out harmful ultraviolet radiation.

Ozone Hole

Lower than normal concentrations of ozone in the atmosphere due to chemical reactions between ozone and chlorofluorocarbons

Ground-level Ozone

Concentrations of ozone gas near the ground

the protective ozone layer above the Earth is deteriorating, and that in some regions, an ozone *hole* has been detected.

GOALS OF PROJECT OZONE

1. Students will explore air pollution by investigating the nature of ozone and how it is formed in the troposphere and the stratosphere.

2. Students will design studies to explore ground-level ozone in their cities and towns, and then use these results to collaborate with other schools.

3. Students will use the Eco-badge system to monitor ground-level ozone.

4. Students will post data to the Project Ozone website and analyze the Project Ozone database.

5. Students will network with other schools by accessing the Project Ozone Web site.

THE PROJECT OZONE WEB SITE

To help you track your progress and stay in touch with others working on Project Ozone, access the Project Ozone Web site at http://www.science-as-inquiry.org/ozone. You can use the site to direct the work of your students in a variety of ways. For example, when students are ready to "post" their data (Figure 7.2) so that other students around the globe can benefit from their work, they can do so from the Data Sharing link. One of the links on the Project Ozone Web site (Figure 7.3) is "Data Sharing." Clicking on this link will take you to an ozone data form that your students can use to post data. You will also find links to retrieve others' data and links to important environmental science sites related to Project Ozone.

SPECIAL MATERIALS FOR PROJECT OZONE

There are several items that you will need to have available for Project Ozone. Not all the materials that you will need are listed on Figure 7.4, only the ones you are most likely not to have on hand and thus may need to order.

Additionally, on page 158 and following, you will find suggestions for a Project Ozone Mini Learning Log, a Project Ozone Portfolio, and a certificate you can photocopy and present to students when they complete Project Ozone.

ACTIVITY 7.1 OZONE: THE GOOD AND THE BAD

In this introductory activity, students explore what they know about ozone. Then they learn to differentiate between ground-level ozone (the bad ozone) and ozone in the upper atmosphere (the good ozone).

Objectives:

- To discuss prior knowledge of ozone
- To generate questions about ozone
- To explain the difference between ground-level ozone and ozone in the upper atmosphere

Figure 7.2
Project Ozone Learning Cycle Map

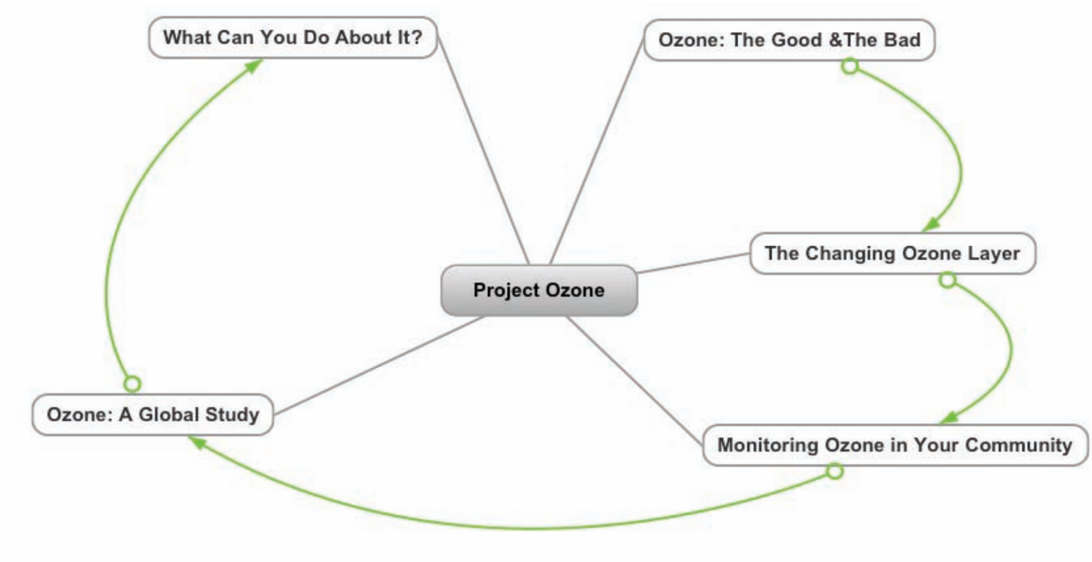


Figure 7.3
Project OzoneWeb Page:
http://www.science-as-inquiry.org/ozone

Figure 7.4 Project Ozone Special Materials List

Item	Supplier
Eco-Badge Kit. Chemical strips to monitor ozone. One kit contains 30 eco-badges and a color card. Approximate cost: $45 per kit.	Vistanomics, Inc., http://www.ecobadge.com
Hand-Held Wind Measurer. Sturdy device to measure wind. Approximate cost: $15 per measurer.	Forestry Suppliers, Inc., http://www.forestry-suppliers.com
Psychometers. Wet and dry bulb thermometers to measure humidity. Sold as a kit containing five psychrometers. Approximate cost: $20 per kit.	Forestry Suppliers, Inc., http://www.forestry-suppliers.com

Materials: Newspaper and science magazine articles about ozone, sections from science texts about ozone, chart of the atmosphere, large sheets of paper, colored pens or crayons

Web Site Information: The Project Ozone home page has information about ozone, as well as links to important ozone sites on the Internet.

Advance Preparation: Well in advance of doing this project with your class, start collecting newspaper and magazine articles on ozone. Look for articles that focus on any of these topics: ozone, ozone hole, smog. Also, visit the Project Ozone home page, where you will find relevant information. (http://www.science-as-inquiry.org/ozone)

Procedure:

1. Divide your students into teams of four students each, and give each team a large sheet of paper and colored pens or crayons. Have students draw a picture showing the Earth and the first two layers of the atmosphere (the troposphere and the stratosphere), as well as a satellite in space and the sun in the background (Figure 7.5).

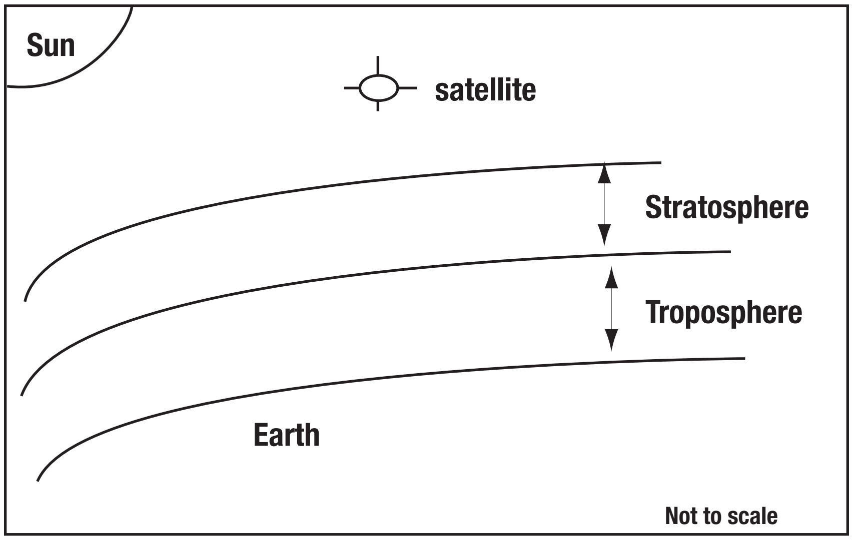
2. Once students have drawn their pictures, give them the following instructions:

> *In the next 10 minutes, I want you to work as a team to discuss what you know about ozone. Use the picture to draw and explain what your team knows. In your drawings and explanations, please try to use the following ideas, as well as others that you may know: ozone, smog, car emissions, ultraviolet light, people, plants.*

3. Walk around the room and assist the students as needed. At the end of the 10 minutes, tell the students that you are going to randomly call on one person from each group to show the group's drawing to the class and briefly explain it. Give the students another 2 minutes to put their heads together to make sure everyone in the group can explain the picture if called on to do so.

4. Randomly call a number (draw a card from a set numbered 1 through 4) and ask the

Figure 7.5
Two Layers of Earth's Atmosphere



person from each team who has that number to stand and explain his or her team's drawing. Remember, this activity is intended to give you insight into what the students already know about ozone. Students will exhibit a range of knowledge.

5. When you have finished hearing the reports, ask a member from each team to mount the pictures on the wall in the classroom. Keep these pictures visible throughout the project, and refer to them when appropriate.

6. To help students distinguish between and identify different problems associated with "bad" ozone (ground-level ozone) and "good" ozone (ozone in the upper atmosphere), provide each team of four with two "think pieces." The "think pieces" should be no more than two pages long and, as the name implies, should be used to get the students thinking about the topic under consideration: ozone. Use the "think pieces" that are included in Figures 7.6a and 7.6b or draw on the articles that you have collected from the newspaper or science magazines or have downloaded from the Internet. Whatever you choose, be sure the "think pieces" discuss stratospheric and tropospheric ozone.

7. Further divide the groups of four into pairs so that the pairs have one "think piece" between them. Then have them follow these steps:

a. One student in each pair reads the "think piece" to his or her partner.
b. Following the reading, each pair works by itself to analyze the article. Pairs might make a drawing or write a brief summary of what they discussed.
c. Each pair presents its drawing or summary to the other pair.
d. The groups of four then make a T-chart summarizing the differences between "good" and "bad" ozone.
e. When the teams have finished, post the T-charts in a prominent place in the classroom. Then summarize the work the students did on the "think pieces" by discussing the following concepts:

- Tropospheric (lower atmospheric) ozone is produced when the gases given off from burning fossil fuels combine with sunlight. The result is ozone, or smog.
- More data is needed on the sources, patterns, and effects of tropospheric ozone.
- Lower atmospheric ozone is found in

Figure 7.6a
Think Piece 1

Think Piece 1

Stop Making Chemicals That Destroy the Ozone Shield

According to some scientists, global air pollutants are threatening to destroy the Earth's protective shield against the harsh ultraviolet rays of the sun. This shield, located in the thin upper reaches of the atmosphere (known as the stratosphere), consists of ozone.

The chief culprit threatening the ozone layer is a family of industrial compounds known as chlorofluorocarbons (CFCs). These chemicals include coolants used in air conditioners and refrigerators, as well as chemicals used in hair sprays and dry-cleaning fluids. The CFCs released into the atmosphere eventually reach the stratosphere, where they react with ultraviolet photons. The UV photons break the CFCs down, releasing a free chlorine atom that then attacks ozone molecules. According to some scientists, this reaction is devastating to the ozone layer.

The sudden discovery of the ozone "hole" over Antarctica showed that the concern was real. Studies indicated that the concentration of ozone in a column over the South Pole had decreased by 40 percent, and that similar "holes" had been detected since then.

More than 40 nations met in Montreal, Canada, to adopt an agreement limiting the release of CFCs into the atmosphere. The Montreal Accord called for a 50 percent cut in CFCs by the year 2000. Soon after the Accord was reached, evidence showed that the ozone shield was being destroyed even faster than predicted. So, in 1990, a revision to the Montreal Accord was written, calling for the complete banning of CFCs.

high concentrations in many of the urban centers of the Earth.

- Stratospheric (upper atmospheric) ozone is formed when ultraviolet radiation brings about the breakup of O_2. The free oxygen combines with another molecule of oxygen to form O_3 (ozone).
- Over a long period of time, the concentration of ozone in the stratosphere has increased enough so that a protective shield has formed. This screens out almost all of the ultraviolet radiation reaching the Earth.
- Presently, there is a concern that certain chemicals called chlorofluorocarbons (CFCs) released into the atmosphere in recent years are reacting in the stratosphere by breaking down in the presence of ultraviolet radiation. The free chlorine atoms that are released in this process attack ozone molecules, breaking them into oxygen and chlorine oxide. This process is responsible for the depletion of the ozone layer, and has resulted in the presence of a hole in the ozone layer over the Antarctic during spring.
- Depletion of the ozone layer could result in an increase of ultraviolet radiation reaching the Earth's surface, which would cause damage to nearly every form of life.

Optional Extensions

1. Have your students keep a scientific log or journal of their work on Project Ozone. Students can collect articles and relevant newspaper clippings about ozone, as well as keep track of their work on the project. (For more

Figure 7.6b
Think Piece 2

THINK PIECE 2

Researchers Study City Smog

Several years ago, more than two hundred researchers descended upon the city of Atlanta to study how smog forms. As one of the chief researchers said, "To study smog, you've got to have ozone." And ozone they had. The days that they were in Atlanta were hot and muggy, just the right conditions for the formation of ozone.

According to scientists, ozone forms at ground level when hydrocarbons and nitrogen oxides from factories, automobiles, and trees react in the presence of sunlight on hot, sunny days when the air is stagnant.

Ozone formed in one location may be blown by the wind miles away to another location and cause serious health problems there. Ozone flowing from cities may do enormous damage to crops and forests in rural areas.

The scientists in the Atlanta study were trying to learn more about how ozone forms and how ozone from Atlanta impacts the surrounding areas.

According to one report, the researchers were bombarding Atlanta's skies with laser beams, high-altitude balloons, and helicopters. Air samples were being collected at 14 locations in the city on a 24-hour basis for the eight-week study.

Ozone is a growing problem, not only for urban areas, but for rural areas too, where winds carry the polluted urban smog (the chief constituent of which is ozone). In the Atlanta study, monitoring sites have been placed "upwind," to see what the air is like before it reaches Atlanta, and "downwind," to measure the air that flows out of the city. Scientists want to know what the effect is of the city's dirty air on surrounding areas. Another monitoring site is set up in the Fernbank Forest, a preserved area in the middle of the city. Measurements are being made of the hydrocarbons being released from trees.

More information is needed on ground-level ozone, and you, like these researchers, can begin to study the ozone patterns in your community and share your results with others.

about student logs, see the information at the end of this chapter.)

2. Students might like to produce a newsletter on ozone. Newsletters typically are short—perhaps two pages—and summarize interesting ideas about a topic. A Project Ozone Newsletter could be shared with other students in school, and over the Web. Newsletters can easily be published on the Web using Wikispaces.com

3. You and your students might want to work together to create an "air pollution" or "SmogWatch" Web site. Be sure to make it known to other schools by posting a note on the Project Ozone blog at http://www.science-as-inquiry.org/ozone

4. Provide students with a set of questions similar to the ones shown in Figure 7.7 (and accessible from the Project Ozone Web site) and send them on a virtual scavenger hunt.

ACTIVITY 7.2 THE CHANGING OZONE LAYER

In this activity students explore the nature of the all-important ozone layer, which, as they have learned, protects the surface of the Earth from the ultraviolet radiation of the sun. They discover how ozone is produced in the upper atmosphere and what appears to be causing the deterioration of the Earth's protective layer. In addition, students discuss ways of curbing this trend and, in the optional extensions, explore a means for detecting total-column ozone levels.

Figure 7.7

Project Ozone Scavenger Hunt Question Sheet

Using the Internet as your source of information, find answers to the following five questions. Make sure that you provide not only an answer, but also the site from which you obtained the information.

1. What are the six "common pollutants" that the EPA uses as indicators of air quality?

   Answer: ______________________________

   ____

   Source: ______________________________

2. What is a nonattainment area, as defined by the EPA's Clean Air Act of 1990? To what extent is your locality a nonattainment area?

   Answer: ______________________________

   ____

   Source: ______________________________

3. What are at least two human health problems associated with high levels of ground-level ozone?

   Answer: ______________________________

   ____

   Source: ______________________________

4. How is ozone produced in the Earth's lower atmosphere?

   Answer: ______________________________

   ____

   Source: ______________________________

5. Scientists refer to two types of ozone: good ozone and bad ozone. What does this mean?

   Answer: ______________________________

   ____

   Source: ______________________________

Objectives:
- To explain how ozone is destroyed by CFCs in the stratosphere
- To identify ways of curbing the deterioration of ozone
- To discuss ways of detecting and measuring ozone (total column)

Materials: Aerosol spray can, set of polystyrene foam spheres or a variety of colors of clay to make molecular models

Web Site Information: From the Project Ozone Web site, students might take a virtual field trip to investigate upper atmospheric ozone and its depletion by visiting the EPA Web site (Figure 7.8) at http://www.epa.gov/ozone/strathome.html/

Procedure:
1. Divide your students into several small teams. Begin the lesson by showing an aerosol spray can product, and spraying a small amount into the air. Then say: "Some of the chemicals in spray cans can affect the ozone layer. How can this be?" Give students a few minutes to discuss in their groups what they know about this statement and what might be creating the problem.

2. Explain to students that, over millennia, a layer of ozone (O_3) (see Figure 7.9) has built up in the atmosphere as a result of the interaction of photons of ultraviolet light and oxygen (O_2), as shown in the chemical reaction given in Figure 7.10. This reaction is one you might refer to as the ozone formation cycle. Point out that the ozone in the stratosphere absorbs ultraviolet radiation and accomplishes two things: it shields the Earth from dangerous ultraviolet photons and it participates in the ozone formation cycle, in which more ozone is produced when an ozone molecule is broken down as it absorbs photons.

3. Explain to students that the concentration of ozone in the stratosphere is very small. If it could be compacted and brought to the surface of the Earth, it would be a layer about 3 mm thick. Explain to students that chemicals produced by human activity now endanger the ozone layer. Of greatest concern are the molecules known as CFCs (chlorofluorocarbons). CFCs are chemicals typically used in hair sprays, refrigerants, and cleaning fluids. Structurally, they are very stable; consequently, they do not have to be replaced very often. While this makes them practical to use, it also means that if they are released into the environment, they will remain there for a long time.

In the mid-1960s, using ground-based and satellite measuring devices, scientists determined that the total-column ozone over the Antarctic had decreased by 40 percent in a single year. Total-column ozone is a measure of the amount

SIDEBAR 7.3

Chlorofluorocarbons (CFCs)
A family of gases made by humans and used as refrigerants that have risen into the atmosphere and destroyed molecules of ozone

Ozone Layer
A layer of ozone gas in the upper atmosphere that protects life on Earth by filtering out harmful ultraviolet radiation from the sun

Photons
A quantum of light radiation

Hydrocarbons
Compounds consisting of carbon and hydrogen and the major consitutent of oil and natural gas

Nitrogen Oxides
Compounds comprising nitrogen and oxygen

Figure 7.8
Ozone Hole Map. Darker area means less ozone, lighter areas more ozone. The darker area outlines the ozone hole over the Antarctic. The scale shows total ozone in Dobson units. Note that the columns beneath the dark areas show readings of 110 Du vs 440 Du in other area.
(http://www.nasa.gov)

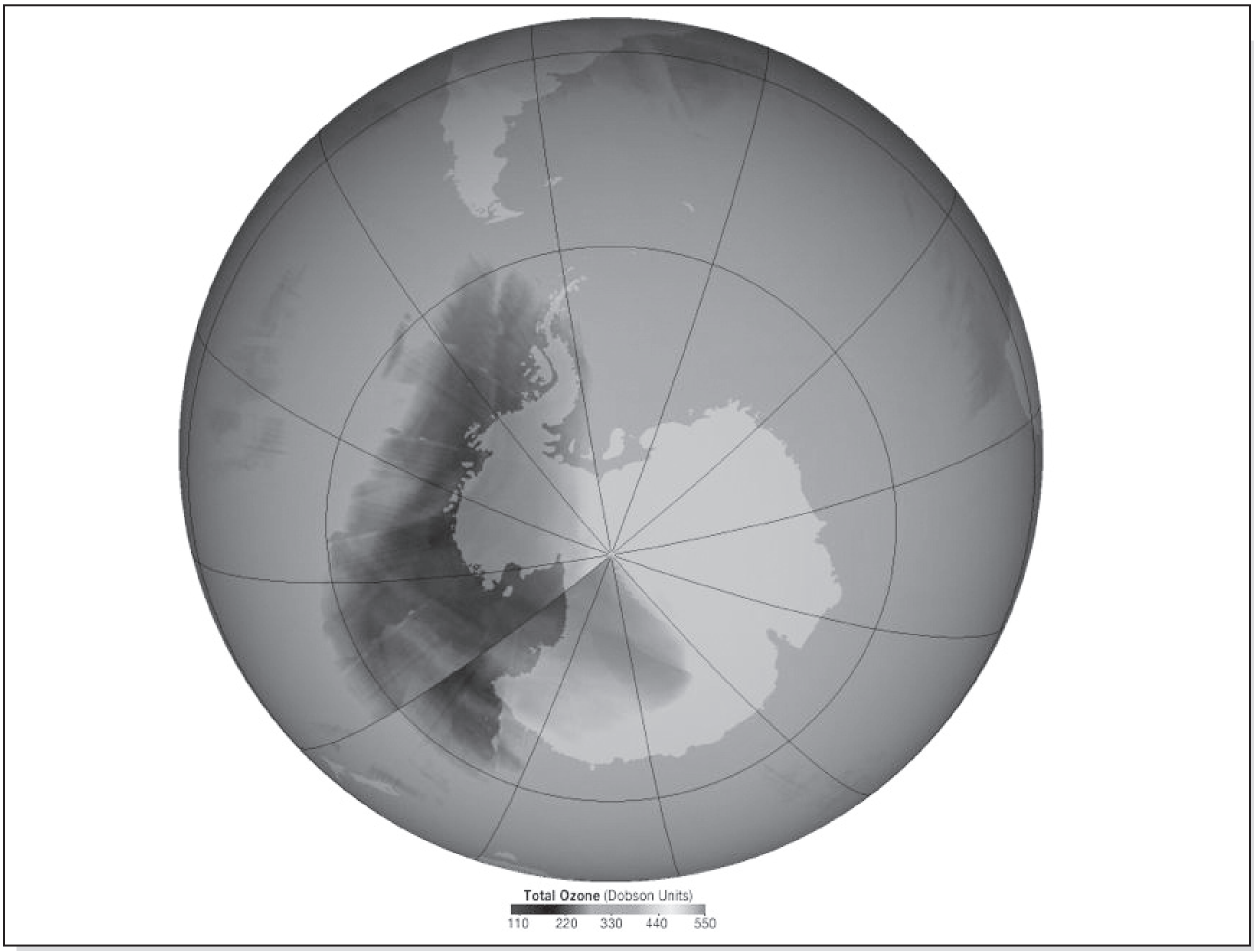


Figure 7.9
Buildup of the Ozone Layer

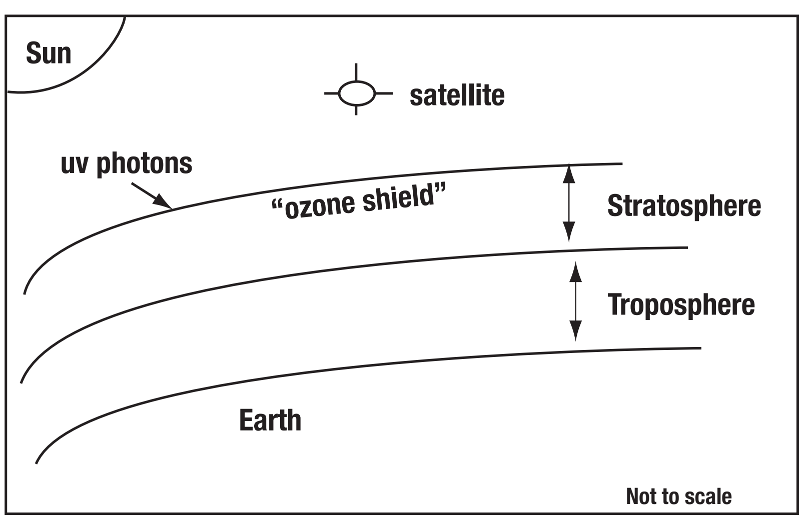


Figure 7.10
How Ozone Is Created in the Upper Atmosphere

$$O_2 + \text{Ultraviolet photon} \rightarrow O + O$$

$$O_2 + O + M \rightarrow O_3 + M^*$$

$$O_3 + \text{Ultraviolet photon} \rightarrow O_2 + O$$

M* = A molecule that is needed to take away the excess energy in a reaction.

SIDEBAR 7.4

Photochemical Reactions

Reactions in the atmosphere that take place between air pollutants in the presence of sunlight

of ozone in a column of air from the ground to the upper atmosphere. This led to the concept of an "ozone hole," a concept that has reappeared several times since that time. Then, in the late 1970s, scientists reported that CFCs that drift into the stratosphere react with ultraviolet photons, releasing chlorine atoms that attack ozone molecules (Figure 7.11). They predicted a further depletion of the amount of ozone if large amounts of CFCs drifted into the stratosphere.

In the stratosphere, the reaction that continues to concern scientists appears in Figure 7.12. It shows what happens to a CFC molecule—normally made up of 1 carbon (C), 2 chlorine (Cl), and 2 fluorine (F) atoms—in the presence of UV light. Specifically, a photon of ultraviolet light (UV) breaks the bond holding one of the chlorine atoms to the CFC molecule and a chlorine atom is released. It reacts with ozone, destroying the ozone and creating another molecule that can, in turn, react with oxygen to produce free chlorine, which can attack another ozone molecule. Thus an individual CFC molecule can end up destroying many ozone molecules.

4. To help students understand these processes, give them a number of polystyrene foam spheres (or clay) and have them make the following:

- O (one sphere)
- O_2 (two spheres of same size)
- O_3 (three spheres of same size)
- CFC (three different spheres: 1 carbon, 2 chorine, 2 fluorine)
- UV photons (very tiny spheres)

Then have the students use the spheres to replicate the following reactions:

- The way ozone is produced in the atmosphere
- The way ozone is destroyed in the atmosphere

Once finished, have the teams display their models and explain their creations.

5. Ask students to talk about the implications of these *photochemical reactions*. How do they impact students' lives?

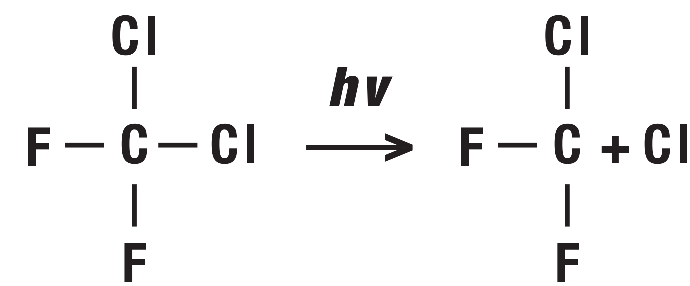
Optional Extensions

1. Have students visit the Project Ozone home page and the links there to other resources devoted to the study of the problem of ozone in the stratosphere (ozone hole, ozone depletion). Then have them do a search of the literature in the school media center and find several articles on the topic in science-oriented journals or magazines. How do the reports compare?

Figure 7.11
Chemical Reaction in Which Chlorine Reacts with Ozone

$$ClO + O_3 \rightarrow ClO + O_2$$
$$ClO + O \rightarrow Cl + O_2$$

Figure 7.12
Photochemical Reaction in Which UV Breaks Down a CFC Molecule



2. Students living in the northern hemisphere might want to collaborate with their counterparts in the southern hemisphere—especially those living in Australia and New Zealand—where ozone depletion is a very real problem. Students could share information and agree to collaborate in the sharing of total-column ozone data.

3. Students might find it interesting to explore ways at the personal, local, regional, and global levels for dealing with the problem of ozone depletion. What actions might and should be taken, and why would they be effective?

ACTIVITY 7.3 OZONE IN YOUR COMMUNITY

In this activity, students explore ground-level ozone in their community by using the Eco-Badge, an ozone test-strip monitoring system. Students set up monitoring sites in order to make inferences about ozone levels in the greater area. They use the Internet to post their data on the Project Ozone Web site.

Objectives:
- To conduct experiments to determine levels and patterns of ozone in the local community
- To analyze the data and present it in graphical and map form

Materials: Eco-Badges (Figure 7.13), ozone colormetric chart, hand-held wind measurers, thermometers, psychrometers, plastic tape, acetate sheets, clock, map of the city and surrounding towns, markers, small plastic bags.

Web Site Information: Show students the Project Ozone website and point out to them the link for Data Sharing. Also point out the link for Data Access, and explain that the two links enable them to share their research as well as access the research of other schools.

Procedure:
1. Show your students a topographic or road map of your region, and explain to them that they are going to study ozone in the local community. To do this, they are going to set up some monitoring sites (students' homes make

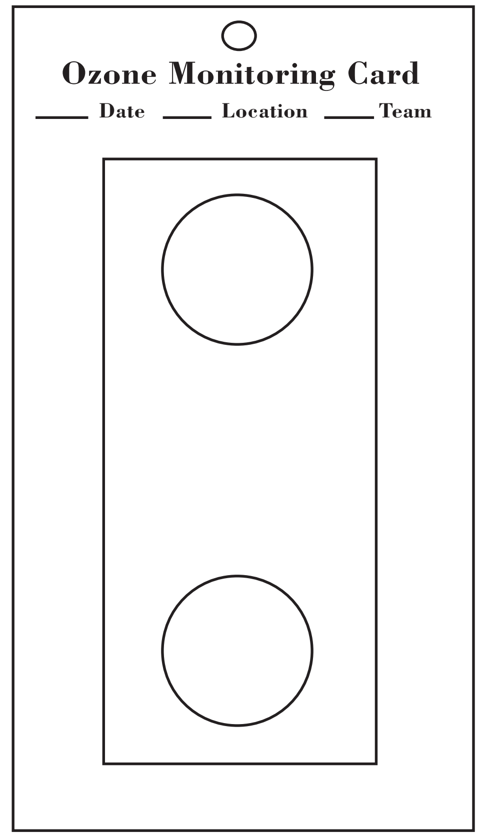
suitable sites), and then collect data on ozone levels for a short period of time. The purpose of the study is to measure ozone concentration levels and correlate these with local weather conditions—especially temperature, wind direction, and sunlight. Explain to students that their work will contribute to a better understanding of ozone in the local community and, at the same time, help them understand how ozone forms and its patterns of concentration.

2. Divide students into four-member research teams. Make each team responsible for at least one ozone monitoring site. Suggest that since the students live varying distances from school, using their homes as sites will expand the region that the class can monitor. In addition, one of the sites should be the school. Once each team has agreed on a site, the site should be identified on a map of the community. A good highway map of the area will do; however, if you can, try to get a topographic map of your community. Place the map on a wall and use markers to identify the location of the sites.

3. Describe for students how the ozone test strips are used. Basically, begin by taping the ozone test strip onto a small index card (see Figure 7.13). Since the chemical on the test strip is activated when it is exposed to the air, students must work quickly. If the teams are going to do a 1-hour test, you can cut the strips in half and give students only the top part of the strip (the 1-hour test
circle). (In this case, just half the strip would be taped to the card.) Copy this template onto card stock. Students can tape the Eco-Badge to the card, and use it as a device to monitor ozone.

Alternatively, you can cover the test strip with a piece of clear acetate. Cut small holes the size of the two test sections and tape the acetate directly over the ozone test strip. Cover the 1-hour test section with one of the circles of acetate. This way, students can run the 8-hour test (bottom part of the strip), and wait to do the 1-hour test later.

Figure 7.13
Ozone Monitoring Card



Students then place the cards in the monitoring locations that have been selected. When they do so, they should observe the temperature, humidity, wind, cloud cover, cloud type, visibility, and weather. Let them know that data tables (see Figure 7.15) will be provided for recording data.

4. Students can perform several tests at each site.

- Test1: Measure ozone levels over four or five 1-hour intervals throughout the day. To do this, students will need four or five 1-hour test strips.
- Test 2: Measure the ozone level over an 8-hour period using an 8-hour test strip.
- Test 3: Measure ozone levels over several days using several 8-hour test strips.

5. Each team should be responsible for conducting experiments for a one-week period. This will enable students to monitor ozone over an extended period of time, as well as take daily ozone readings.

6. Work with your class to set up the experiments it will conduct. In each case, have students formulate hypotheses that they will test through the experiments they conduct. For example, if the students do an experiment in which they measure ozone throughout the day, an hypothesis for this experiment might be the following:

Hypothesis: There will be no differences in the ozone levels measured in the shade at 1-hour intervals throughout the day.

In addition to ozone levels, students should monitor other weather data, including air temperature, humidity, wind direction, and wind speed. Additional hypotheses can be formulated with respect to these data.

7. Following hypothesis formulation, students should write out brief proposals describing the studies they wish to conduct. The proposals should include a statement of the problem, one or more hypotheses, and a description of the methods students will use in their study.

8. Now students are ready to begin monitoring ozone and other weather variables. Distribute copies of the Project Ozone Observation Form so students can record their data (Figure 7.14).

9. After students have completed their data collection, they can create a data table. Have the students set up a data table similar to the one shown in Figure 7.15 (see Figures 7.16, 7.17, and 7.18).

Include a column for each variable such as time, date, ozone, temperature, wind, and latitude and longitude. NOTE: Latitude and longitude are required if your students share their data on the Ozone Website.

Figure 7.17, for example, shows one way the ozone readings should be analyzed, which is in terms of the number of days that exceeded the optimal level of ozone (120 parts per billion). This value will change to 60 ppb as the EPA's new recommendations are put into practice. Note that in this case, the optimal ozone level was exceeded on three days.

10. Have students propose explanations of the data they have collected and analyzed. Ideally, they should look at the data gathered from all of the sites monitored by the class and try to make sense of the data. Have students compare their data to that in the Air Quality Chart shown in Figure 7.19. What is the pattern of ozone in their community? What is the level of ozone over the period they studied? What is the cause of the ozone? What can be done to reduce the level of ozone in their community?

11. Once each team has studied the data and formulated a set of explanations, conduct a class session in which each team has an opportunity to present its data to the others. To encourage interdependence within each group and the class as a whole, tell students that you will randomly call on a student from each group to present the data, and that the whole class will be responsible for making a general statement about ozone in the community based on the reports.

12. As a final step, have students compare their findings to real-time ozone data collected by the EPA. Students can visit a clickable map of the United States and find out how their readings compare with those collected by professional scientists. To find the map, have students check this Web site: http://www.airnow.com/

At this site, your students can click on any state and receive real-time data from the Environmental Protection Agency (Figure 7.20).

Figure 7.14

PROJECT OZONE OBSERVATION FORM

Team Name: ______________________ Team Members: ______________________

Measurement Location: ________ Inside: ______________ Outside: ______________________

Date: ______________________ Latitude: ______________________

Start Time: ______________________ Longitude: ______________________

Quantitative Measurements

Ozone (Eco-Badge readings):

Location	Start Time	End Time	Reading 1 (parts per billion)	Reading 2 (parts per billion)	Reading 3 (parts per billion)	Average (parts per billion)

Temperature: ______________ °C

Relative Humidity: ______________ %

Wind Speed: ______________ km/hr

Wind Direction: ______________ degrees

Precipitation: ______________ cm

Qualitative Observations

Circle one of the words to describe your observations.

Ozone	Good	Moderate	Unhealthful	1st Stage Alert
Temperature	Hot	Warm	Cool	Cold
Humidity	High	Average	Low	None
Clouds	Cumulus	Cirrus	Stratus	None
Sunlight	Sunny	Mainly sunny	Mainly cloudy	Cloudy
Wind Speed	Strong	Medium	Light	Zero
Wind Direction	North	East	West	South
Precipitation	Rain	Drizzle	Snow/sleet	None

Figure 7.15 Sample Data Table

Row	Time	Date	Ozone in ppb	Temp. °C	Humidity	Wind Speed	Latitude	Longitude
1								
2								
3								
4								

Figure 7.16
Graph of Data Collected at Ozone Monitoring Sight

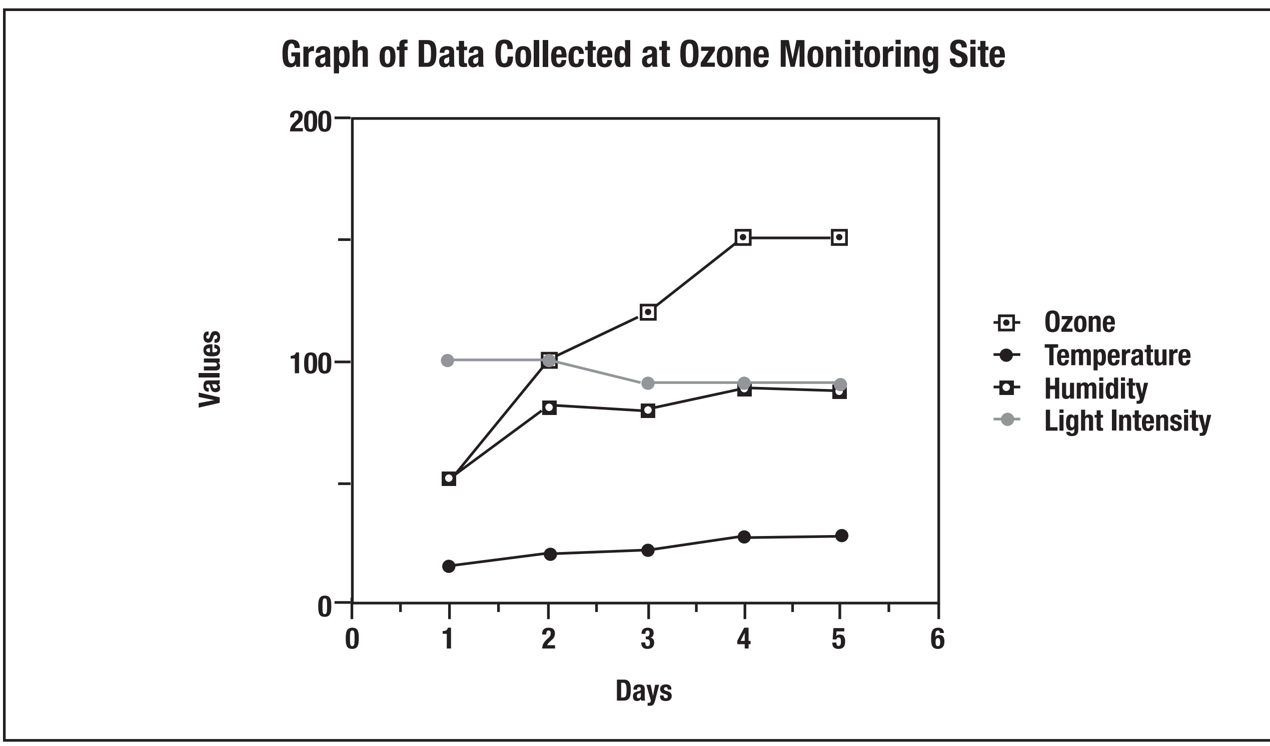
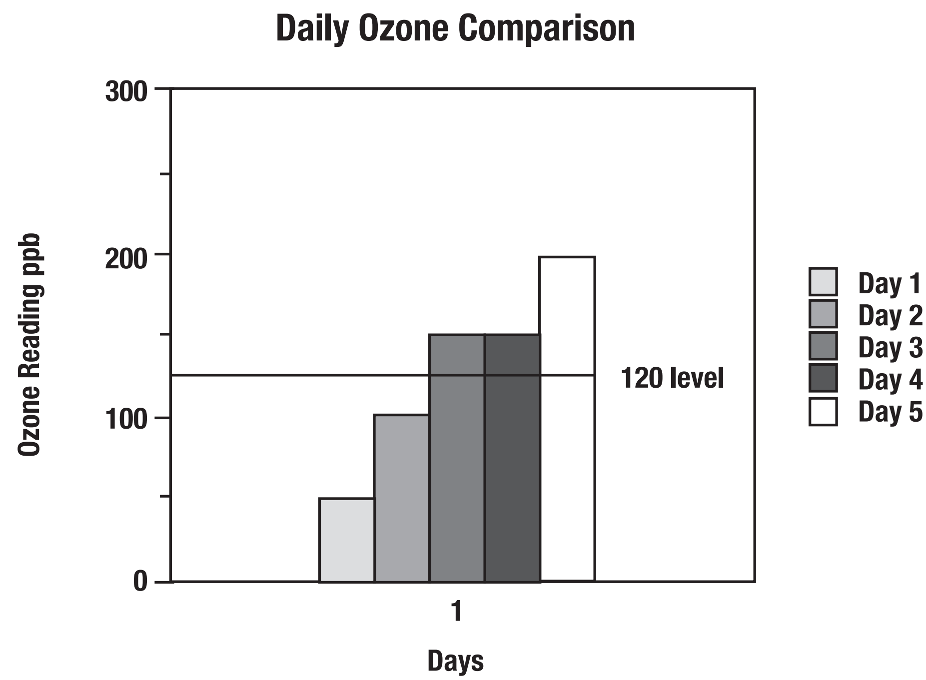


Figure 7.17
Bar Graph Comparing Daily Ozone Levels



Activity 7.4 Ozone: A Global Project

Students use the Project Ozone Web site to collaborate with other schools on the problem of ozone and share data in order to gain knowledge about ozone at the global level. Students also discuss what can be done to halt the trend toward increasing urban smog levels.

Objectives:

- To use the Project Ozone Web site to send and retrieve data collected on ground-level ozone
- To use the data submitted by other schools to compare and contrast ozone levels in different regions, cities, and countries

Materials: Data and conclusions from Activity 7.2; large map of the world; string, pins, labels, or cards (to post information on the map); access to the Internet (to submit and retrieve data and to participate in a Web discussion)

Web Site Information: The Project Ozone home page lets students send and retrieve data and participate in Web discussions about ozone.

Procedure:

1. Discuss with students the value of cooperating globally with other people to share data, draw conclusions, and make decisions about important problems, such as ground-level ozone. Explain to students that they are going to collaborate with other students to find out about the problem of ozone in other regions or countries, and, at the same time, to share the results of their local ozone research.

Figure 7.18
Map of world showing the location of schools participating in Project Ozone.

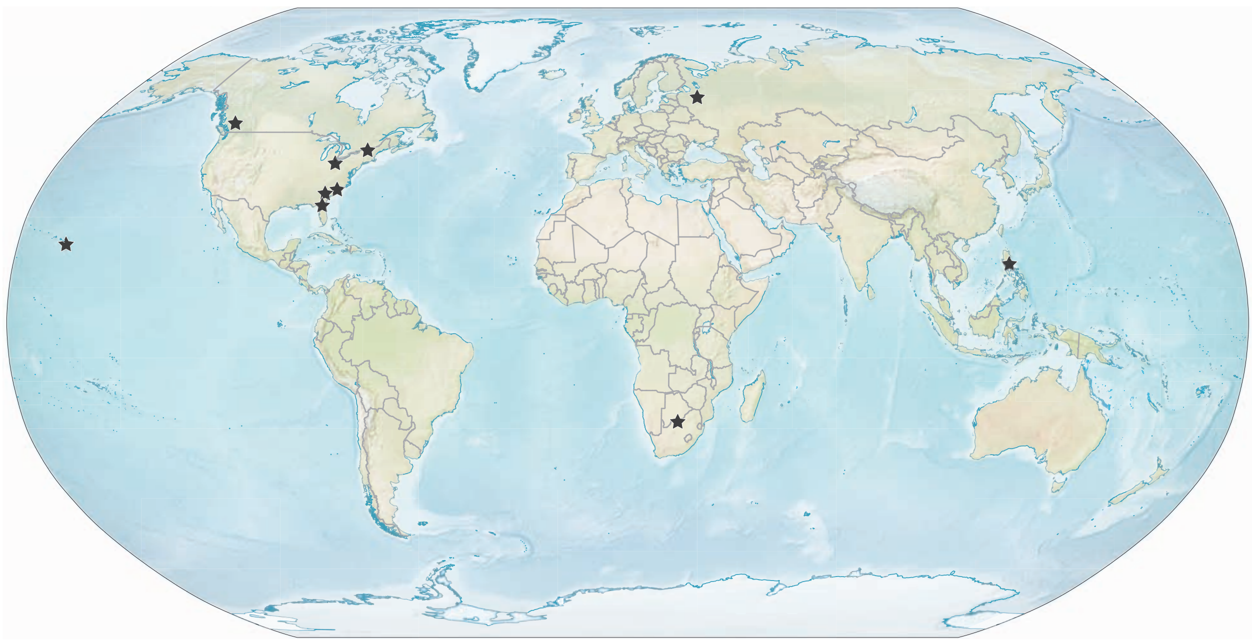
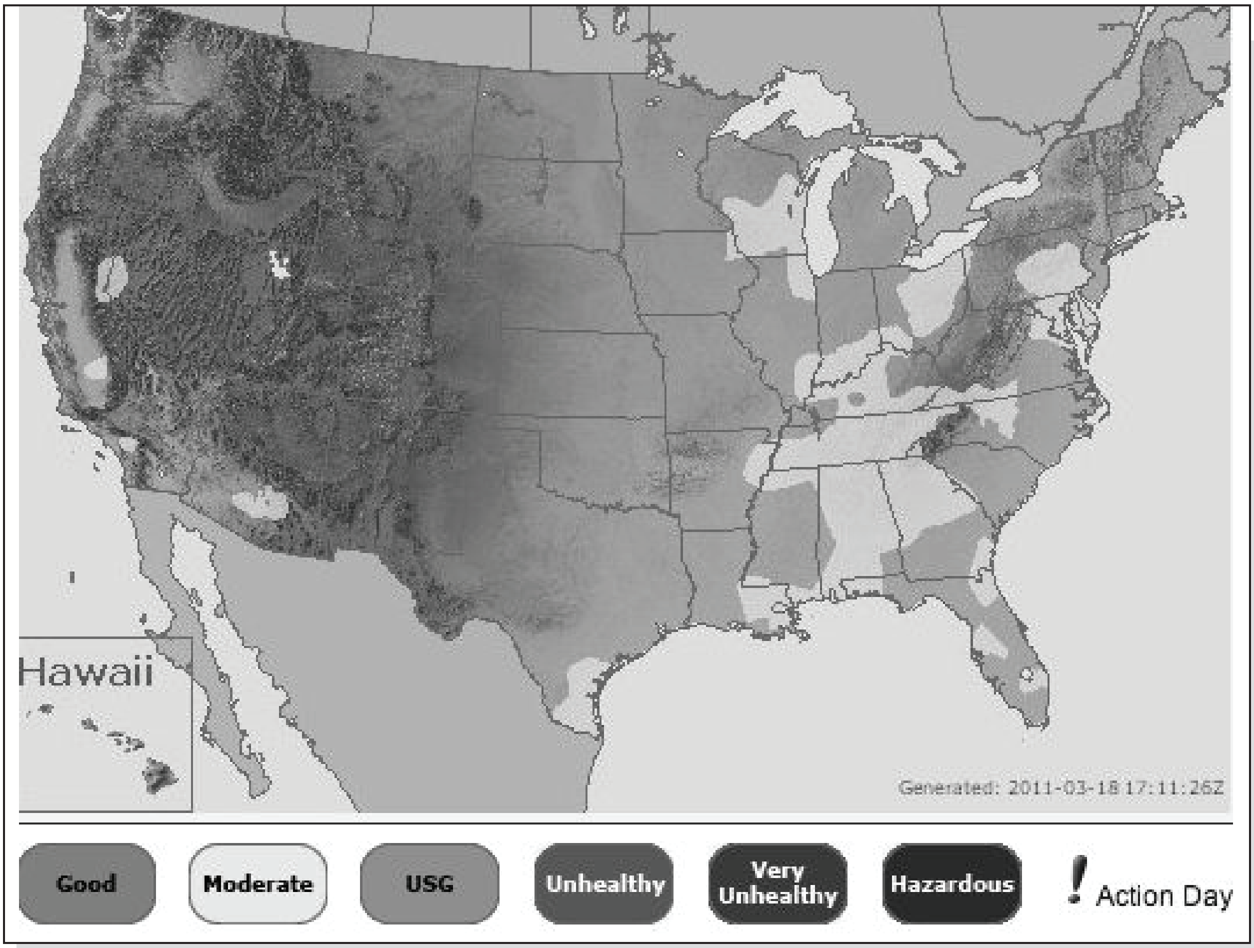


Figure 7.19 Air Quality Chart for Interpreting Ozone Data

Air Quality	Good	Moderate	Unhealthful	1st-Stage Alert	2nd-Stage Alert
Ozone, ppb on Eco™ Filter	10–50	50–200	200–300	300–350	>350
Part per billion	<50	50–120	120–190	190–340	>340
Ozone index reported to public (ozone level/ 120 x 100)	50	50–100	100–156	156–260	>260

Figure 7.20
EPA Web site. At this site, your students can click on any state and receive real-time ground-level ozon data from the EPA. (http://www.airnow.gov)



2. Work with your students to help them understand how to use the Project Ozone Web site to submit the data they collected on ozone and other weather-related elements in Activity 7.2.

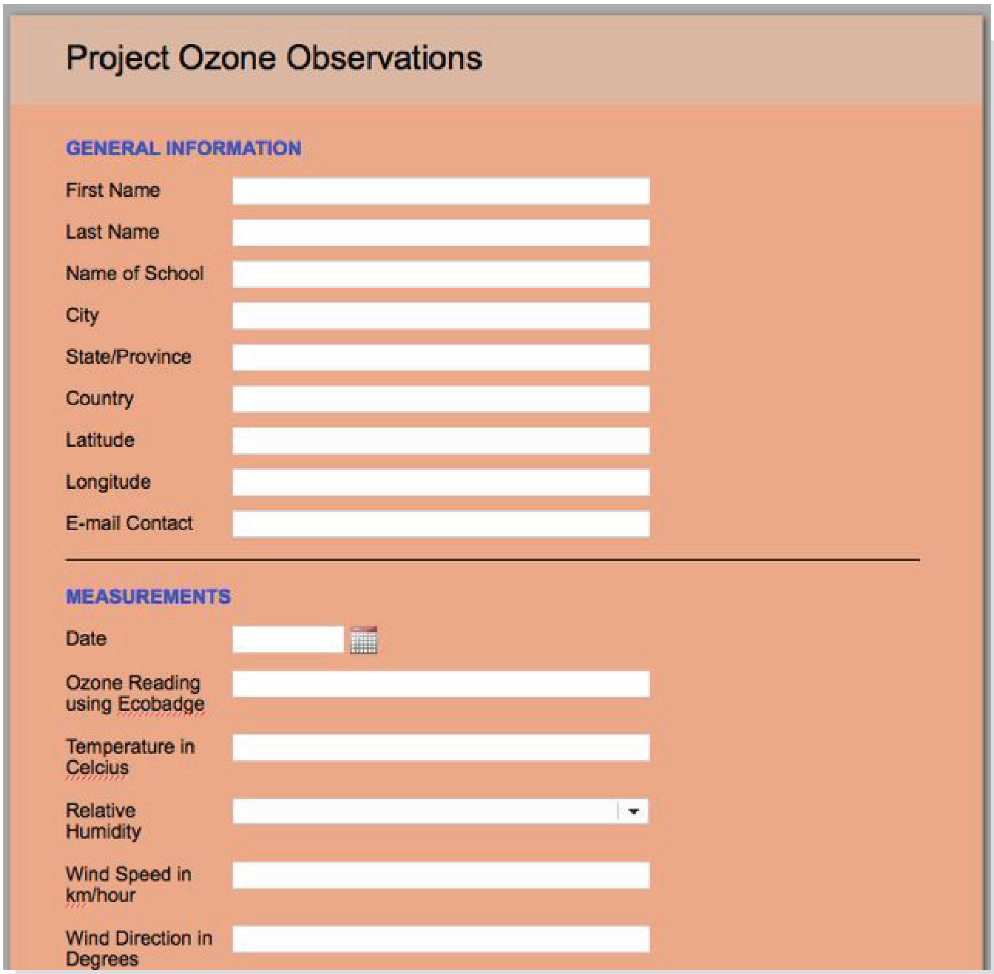
3. Data Transmission. Once the data have been compiled, student teams submit their data to the Project Ozone Database. From the Project Ozone home page, students select "Data Sharing." Students will be able to enter their data directly into a Web form (Figure 7.21a), and send it electronically to the Project Ozone Database.

This is the submission form for Project Ozone. You can reach this page from the Project Ozone Web site. Simply click on "Submit" and then have your students enter the data they collected and submit it to the Project Ozone Database.

Following is a list of the data that will be submitted:

- School name
- City
- State
- Country
- Latitude
- Longitude
- Date
- Time of observation
- Ozone in parts per billion
- Ozone description

Figure 7.21(a)
Ozone Data Sharing Form accessble at the Project Ozone website: http:/www.science-as-inquiry.org/ozone



Project Ozone Observations

GENERAL INFORMATION

First Name
Last Name
Name of School
City
State/Province
Country
Latitude
Longitude
E-mail Contact

MEASUREMENTS

Date
Ozone Reading using Ecobadge
Temperature in Celcius
Relative Humidity
Wind Speed in km/hour
Wind Direction in Degrees

- Outside air temperature
- Temperature description
- Humidity
- Wind speed
- Wind direction
- Precipitation
- Weather conditions

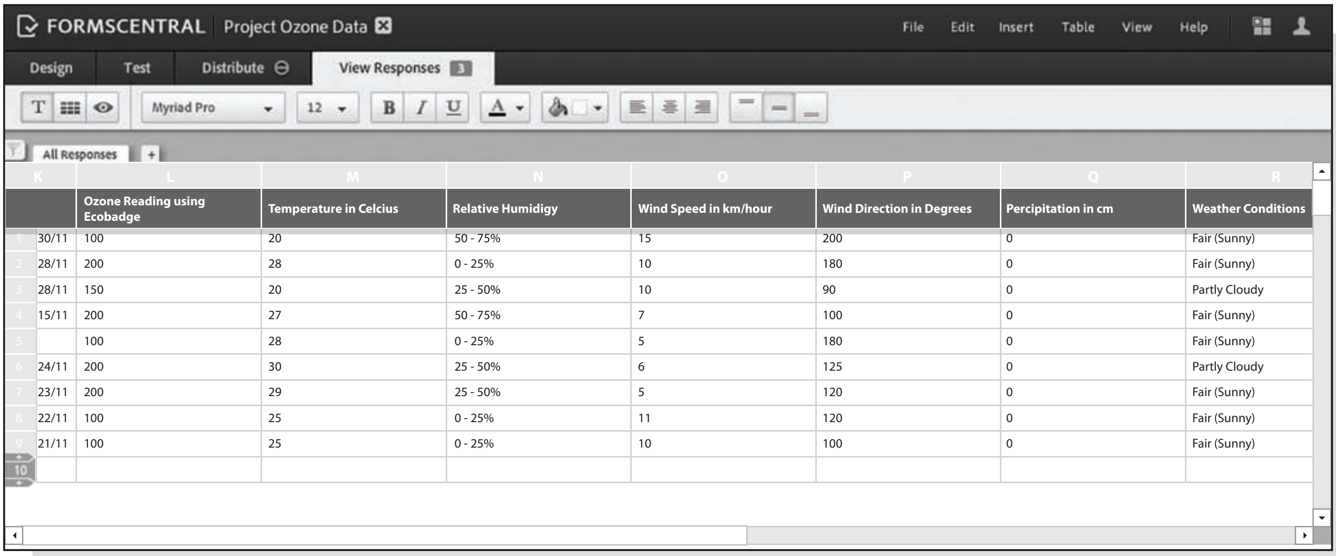
4. From the Project Ozone home page, students select "Data Access" (Figure 7.21b) and download the data that appears in the Ozone data table. Have the students stick pins on the world map for each location represented in the data. Discuss the results as a class. Have students draw comparisons among the reporting cities to explain differences in levels of ozone.

5. Have students write brief analyses of the data, using their graphs and maps to support their ideas. Have students share the results in class, perhaps in the form of a conference. Students can also post their results on the Project Ozone Weblog accessed from the Ozone home page. Encourage students to respond to blog entries by other schools.

Optional Extensions

1. Encourage your class to make contact with

Figure 7.21(b)
Results table from the Project Ozone Website. Data from this table can be downloaded onto your computer and opened in programs such as Excel.



K	L: Ozone Reading using Ecobadge	M: Temperature in Celcius	N: Relative Humidigy	O: Wind Speed in km/hour	P: Wind Direction in Degrees	Q: Percipitation in cm	R: Weather Conditions
30/11	100	20	50 - 75%	15	200	0	Fair (Sunny)
28/11	200	28	0 - 25%	10	180	0	Fair (Sunny)
28/11	150	20	25 - 50%	10	90	0	Partly Cloudy
15/11	200	27	50 - 75%	7	100	0	Fair (Sunny)
	100	28	0 - 25%	5	180	0	Fair (Sunny)
24/11	200	30	25 - 50%	6	125	0	Partly Cloudy
23/11	200	29	25 - 50%	5	120	0	Fair (Sunny)
22/11	100	25	0 - 25%	11	120	0	Fair (Sunny)
21/11	100	25	0 - 25%	10	100	0	Fair (Sunny)

one or more schools that would like to carry out a collaborative study. Have your students look at the data from the Ozone Database and pick out a school whose ozone data differ significantly from those they collected. Have students formulate some questions aimed at finding out about the town or city in which the comparison school is located, in order to understand its ozone problem (or lack thereof). Using e-mail, students can contact the school and explore these differences and possible explanations for them.

2. Assign students to look into the laws that regulate the emission of gases that contribute to the formation of smog. For example, in the United States, the EPA has established compliance laws regarding the ozone standards for U.S. cities. Students also may want to check out the standards that regulate emissions in other countries.

3. Similarly, ask students to inquire into legislation regulating pollution. For example, American schools should examine the EPA's Clean Air Act of 1990 and the revision of the Clean Air Act in 1997, and then share essential parts of it with schools in other countries.

4. Students might find it interesting to explore ways—at the personal, local, regional, and global levels—for dealing with the problem of ozone depletion. What actions should be taken, and why would they be effective?

Activity 7.5 Ozone: What Can Be Done?

The purpose of this activity is for your students to design a locally implemented Ozone project. Students should work with their team to design and carry out their projects. Project products can be in many forms, such as:

- PowerPoint® presentation
- Three-panel poster report
- Play
- Debate
- Web page using an online hosting site such as Wikispaces.com

- Report submitted to the Project Ozone Blog (http://www.science-asinquiry. org/ozone/ weblog)

Students will be involved in the following types of inquiry activities:

- Brainstorming questions that they would like to investigate about air pollution
- Designing a research method or set of procedures to help them answer their question(s)
- Monitoring the variables that are being investigated in their study
- Analyzing data including graphical and verbal analysis
- Summarizing the results and evaluating their methodology

Objectives

- Design projects based on questions and inquiries about ozone
- Identify, discuss, and use research skills to answer scientific questions
- Use the research you have completed on ozone and the resources of the Internet to present your project as a PowerPoint® presentation, a three-panel poster report, or a Web site.

Procedure

1. Working in teams, encourage students to visit one of the following sites and report back to class. How can these sites be of help in designing their project?

- Project Clean Air: The site of a non-profit organization of concerned citizens working together to improve air quality. Examples of activities and projects. Visit the site: http://www.cleanair.hk/eng/index.htm
- Children of the Earth United: A site designed to provide resources for students to develop a greater understanding and respect for animals, plants, water, soil, air, and energy systems. Examples of activities and projects. http://www.childrenoftheearth.org/
- The Ozone Hole Tour. A powerful U.K. site designed to teach you about the "good ozone," its depletion, and progress being made to reduce this trend. http://www.atm.ch.cam.ac.uk/tour

2. Students should discuss with their teammates the nature of a research project. You might begin by thinking about a question, and then how such a question might be answered. For example:

- Is the ozone level near plants (such trees and shrubs) different than the ozone level in an open field?
- What can citizens in our community do to reduce smog that pervades our environment, especially in the summer?
- What health issues related to air pollution should we bring to the attention of citizens in our community?
- What is the threat of "ozone action days" in our community? What should citizens in our community do to help reduce the number of ozone action days in our environment?
- What scientific reasons support the use of suncreen? Do you think where people live on the Earth affects the amount of suncreen they should use?

3. Work with your teammates and other members of your class to create a list of possible ozone projects and from the list decide upon the one that your team will do.

Data/Project Sharing

4. When your team has completed its project, prepare your report (PowerPoin^{t}®, three-panel poster, Web site) for class presentations.

5. Students should summarize their reports and write comments on the Project Ozone Blog at http://science-as-inquiry.org/ozone/weblog

Extensions

1. Have students write an editorial letter or report of their study and its implications for the local community, and send their findings to the local newspaper.

2. Have students create a scrapbook of articles on pollution (don't limit them to air pollution).

3. Make contact with a local environmental action group and let them know that you are working on global problems. Students can send the local group a copy of their report and encourage the group to visit their class.

4. Have students create a Web site that focuses on the problems and solutions related to air pollution.

STUDENT MATERIALS

Project Ozone Mini Learning Log

You may want students to organize their work on Project Ozone using the Project Ozone Mini Learning Log (Figure 7.22). Photocopy the pages and then fold them to produce an eight-page log for each student.

Project Ozone Portfolio

In addition to or as an alternative to the Mini Learning Log, consider having students keep a portfolio of their work on Project Ozone. (For some background on portfolios, see the discussion in Chapter 8.)

Materials: Three-ring binder for each student (1" binder), index tabs to separate binder sections, marking pens, folder for each student in which he or she keeps all completed project work.

Portfolio Elements: Have students set up their portfolios so that they contain the following elements:

- Title Page: Name, course, dates
- Personal Log: Excerpts from the student's log or journal
- Growth Through Writing: Students respond in writing to an open-ended question at the beginning of the project and then again at the end of the project. Sample Question: Using the following ideas and concepts, discuss the differences between ground-level ozone and upper atmospheric ozone. (Terms: sunlight, CFCs, automobiles, refrigerants, smog, ozone shield, urban areas, southern hemisphere)
- Ozone Research: A report of research conducted by the student during Project Ozone
- Social Issue: Either a written report or a collection of newspaper articles and editorials about the implications of ozone on humans and other living things
- Ozone in the News: A collection of newspaper and magazine articles on ozone.
- E-mail messages: A collection of all e-mail messages sent to and received by the student during the project
- Overall Reflection: An at-the-end reflection on and assessment of the portfolio written by the student. The student should answer these questions: Which element of the portfolio represents your best piece of work? What does this portfolio show about your abilities? How would you change your portfolio if you were to do another one?

Project Ozone Certificate

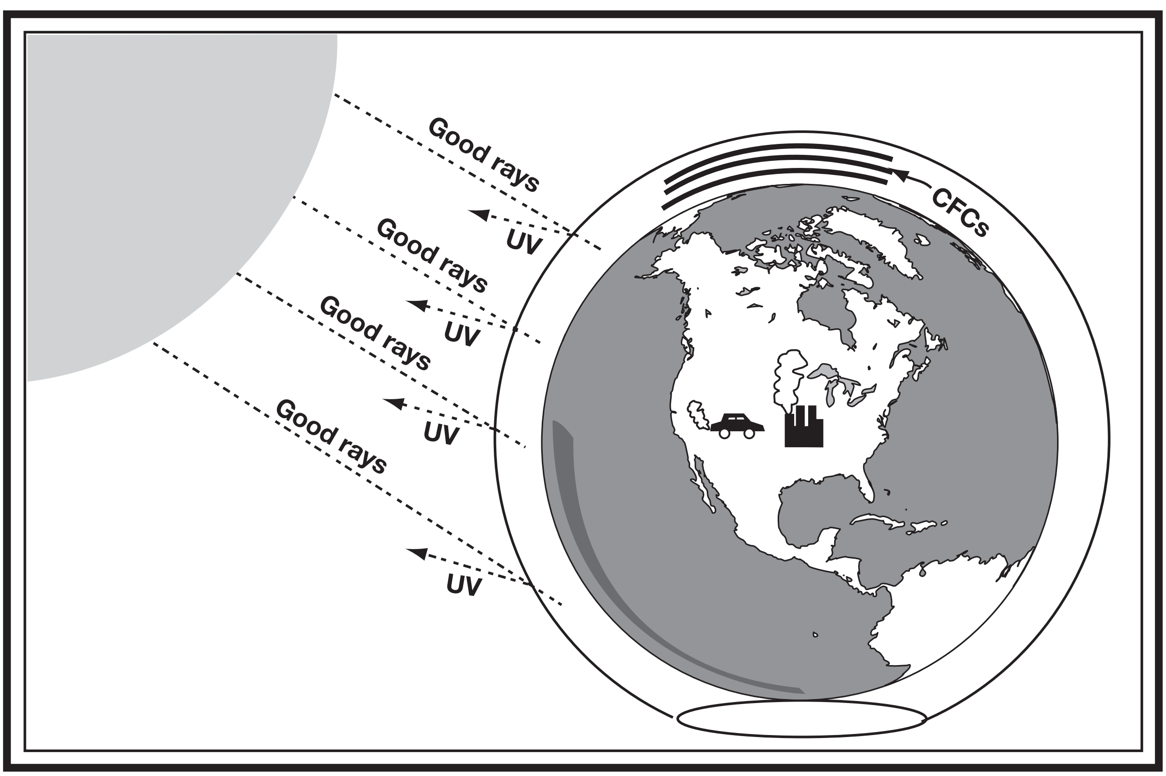
If you wish, use the certificate in Figure 7.23, which is designed to be presented to students when they complete Project Ozone.

This chapter presented a complete web-assisted teaching unit on a problem that has global consequences. The quality of the air that humans breathe is a critical health issue around the world. In this project your students can become part of an effort among students and teachers to learn more about their own

Figure 7.22
Project Ozone Mini Learning Log

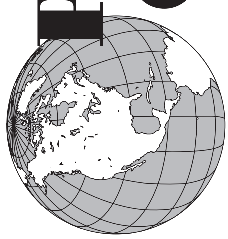
Project Ozone

Mini Learning Log



Directions: Photocopy the next four pages (front to back). Fold them to make an eight-page *Mini Learning Log*.

Figure 7.22
Project Ozone Mini Learning Log



Project Ozone
Mini Learning Log

Name ____________________

Date ____________________

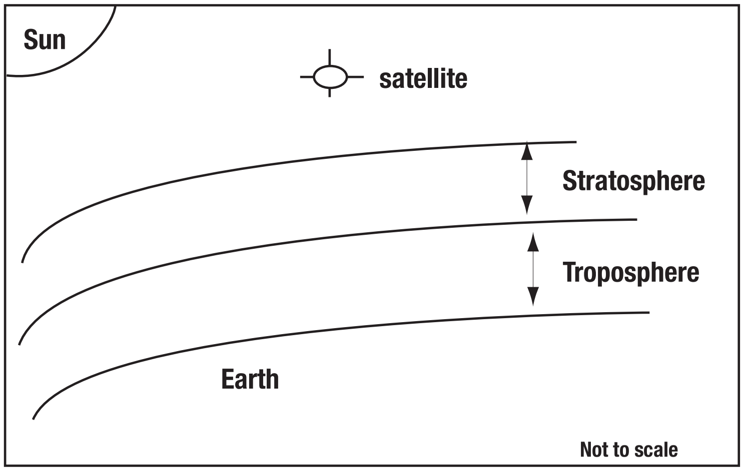
1

Ozone Resources

8

Figure 7.22
Project Ozone Mini Learning Log

What we have heard about ozone



Ozone, smog, car emissions, ultraviolet light, people, plants.

2

Further questions I have about ozone

7

Figure 7.22
Project Ozone Mini Learning Log

What I have learned about ozone	Group Your Ideas: Put two or three ideas together to form categories.
6	3

Figure 7.22
Project Ozone Mini Learning Log

List some things you want to learn about ozone.

4

Predict what you think you'll learn about ozone.

5

Figure 7.23
Project Ozone Certificate

environment and then use the Internet to share their findings, and learn about other city's environments as well. Your students will learn to use the Internet using many of its tools, including key pals, global classrooms, information exchanges, and data sharing. And your students will be participating in a social-action project in which they make use of their findings to help improve the quality of the environment in their community.

Part III Active Assessment for Active Learning

Chapter 8 Assessing Performance in Science

Figure 8.1
Science learning is an active process of engagement, cooperative exchange, and problem solving. This type of learning requires a different way of assessing student progress.

This chapter presents a variety of ways to assess student performance in science. Science teaching that is full of active learning strategies requires assessment methods that are active as well. In recent years, the emphasis on assessment has shifted away from paper-and-pencil tests and toward an array of performance-based and alternative assessment practices. The assessment strategies that are presented here will provide you with the tools you need to implement multiple methods of assessment in your classroom.

Multiple Methods of Assessment

Assessment is rich with ways to evaluate the progress of students in a science class. Following are some strategies and the types of science outcomes they reveal.

- **Portfolios.** Portfolios consist of materials that students and teachers select to represent a student's best work. Portfolios can reveal many things—for instance, gains in a particular subject area over a short or long period of time, progress on long-term projects, or performance in group work.
- **Journals or Logs.** Journals or logs consist of writings, drawings, and illustrations created by students to document their thinking in science. They can be used by students to record their feelings and attitudes about science, as well as their responses to group and cooperative work.
- **Computers.** Computers help track the process of learning and thinking. Because they are interactive, they provide a sort of record of how well students learn with feedback, as well as their ability to deal with realistic situations.
- **Videotapes.** Videotapes record ongoing activities and student explanations in rich detail. This makes it possible to determine such things as how students present their ideas and answer challenging questions, and how students carry out tasks and perform experiments. For example, you might videotape a group presentation and then use the tape to review the group's communication skills; also, send the tape home for parents to observe.
- **Hands-On or Performance Tasks.** Hands-on tasks ask students to show what they know by working with or manipulating concrete materials. Science students might be instructed to design and conduct an experiment to test a hypothesis, using scientific equipment or procedures to do so. For example, they might use a hand-held lens to analyze and interpret the crystals in a rock.
- **Group Activities.** Group tasks can be quite helpful in assessing certain science skills. For example, group tasks show how well team members work cooperatively, communicate, and integrate each member's contributions into a final product.
- **Paper-and-Pencil Assessments.** Continue to use pencil-and-paper assessments as appropriate, to measure students' knowledge of facts, concepts, and procedures; their ability to read and understand text; and their ability to solve problems.
- **Multiple-Choice Tests.** Expect multiple-choice tests to continue to play a role in the science classroom—both because their

format is efficient and scores on some multiple-choice standardized tests correlate moderately well with subsequent academic performance as measured by grades. However, as this chapter demonstrates, we as teachers can make improvements in multiple-choice tests to bring them in line with new science curricular goals.

ASSESSMENT: THE BIG PICTURE

The trend in science education reform is toward assessments that

- are embedded within instructional materials
- use a variety of methods to assess student progress
- emphasize teacher observation and judgment
- provide methods for getting at the reasons behind student answers

This perspective follows naturally from the active learning strategies presented earlier in the book. In this context, assessment is an integral aspect of each of the following phases of instruction: pre-instruction, during instruction, and post-instruction. We will use the terminology to describe assessment during these phases of instruction as diagnostic (pre-), formative (during), and summative (post-). It turns out that various research studies have shown that diagnostic and formative assessments have positive effects on student learning, and that teachers implementing these assessment tools have more successful learning experiences with their students. The active assessment strategies that follow can be used in one or more of these phases of instruction, as summarized in Figure 8.2.

DIAGNOSTIC ASSESSMENT STRATEGIES

Eliciting students' prior knowledge on a topic is helpful not only to us as teachers, but to the students, for it gives them the opportunity to consider their current understanding of the concepts and ideas they are to learn about. Uncovering students' prior knowledge can be achieved in a variety of ways. Least effective is giving students a paper and pencil "pre-test." Most effective is engaging the students in an activity, discussion, interview, or conference where they can express their ideas verbally, visually, in writing, or kinesthetically. Please refer to Chapter 4 for specific examples of diagnostic strategies.

Formative Assessment Strategies

Formative assessments are everyday methods that we use to help students improve their learning and understanding of science, as well as a way for teachers to inform and improve their teaching abilities.

Teachers who use formative assessment use intellectual tools to provide insight into the nature of their students' understanding and reasoning in science. These kinds of assessments occur daily, and are called "formative" because they provide evidence for the "forming" or developing understandings that emerge through daily instructional activity.

Formative assessments are not always connected to an assigned grade. Class discussions and review sessions, the student questions and comments that emerge during instruction, and the way teachers learn to read student engagement, are all types of formative assessment. Others include student writing in learning logs, lab groups posting answers and data online, and having students listen to and respond to well-chosen questions. All of the assessments that follow in this section are formative if the teacher is using the substance of these methods and interactions to improve teaching and learning.

Here are a few formative assessment strategies: observing students, asking questions, student talk, T-Chart conversations, word webs, student writing, alternative multiple choice questions, and open-ended questions. Student logs and portfolios can be used for both formative and summative assessment.

Figure 8.2
Model of Assessment for Science Teaching

Pre-Instruction (Diagnostic)	During Instruction (Formative Assessment)	Post-Instruction (Summative Assessment)
Goal: Assess students' prior knowledge, ideas, beliefs, and attitudes **Strategies:** • T-charts • Journal writings • Drawings • Interviews/conversations • Questionnaires • Concept maps	**Goal:** Embed assessment within instruction to gain insight into students' knowledge, ideas, beliefs, and attitudes (a seamless process linking instruction and assessment) **Strategies:** • Portfolio—collections of student work • Journals and logs—document student thinking and reflection • Activities as assessment—hands-on activities that assess performance • Observations • Interviews • Products —journal or log —drawings —list of readings —collections —written assessment —videotapes —audiotapes • Paper-and-pencil tests • Written tests • Alternative multiple choice	**Goal:** Evaluate students' progress and reflect on the effectiveness and quality of instruction **Strategies:** • Survey of student opinions and attitudes (learner satisfaction form) • Student interviews • Written assessments (standardized or open-ended—see Plant in a Jar) • Performance assessments (problem-solving tasks) • Assessment of portfolios (rubrics)

Figure 8.3 Observation Chart

Interpersonal Skills	Team 1	Team 2	Team 3	Team 4	Team 5
• Active Listening					
• Staying on Task					
• Asking Questions					
• Contributing Ideas					

Figure 8.4 Scientific Observations Checklist

Scientific Skills	Student 1	Student 2	Student 3	Student 4
Problem Solving • Solved problem with little guidance • Stayed on task				
Experimenting • Recognized a number of problems • Created sound hypotheses • Used sound experimental design • Used materials creatively				
Collecting Data • Made unique observations • Used measuring devices correctly • Data collected was complete				
Drawing Conclusions • Provided in-depth analysis of data • Developed well-supported conclusions				
Communicating • Student did not need prompting • Student communicated orally				

Observing

Observing students doing science in the classroom is a valid way to assess student learning. Often it is during these informal assessments that we see evidence of learning and achievement that is not necessarily apparent using other, more formal methods.

Observing Social Behavior

Observation of social behavior is an effective way to determine the level of involvement of students working in groups. Paying attention to students' behavior—verbal as well as nonverbal—is also a good way to gain insight into their learning. One useful idea is to create an observation form. This enables you, the teacher, to observe student behavior during cooperative learning activities and to record instances of the social/interpersonal skills that are being encouraged. The interpersonal skills "active listening," "staying on task," "asking questions," and "contributing ideas," for example, lend themselves to an observation chart (Figure 8.3). The teacher records the names of the students in each group, spends a few minutes watching each group individually, and then records instances of the interpersonal skill. Later, the teacher returns to the group and provides specific feedback to the group about its interpersonal skill development.

Observing Hands-on/Minds-on Behavior

Observing students as they experiment, collect data, draw conclusions, and communicate helps you assess their problem-solving ability. A checklist, such as the one in Figure 8.4, can be useful in such situations. The form has been set up for observing students engaged in cooperative learning activities.

Asking Questions

Asking questions is another means for informally assessing student learning. One of the most powerful uses of classroom questions as an assessment tool is during cooperative learning activities and/or laboratory activities. The role of the teacher at such times is one of classroom monitor. He or she visits individual groups to explore the content of and the methods that students are using in their investigations and small-group work. The following techniques should be useful in assessing student understanding.

Ask a Variety of Questions

Try to strike a balance between low-order (recall) and high-order (application, synthesis, evaluation) questions. The use of higher-order questions has been shown to be motivational, whereas the use of lower-order questioning is an effective probing strategy.

Allow Wait Time

Science teachers who practice waiting at least three seconds after asking a question establish a classroom atmosphere that is beneficial to a student's cognitive, as well as affective, learning. Rowe found that the length of student response increases, the number of failures to respond decreases, confidence increases, speculative responses increase, student questions increases, and variety of student responses increases.[1]

Probe

If, after asking a question and waiting at least three seconds, a student gives an incorrect answer, then the teacher should probe the student answer with other questions. Probing provides a second opportunity for the student to express his or her understanding. Berliner explains that probing for the purpose of helping students clarify and improve on their answers is a more effective way of increasing student achievement than probing for the purpose of getting an answer.[2]

---

[1] *Rowe, M. B. "Science Silence, and Sanctions," in Science and Children (October 1969), pp. 22–25.*

[2] *Berliner, D. C., "But Do They Understand?" in Educating Handbook: A Research Perspective, Virginia Richardson-Koehler, ed. New York: Longman, 1987, p. 270.*

Figure 8.5
Use T-charts to encourage students to talk about their writing and to consider the ideas and questions they have about the topic of the chart.

Rocks and Minerals

What have we heard about rocks and minerals?	What questions do we have about rocks and minerals?
They can be classified into three main groups--igneaous, metamorphic and sedimentary. Rocks are comprised of one or more minerals. There are hundred of different kinds of rocks and minerals. Fossils are sometimes found in sedimentary rocks. Sedimentary rocks are formed when sediments are deposited in an ocean.	How are rocks formed? Do rocks last forever, or do they disintegrate? What is the oldest rock on the Earth? What causes rocks to have different colors? Why are some rocks heavier than others?

Redirect
If you are working with a cooperative group, redirecting a question to another group member can be a useful technique. Suppose you ask one student in the group a question and this student is unable to answer or gives an incorrect answer, you might then redirect by asking another student in the group the same question.

Student Talk

Student talk can serve as a good guide to (science) understanding. Use either small-group or whole-class talk to document student learning and knowledge. Discussions are especially helpful ways to discover the range of prior knowledge among a group of students. Here are suggestions for generating student/teacher discussions:[3]

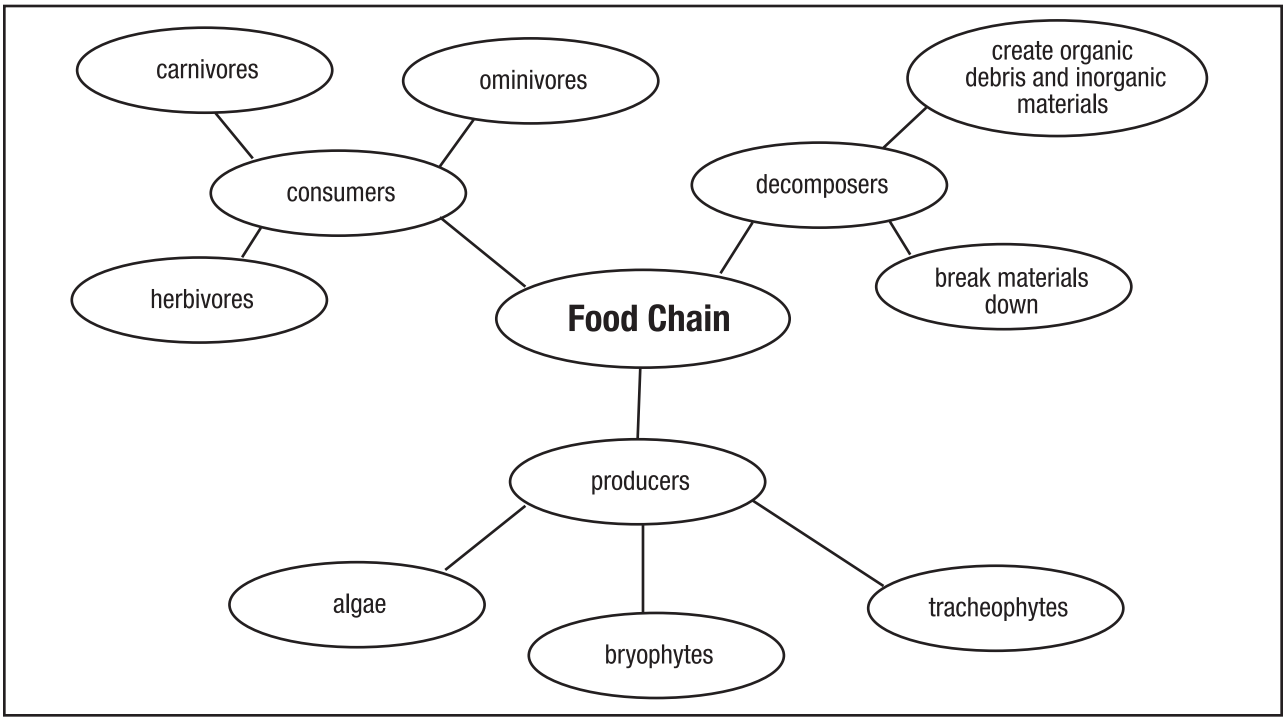
- Discussions should begin with open-ended questions, such as these:
    What have you noticed lately about the caterpillars?
    What are some things you know about shadows? What is shade?
    What sorts of questions do you have about the sun? Is there anything in particular that you have wondered about?
- Refrain from correcting or unduly modifying the students' comments.
- Let discussions proceed in a manner encouraging the involvement of most of the students.
- Try to record the students' statements.

Here are some specific teaching strategies designed to encourage student talk as an assessment strategy.

T-chart Conversations
Provide a sheet of newsprint and marking pens for each group of students in your class. Suggest a topic, have students make a T-chart (Figure 8.5), and then provide two thinking prompts: What have you heard about the topic? What questions do you have about the topic? (In this strategy, the T-chart serves to involve all members of the group in the topic and to help structure student conversations.) Students brainstorm for 5 minutes, then discuss the data they have recorded. At this point, you may need to ask questions related to the charts in order to encourage students to talk aloud about their ideas.

[3] *After Chittenden, Edward, and Wallace, Vivian. "Reforming School Assessment Practices: The Case of Central Park East" in Planning and Changing 22 (1993), p. 141–46.*

Figure 8.6
After students have completed a team web, they are ready to discuss their ideas with other teams of students. Have a student representative from each team in the class rotate to another team and present his or her team's web. Help students field the questions and comments that emerge.



Word Webs

Word webs are another excellent tool for stimulating student talk about a topic or concept. Give pairs or small groups of students a sheet of newsprint and ask them to write down a concept in the center of the sheet. From the central concept, suggest that students brainstorm what they know about the concept by writing down other words that connect to the central idea (Figure 8.6). When the webs are completed (about 10 minutes), ask students to share their webs with students in another group, or ask team representatives to discuss their team's ideas with the whole class.

Student Writing as an Assessment Strategy

Writing is a powerful way to help students learn science; it is also a powerful way to find out what students are thinking and thus it is a valid assessment strategy. The purpose of writing in science bears highlighting. Here are four goals suggested by Lesley Bulman:[4]

- To help the growth of understanding of science concepts
- To provide a record of concepts and activities that can be used for revision later
- To provide feedback to the teacher on the growth of the students
- To develop students' ability to communicate

[4] *Bulman, L. (1985). Teaching Languages and Study Skills in Secondary Science. London: Heinemann.*

More than 70 percent of the writing in science classes is of the following two types: (1) copying dictated notes, or "teacher talk," and (2) answering questions on worksheets, exercises, tests, or exams. Clearly, there is room for change in the ways that we ask students to write. Over-reliance on multiple-choice and true–false formats, in particular limits our opportunities to document student knowledge and understanding through writing.

There are many alternative assessment strategies that include writing as a means of documenting student thinking. Here, you will find just a few of those strategies. Later in the chapter, you'll see how writing is integrated into hands-on performance tasks, as well. Let's start with a science lesson that focuses on writing.

Rocky Writing: An Alternative Writing Assignment

Objectives:

- Assess students' observational skills
- Record notes about a natural object—a rock
- Reconstruct notes in poetry form

Overview: As part of a science unit on local geology, students select a rock, which they observe carefully, using all five senses. They then write down words and phrases based on their observations. After reading and thinking about what they've jotted down, students write an ode to their rock. This assignment is an example of an embedded assessment activity in which students' abilities to make observations and write (poetically) about them are assessed.

Procedures:
Have students gather rocks, perhaps as part of a field trip, or bring in enough rocks yourself so that each student will have one to observe.

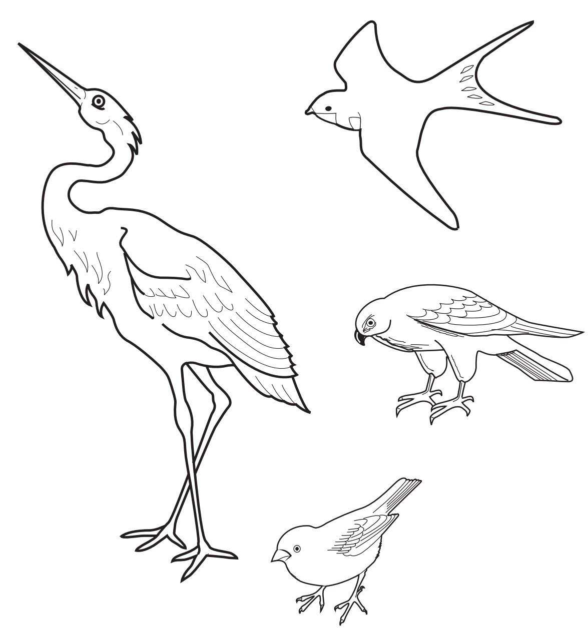
1. Stimulus
Once all students have a rock on their desks, discuss what the students can observe about a rock based on each of the five senses. Have a student recorder write down key words on the board or on chart paper, such as these:

Sight—size, shape, color
Hearing—rattle, scraping
Taste—mineral content, dirt
Touch—contour, roughness, smoothness, unevenness, bumpiness
Smell—sweet fragrance, earthiness

Have students fold a sheet of composition paper five times, labeling one section for each of the senses, and the sixth section "Other Ideas." Ask students to observe their rocks and to jot down notes about what they observe.

2. Writing
After students have had time to observe and take notes, ask them to use their observations to write an ode to their rocks. Tell them that an ode is a lyric poem that frequently begins "Oh (subject) . . ." and praises a person. Thus students would begin their poem with "Oh

Figure 8.7
Drawings of Birds
Educational Testing Service



rock . . ." and speak to their rock as though it were a person, using personification.

3. Follow-up

After students have written for a while, have them read their poems to a partner. Partners can assist each other in adding ideas or revising the poem, as needed. Students' poems might go something like this:

> Oh, wonderful little gray rock,
> Bumpety, lumpety, and tough.
> You have tumbled down from the high
> mountain,
> You have survived the trampling of many
> rough feet,
> The crush of an automobile's wheels.
> I will give you an easier life now
> Perched on my bedroom windowsill.

4. Assessment

Circulate through the room to observe student activity as students observe, write, and share. After students have shared their work, have them determine criteria (scientific and poetic) for an especially good poem, answering the question: What made some poems stand out as especially effective? Students can revise their poems based on the established criteria. Have students display their rock writing along with their rocks on a table or shelf. Note: An alternative way to assess the students' work is to use a scoring rubric that examines their "notes" and their final poem.

Scoring Rubric for Ode

0 = Student did not include observations in the poem, included observations in the poem that were very inaccurate, or did not write a poem.

1 = Student included some observations in the poem, but the poem did not reflect accurate observations of the rock.

2 = Student included more than one sensory observation in the poem, and the poem accurately described the rock.

3 = Student included more than two sensory observations in the poem, and the poem reflected outstanding observations of the rock.

Alternative Multiple Choice

This strategy asks students not only to select an answer to a multiple-choice question, but also to provide one or more reasons for their choice. Begin by looking over the multiple-choice questions you are currently using and selecting those that lend themselves to this new strategy. Change the questions as needed. Following is a multiple-choice question that fits the alternative format:

1. Which of the birds pictured below probably lives around ponds and eats snails and small fish?

   What are your reasons for the choice you made?

Open-ended Questions

Open-ended questions provide a means for students to inquire, to apply scientific ideas to solve a problem, and to communicate effectively. In so doing, they enable us, as teachers, to assess students along the lines outlined in the Standards. Some of the characteristics of open-ended questions that make their use compatible with current reform trends include the following:

Figure 8.8
Developing Open-ended Questions

• Identify the context ⟶ • Develop subconcepts ⟶ • Create a writing format ⟶ • Write the question ⟶ • Design an assessment rubric

Figure 8.9 Scoring Rubric

Scoring Rubric for Open-ended Questions

Outstanding: 4 points

The student's response clearly demonstrates superior understanding of the concepts and processes. Rationale is clear and logical, and, where appropriate, diagrams and illustrations are provided.

Competent: 3 points

The student's response effectively presents knowledge of the concepts and processes. No serious flaws are evident, but one or more elements in the response is missing. Rationale is logical for the most part.

Satisfactory: 2 points

The student's response shows a limited understanding of the concepts and processes; the response is incomplete and the rationale appears to be unclear.

Unsatisfactory: 1 point

The student's response shows serious flaws in terms of understanding the concepts and processes, and shows little or no understanding of the words, drawings, and diagrams that may have been included.

No Response: 1 point

The student provides no relevant response.

- There are many ways to answer the question.
- There is a range of appropriate responses.
- The questions are typically problem-oriented, thereby requiring the application of science knowledge.
- Students can use many means to respond: a short paragraph, a picture or diagram, or perhaps a data table or graph.
- Assessment can be flexible, thereby allowing for a range of responses.

Designing Open-ended Questions

Process

As summarized in Figure 8.8, the first step in designing an open-ended question is to identify a big idea in science. Scientific inquiry, forces and motion, origin of the Earth system, personal and community health, and the structure of the atom are examples of big ideas in science.

Once a big idea has been selected, you can develop subconcepts to help you refine the focus of the open-ended question that will emerge. Create a writing format by thinking about the format of the question. For example you might want to write a scenario that outlines a real problem in the community, for example, how students might solve a pollution problem reported in the media. Next you should write the question, and then design an assessment rubric.

Following are some tips for designing open-ended questions:

1. Instead of starting with the "pure" scientific concept, you might start with a context, or a situation that you can use to create an open-ended question or inquiry. Examples might be why is copper so important in our world? How does it effect our drinking water, electricity, and computers? Another example might be water from a local stream. Why can't we drink it directly? What good does boiling the water do? How is it possible for a thrown baseball to curve or drop or lift? Contexts, rather than concepts, provide a potentially richer environment for you to generate open-ended and relevant questions for students to ponder.
2. Using a demonstration, diagrams, pictures, graphs, data tables, and, sometimes, hands-on materials enhances the quality of open-ended questions.
3. Open-ended questions are appropriate for individual or small-group use. When working in small groups, students are free to talk and discuss the question among themselves, but each student should respond individually.
4. Try using a scoring rubric to assess open-ended questions. You can design your own rubrics inductively. Begin by reading a sample of responses to the open-ended question; then identify the qualities of "good" or "complete" responses as opposed to those that are "poor" or "incomplete." Examining already-developed rubrics, like the one shown in Figure 8.9, should help you develop your own rubrics more easily.

Examples of Open-ended Questions

Two examples of open-ended questions that you might try in your own classroom are "Plant in a Jar" and "Heating the Air." Plant in a Jar is an assessment task that emphasizes the importance of the explanation of scientific phenomena as a way to assess student understanding of big ideas in science. Each assessment also provides a context for the students to engage with, rather than simply a conceptual question. Each assessment task possesses attributes that make them good assessment exercises:

- The situation can be described with words, diagrams, or real materials.
- The situation can be understood by students of various ages.
- The explanation for the prediction can be developed at several levels of complexity.

Plant in a Jar

For the Plant in a Jar assessment (Figure 8.10), you'll also find information on what we might expect from typical elementary, middle, and high school students (Figure 8.11), along with sample student responses accompanied by typical ratings (based on the rubric in Figure 8.9; see Figure 8.12) that teachers have given the responses.

Heating the Air

"Heating the Air" (Figure 8.13) is an example of a physical science open-ended question. Note that in this case, the question is designed to be answered by a small group of questions. In this case, students explain how the air is heated, but they must also illustrate their ideas by using terms given.

Summative Assessment Methods

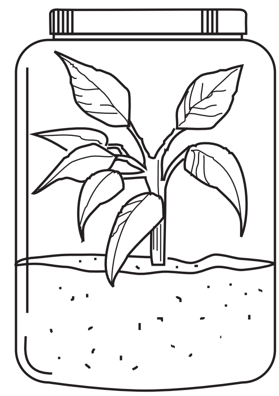
Performance Tasks

Performance tasks typically involve students, either individually or in small teams, in the act of solving a problem or thinking critically about a problem, data, or an observation. Performance tasks also engage students in activities that draw on their ability to use science thinking skills, such as sorting and classifying, observing and

Figure 8.10
Plant in the Jar: An example of an open-ended question for formative and summative assessments.

Adapted from *National Science Education Standards,* pp. 92, 95–96. © 1996 by the National Academy of Sciences. Reprinted by permission of the National Academy Press, Washington, D.C.

Plant in a Jar



Task: Explaining a Prediction
Some moist soil is placed inside a clear glass jar. A healthy plant is planted in the soil. The cover is screwed on tightly. The jar is located in a window where it receives sunlight. Its temperature is maintained between 60°F and 80°F. How long do you predict the plant will live? Write an explanation supporting your prediction.

Directions: Use relevant ideas from the life, physical, and earth sciences to make a prediction. If you are unsure of a prediction, your explanation should state that and should tell what information you would need to make a better prediction. You should know that there is not a single right prediction.

Figure 8.11 What Should We Expect of Students in the Plant in the Jar Task?

- Elementary school students: Elementary school students would likely base their predictions on their work with plants; they would probably use very few scientific terms.
- Middle school students: Middle school students should use more scientific language and mention concepts such as light, heat, carbon dioxide, water, energy, and photosynthesis.
- High school students: High school students might see the plant in the jar as a model of the Earth's ecosystem, noting the complementary processes of photosynthesis and respiration.

Figure 8.12
Student Responses to the Plant in the Jar Task.

Adapted from *National Science Education Standards*, pp. 92, 95–96. © 1996 by the National Academy of Sciences. Reprinted by permission of the National Academy Press, Washington, D.C.

STUDENT 1 (AGE 10)

- The plant could live. It has water and sunlight. It could die if it got frozen or a bug eats it. We planted seeds in third grade. Some kids forgot to water them and they died. Eddie got scared that his seeds would not grow. He hid them in his desk. They did. The leaves were yellow. After Eddie put it in the sun it got green. The plants in our terrarium lived all year long. (Typically rated a 3.)

STUDENT 2 (AGE 12)

- I predict the plant will not live for more than 3 days. Why? Because the lid on the jar is screwed on tightly and it has no holes in it, therefore it can't get any air or oxygen. The plant can't live with water so the plant will die very soon. Living things can't live without air or water so therefore it won't live more than three days. (Typically rated a 1 or 2.)

STUDENT 3 (AGE 14)

- If there are no insects in the jar or microorganisms that might cause some plant disease, the plant might grow a bit and live for quite a while. I know that when I was in elementary school we did this experiment. My plant died—it got covered with black mold. But some of the plants other kids had got bigger and lived for more than a year. The plant can live because it gets energy from sunlight. When light shines on the leaves, photosynthesis takes place. Carbon dioxide and water form carbohydrates and oxygen. This reaction transforms energy from the sun into chemical energy. Plants can do this because they have chlorophyll. The plant needs carbohydrates for life processes like growing and moving. It uses the carbohydrates and oxygen to produce energy for life processes. After some time the plant probably will stop growing. I think that happens when all the minerals in the soil are used up. For the plant to grow it needs minerals from the soil. When parts of the plant die, the plant material rots and minerals go back into the soil. So that's why I think that how much the plant will grow will depend on the minerals in the soil. The gases, oxygen, carbon dioxide, and water vapor just keep getting used over and over. What I'm not sure about is if the gases get used up. Can the plant live if there is no carbon dioxide left for photosynthesis? I'm pretty sure a plant can live for a long time sealed up in a jar, but I'm not sure how long or exactly what would make it die. (Typically rated a 3 or 4.)

Figure 8.17
Sample Portfolio Pages

My Science Porfolio

Name________

Table of Contents

- Table of Contents
- About Me
- Problem-Solving
- Collaborative Design Project
- Internet Project Sample
-
-
-
-

Introduction

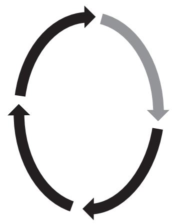
This is my first high school science class and I am hoping to learn a lot about biology. Let me tell you a little about myself…

Problem-Solving Investigation

Three of us worked together on this project. We were interested in finding out about…

Collaborative Design Project

We worked together to design a model of…

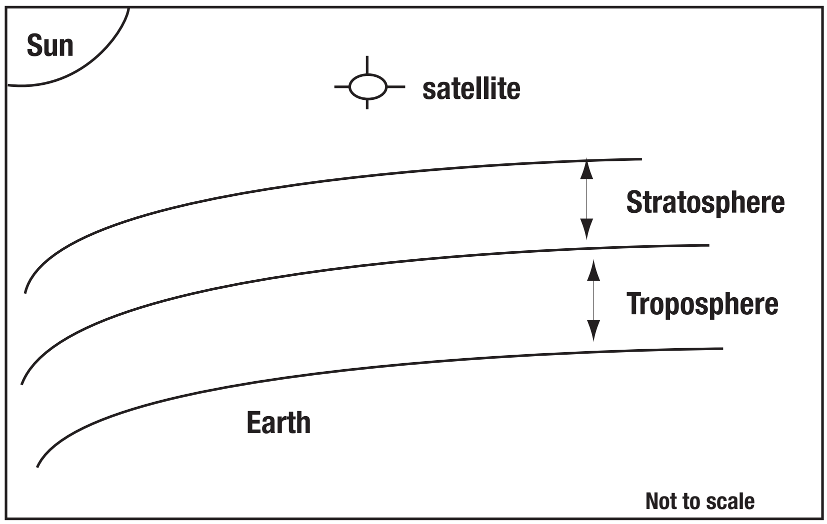


Internet Project Sample

Our class got involved in Project Ozone. As a result we started collaborating online with a group of kids from Kew, Australia. We have included here not only some of our e-mail letters, but the results of our collaborative study in which we compared the ozone levels in our community with those in Kew for a one-month period.

Figure 8.13
Heating the Air: An open-ended question, which could be used as a diagnostic too, or for formative or summative assessment.

Heating the Air



Directions: Working with your teammates, use all of the following terms (you may add other terms if you wish) in a diagram to explain how you think Earth's atmosphere is heated. After you have made your diagram, write an explanation of it.

Terms: atmosphere, warming, carbon dioxide, soil, sun, energy, heat, molecules formulating hypotheses, interpreting data, and designing and conducting an experiment.

Characteristics of Performance Tasks

Performance tasks are creative approaches to student evaluation that you can employ in an overall assessment plan. They are creative because the emphasis is on the methods that students use as well as the ideas that students generate. Performance tasks place the student in situations that are in accordance with what science instruction should look like. Studies indicate that there is a high correlation between performance tasks and a hands-on, conceptual approach to science teaching. Following are some of the characteristics of performance tasks:[5]

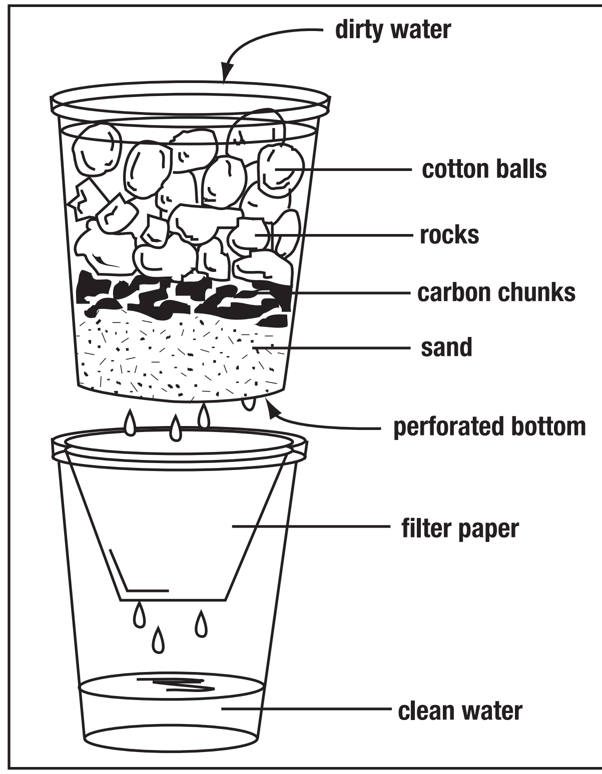
- They typically involve students in real-world contexts.
- They involve students in sustained work, sometimes over several days.
- The focus is on the "big ideas" and major concepts in science, rather than isolated facts and definitions.
- They are broad in scope, usually involving several principles of science.
- They involve students in the use of scientific methods and the manipulation of science tools.
- They present students with open-ended problems.
- They encourage students to collaborate and brainstorm.
- They stimulate students to make connections among important concepts and ideas.
- Scoring criteria are based on content, process, group skills, and communication skills.

Examples of Performance Tasks

Here are five performance tasks ready for use with your students.

[5] *Excerpted from Joan Boykoff Baron, "Performance Assessment: Blurring the Edges Among Assessment, Curriculum, and Instruction." In Assessment in the Service of Instruction, Washington, D.C.: American Association for the Advancement of Science, 1987.*

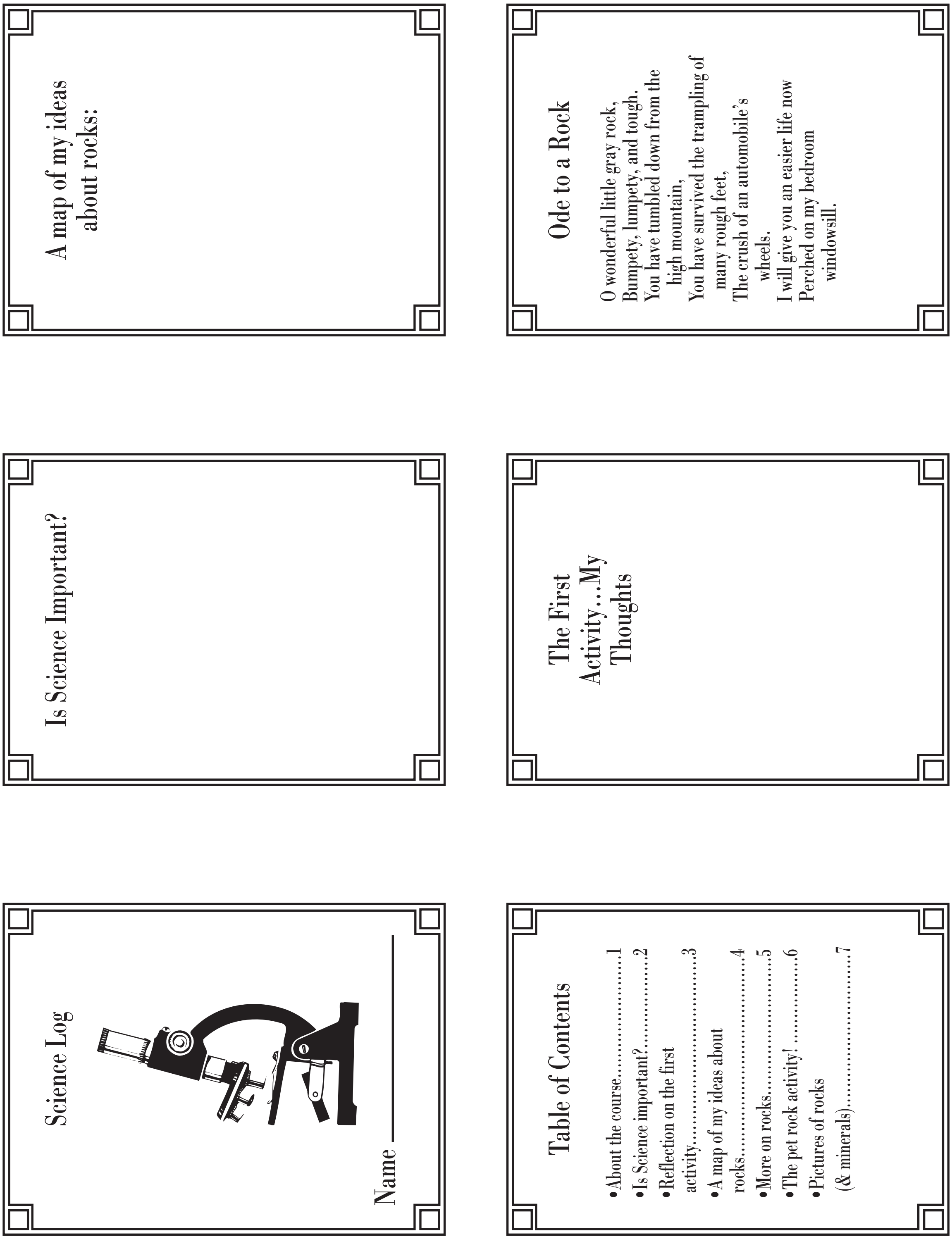
Figure 8.14
Water Filter System: a performance assessment useful for formative or summative assessment



Milk-Carton Cars
Your group is given two identical "milk carton" cars. One has full-width wheels. The second has had its wheel width reduced by one-half. Design an experiment to test the variable of wheel width and its effect on distance traveled. After you have designed the experiment, test each car at least three times. Record and then analyze the data. Write a report describing your project and presenting the results.

Plant Study
Your group wants to study the effect of different amounts of exposure to sunlight each day on the growth of identical plants. Design an experiment that varies the sunlight from 0 hours per day to 24 hours per day. Use at least four identical plants and collect data for at least one month. Graph and then analyze the data. Write a report describing your project and presenting the results.

Figure 8.15
The student log can contain a variety of examples of student work, including answers to questions, lab reports, articles from newspapers, student reflections, and more.



Can Crusher
Your group is given design paper, cardboard, clay, pencils, half-gallon milk cartons, and cardboard tubes from rolls of paper towels. It is also given some "model" aluminum cans made from aluminum foil. The model cans are approximately one-third the size of actual beverage cans. Using the principles behind simple machines, construct a prototype can crusher that can effectively crush the model cans. After testing the prototype, present a demonstration and an oral report to the class. Make a scale drawing of the can crusher device, and write out step-by-step instructions for its construction.

Recycling
Your group is presented with large quantities of the following: plastic containers from consumer products, beverage cans, vegetable and fruit cans, newspaper, cardboard, magazines, and glass bottles and jars. It is also given plastic bags, twist ties, labels, a can opener, a magnet, an aluminum can-crushing device, and a plastics-recycling key. Design a system that can be used to separate, package, and store the recyclable materials for delivery to a recycling center. Based on the experience gained from this activity, apply your system to the school's recycling program. Write a report describing the program's strengths and weaknesses. Present the report to the class and to the school administration.

Dirty Water
Prior to presenting this task to students, obtain the necessary materials (see below) and use the recipe to make dirty water.

Materials:
Small plastic cups, some with holes in the bottom; cotton pieces; activated charcoal; clean sand

Dirty Water Recipe:
To 1 liter of water, add a few drops of blue food coloring, 50 cc of vinegar, and a handful of dirt.

Your team has been asked to find a method to clean up water that will be used subsequently in a fish tank. The water is located in the large jar at the materials table. One possible method of cleaning the water is to make a simple filter. Figure 8.14 shows one such filter system. Find the best method you can to clean up the water using the materials that are provided. As you begin your experiments, be sure to write down the question you are investigating. You might begin the question this way: "What would happen if . . . ?" Make drawings of your models and write a report summarizing your findings. Be prepared to give a short presentation to the class.

The Student Log
Of all the approaches to performance assessment, the student log is, without a doubt, my favorite choice for enhancing thinking and providing students with a place to "do science." Students can use many different forms of expression as they work in their logs, encouraging both right- and left-brain thinking (Figure 8.15). Here's a look at just some of what students can do:

- Write in narrative form.
- Ask questions.
- Make designs for prototypes.
- Record quotes they've found about science.
- Write an (essay about a science issue).
- Jot down ideas.
- Draw or paste in a cartoon.
- Make diagrams illustrating a concept or theory.
- Record the teacher's pearls of wisdom.
- Create concept maps or webs.
- Draw a picture with pen and ink.
- Draw a picture with crayons, paints, or color marking pens.
- Paste in lab reports, data, and activities, then comment on them.
- State an opinion about an issue, theory,

or science concept.
- Write letters.
- Doodle (scientifically, of course!).
- Paste pictures from magazines and comment about them.

These logs themselves can take many forms, including:

- Spiralbound notebooks
- Loose-leaf notebooks or binders
- Folders
- Files in a computer

Spiralbound journals are more permanent, and if students "add" papers to the log (such as data sheets, graphs, drawings, or pictures clipped from a magazine), they can be glued or taped to it. Similarly, they can be open-ended or highly structured (perhaps teacher-generated and based on a single lesson plan or unit of teaching). Here is a Web site you might want to visit to see examples of student log pages. Some of them are amazing. Learning Logs Online: http://www.learninglogs.co.uk

How Should Logs Be Organized?

Take some time to work with your students to get their logs organized. Plan a day when the students bring the materials for their log to class (spiralbound notebook, binder and paper, etc.). Provide colored marking pens for students' use in illustrating their logs. Here are some specific tips:

1. Have students organize their log according to your overall plan for using the logs. If you want the logs to be chronological, without regard to categories of items, then students can write and include items in the log in the order in which activities take place. If, however, you want a topical organization, then have the students use dividers or labels to separate the log into parts—for example, reflections on class sessions, notes from class, project work, and so on.
2. Students should reserve the first five pages of the log for a table of contents. Some teachers like to have students reserve the last five pages for a student-generated glossary.
3. Students should number each page of the log from beginning to end.
4. Students should date each entry in their log.

When Should Logs Be Used?

If you consistently make time for logs, students will value "logging" as meaningful work. Following are two suggestions for incorporating the log into a busy class schedule:

1. **At the end of class.** Ask the students to reflect on the lesson by giving them a prompt that encourages writing, drawing, and illustrating. Some teachers find that five minutes at the end of the class period works well for this type of activity. Here are some ideas for prompts:

    - How did your group do today?
    - What did you enjoy most about class today? (Least?)
    - What connections can you make between the content of today's lesson and a real-world situation?
    - How would you visualize today's class? Can you find a picture or draw one that helps you?
    - How would you chart or diagram what you learned today?

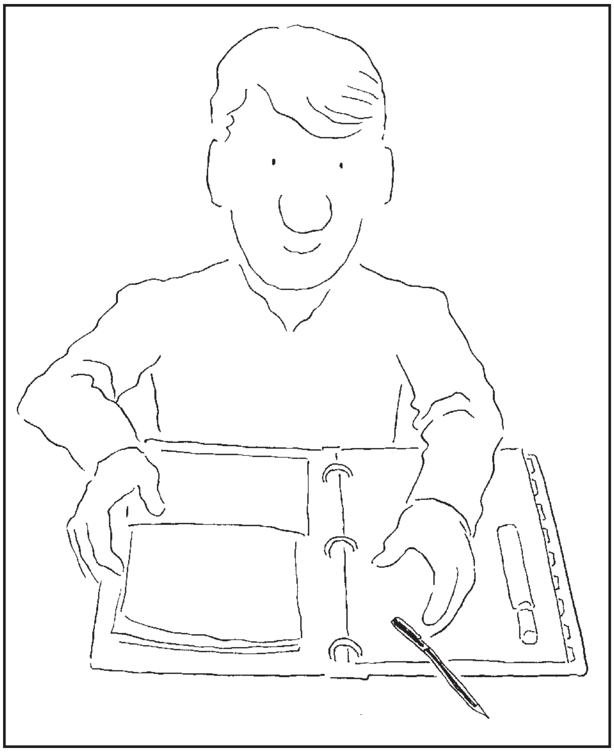
    Here are some other visual stimulators:

    - A map of my ideas would look like this. . . .
    - This illustration or cartoon expresses. . . .
    - The movie (movie title) reminds me of. . . .

    Here are some verbal stimulators:

    - I was disappointed that. . . .

Figure 8.16
Typical Portfolio



- I discovered that. . . .
- I didn't realize that. . . .
- I learned. . . .
- My group thought that. . . .
- My group contributed. . . .

2. **During class.** You can build logs into ongoing lesson plans by having the students work for approximately five minutes on a specific logging activity (drawing a map, making an illustration, expressing the meaning of a concept, etc.). Students can then share their work with others in their group or with the whole class.

How Should Logs Be Used?

Logs can be an integral part of students' work. Thus they should be available during class time for students' use in taking notes, making diagrams and illustrations, and doing narrative writing. They can be an integral part of hands-on activities, as well as a place for minds-on work that encourages students to reflect on the activity. Some teachers occasionally use logs as part of homework assignments. Here are a few other suggestions:

1. **Eliciting student ideas.** Logs are perfect tools for encouraging students to think and write about their knowledge of ideas in science. Use them as a place for students to brainstorm what they know about a topic, as well as a place for students to jot down questions they have about a topic. Logs can help students see how their thinking has changed over time.
2. **Reflecting on past work.** After students have worked in their logs for several weeks, have them look back over their entries. They should read what they've written, study the pictures and drawings, and look over the other entries. This way, students think about their thinking, as well as try to identify patterns in their work.
3. **Sharing with others.** This is a very powerful use of student logs. However, it can be intimidating. What the student shares with others should be his or her choice, and students should not be coerced into sharing if they are uncomfortable with it. Sharing is generally less threatening in small groups. You can structure a sharing session simply by asking students to share a favorite drawing, picture, poem, or statement in their log. You can also ask students to share a common assignment—perhaps a concept map or a reflection on a class session.

The Portfolios

Typically, when science teachers are asked whether they are using portfolios in their science classes, very few of them say that they are. This may be due to the fact that there are many misconceptions floating around about portfolios. The materials that follow will, hopefully, dispel some of these misconceptions and encourage you to use portfolios in your class. You'll find two models for portfolios presented here. The first is a generic approach—one you could use in most any science class. The second is based on a model developed for a biology or life sciences class. After looking it over, however, you may well be able to modify it for an Earth science, environmental science, marine science, or physical science course.

Model 1: Basic Portfolio for Any Science Class

What Is a Portfolio?
A portfolio is a folder or binder in which students can place their work to show what they have done in science class over a defined period of time. A three-ring binder that is not more than 1" wide seems to work best. Students should use dividers to separate one section from another (see Figures 8.16 and 8.17). Portfolios should NOT be designed for a full year's worth of work—that is too long a time period for students to be responsible for a project. You might consider a grading period as defining the maximum length of time that a portfolio should be kept. Some teachers assign portfolios for specific projects. See, for example, the portfolio suggested for Project Ozone in Chapter 7.

Why Should Students Put Work into Portfolios?
There are a number of answers to this question. Here are a few you might wish to share with your students.

- To show what you have learned
- To show you are a self-directed learner
- To gather evidence of the quality of your work
- To show your progress in science
- To go through the process of choosing work you think says something important about you
- To communicate to others what you know and understand

What Samples of Work Should Students Include in a Portfolio?
The following list of items can be used to form the content of a portfolio. Depending on your science class, you should select items from the following list.

- **Cover.** Include the student's name, course title, and a science illustration.
- **Table of Contents.** Include a list of the entries as well as page numbers.
- **Goals.** Students should make a list of the goals that are being accomplished.
- **Biography:** Students tell about themselves, including history and interests and how science has affected their lives.
- **Log Excerpts:** If your students keep a log of their work in your course, have them include samples from their log to reflect growth and interest in science.
- **Writing Samples**
  - Open-ended Questions. Students include samples of pre- and post-question writing to illustrate their growth through writing.
  - Book Reviews. Include brief summaries of books related to the topic.
  - Fuzzy Situations (see Chapter 4). Include the results of writing on one fuzzy situation related to the topic of the portfolio.
- **Problem-Solving Examples**
  - Laboratory Reports. Include any of the laboratory activities that included data collection, analysis, and summarization.
  - Group Investigations. Include any laboratory activity or research project that was completed as part of a research team.
  - Internet Projects. Include a sample of an Internet activity accomplished alone or with a research team.
- **Creative Projects**
  - Web page. Print out a copy of the Web

[8] *This is a shortened version of a portfolio plan developed by Susan Holt, Williamsville East School, NY. Used with permission.*

Figure 8.18
Self-Reflection Form

Self-Reflection Form

(Rationale for including this item in my portfolio)

Name: ______________________ Date: ______________

Title of the Assignment: ______________________

Please describe this entry: ______________________

____

How long did you work on this entry? ______________________

Who else worked with you? ______________________

Why did you choose this piece for your portfolio? ______________________

____

Why do you think it is a good piece of work? ______________________

____

What does this work show about your abilities? ______________________

____

page that was developed as part of a project or activity.
- Models. Include a diagram or photograph of any scientific model constructed.
- Poetry/Plays/Creative Writing. Include a sample of any work in these categories.

- **Self-Reflection:** Include a self-evaluation of each item included in the portfolio.
- **Overall Self-Reflection.** Have students write a short statement in which they look back over the unit of instruction and discuss what they learned about science. They should also indicate the goals met and what they need to work on in the future.

Model 2: Biology/Life Science Portfolio[8]

Background for Students

Many people continue to learn about biology after they have completed a high school biology course. They learn because they are seeking information on a topic of special interest to them. As part of this course, you have learned not only biology content, but also how to learn. For your portfolio, you are asked to demonstrate that you have developed skills that will enable you to be an independent learner who can seek information and apply that information to new situations.

Directions for Students. As part of your final examination, you will be asked to submit a portfolio. It will be worth ten points toward your final examination. To prepare your portfolio, you will be expected to select five samples of your independent work in biology from the list of possible portfolio elements described on the following pages. You are encouraged to think carefully about this list and to choose portfolio elements that reflect your interests and/or talents.

You should add samples of your work to your portfolio throughout the year so that you

Figure 8.19 Portfolio Elements and Examples

Possible Portfolio Elements	Examples
LAB EXPERIMENT AND REPORT* Complete an individual lab experiment in which you select a question, then design, conduct, and report on an experiment that answers this question.	• Rapid Radish or Fast Plant Experiments
ORGANISM LOG* Complete a log/diary with information on a plant or an animal that is raised in the classroom for a period of at least 10 weeks. Your log should include information that you have gathered from both observation and library research.	• Diary of a Plant • Diary of an Animal
WRITTEN REPORT-BIOLOGY* Complete a two-page written report during class time. To prepare for writing your report, you will be expected to research a topic related to biology, organize the information, and prepare a concept map or an organized set of note cards.	• Human Genetic Disease Report
ORAL REPORT—BIOLOGY* Produce a videotaped ten-minute oral report on a topic related to biology. To prepare for videotaping your report, you will be expected to research the topic, organize the information, and prepare a concept map or an organized set of note cards.	• Human System Malfunction Report
DECISION MAKING—ECOLOGY* Participate in a cooperative learning project in which three students work together to investigate an issue related to ecology. Members of the group cooperate to produce a written report, an oral report, and a poster on the causes of, effects of, and possible solutions for problems resulting from human technology. All members of the group then take an individual essay examination on the topic.	• Impact of Humans on the Environment Project
DECISION MAKING—BIOETHICS* Participate in a cooperative learning project in which three students work together to investigate an issue related to bioethics. Members of the group cooperate to learn about the personal, scientific, social, and ethical dimensions of the issue and prepare to participate in a debate on the issue.	• Do People Have the Right to ________ Project
CAREER RESEARCH AND SHADOWING* Prepare an oral report, a written report, a scrapbook, or a videotape on a biology or biology-related career that you have selected. Collect information on this career and interview several individuals working in this field.	• Select a biology career. • Select a career such as law or history or journalism that may be related to biology.

*Can be accomplished during school year.

Figure 8.19 Portfolio Elements and Examples (continued)

Possible Portfolio Elements	Examples
COMPUTER TECHNOLOGY/TELECOMMUNICATIONS PROJECT* Use a variety of computer network facilities to collect information for one of the reports or projects that you do this year. Keep a journal on the types of computer technology that you have used, how this technology was used, and the kinds of information available through that technology.	• Keep a record of how you used the computer facilities to gather information on a biology topic such as cloning, ecosystems, and human diseases.
MULTIMEDIA PRESENTATION Produce a multimedia presentation that uses slides, videotape, laser disk images, and a written or taped script to present information on a biology-related topic.	• Produce a multimedia presentation for the school's "Unity and Diversity Day" or for a future biology class.
SCHOOL/COMMUNITY SERVICE PROJECT Complete twenty hours of biology-related community or school service. You will be expected to keep a journal that details what kinds of things you did and explains how your experiences related to biology concepts.	• Volunteer to work at a hospital, research lab, nursing home, zoo, park, or museum. • Volunteer to be a tutor or lab assistant for biology classes.
FIELD TRIP REPORT Plan a field trip to a museum, nature sanctuary, park, research lab, or other biology-related location. Collect information on the site, visit the site, and prepare an oral report, a written report, a scrapbook, or a videotape about the field trip.	• Select a local site and plan a trip for your classmates. • Select a distant site and plan a trip for your family.
TEACHING EXPERIENCE Present a hands-on biology lesson for preschool or elementary schoolchildren that you prepare and actually teach. Submit your lesson plans before you teach the lesson. Following the teaching, write a report on the teaching experience.	• Show preschool children how plants grow from seeds. • Help elementary school children set up a school garden or a classroom aquarium.

*Can be accomplished during school year.

Figure 8.19 Portfolio Elements and Examples (continued)

Possible Portfolio Elements	Examples
GRAPHIC REPRESENTATION Create an original graphic such as a bulletin board, model, mobile, computer graphic, or series of photographs to represent related biological concepts. Your graphic should be accompanied by a written explanation or an explanatory key.	• Make a three-dimensional model illustrating a biology concept. • Make a mobile on a biology concept.
CONCEPT EXPLANATION Become a "specialist" on a unit that you find particularly interesting by reading beyond the required course level. Make a concept map for this unit that includes your independent study. Your teacher will interview you and ask you to explain your concept map.	• Concept-map the chapters in a unit using three Advanced Placement biology texts.
INTERDISCIPLINARY PROJECT Select a biology topic and demonstrate/explain how it relates to four other subject areas, such as English, social studies, math, art, music, physical education, or business.	• Explain how "Unity and Diversity" or "Constancy and Change" is a theme that is common to many subject areas.
SCRAPBOOK OF BIOLOGY IN THE NEWS Prepare a scrapbook of newspaper and magazine articles that relate to biology. Collect at least ten articles per week for ten weeks. Organize the scrapbook into sections that correspond to the units of study in your biology class. Write a brief explanation of how the information in each article relates to your life.	• Collect biology articles from your family's newspapers and magazines. • Select a topic of interest to you, then photocopy and collect recent articles on this topic.
CREATIVE PROJECT Use your ingenuity, your talent, and/or your sense of humor to demonstrate independent learning about a biology topic that interests you. Consult the card file of suggestions in the classroom to give you an idea of the diversity of projects that you can do, but remember that you are not limited to these.	• For ideas, see the "How to Show What You Know" poster or the "Idea" card file in the classroom.

have a diversity of potential portfolio elements to select from as the due date approaches. For each portfolio element that you select, you must complete a self-reflection card. The self-reflection should be written on a 3" 5" index card and should include answers to these questions:

1. Why did you choose this portfolio element?
2. What did you learn about biology/life science by doing this element?

NOTE: In lieu of the index card, you might instead want to use the self-reflection form shown in Figure 8.18.

Your selection of portfolio elements must be done so that your portfolio includes evidence of your abilities in the following areas:

- Using decision-making skills to seek a solution to a personal or societal issue
- Using the inquiry process to plan and carry out an extended laboratory investigation
- Learn independently by acquiring and processing information
- Communicating in written, oral, and graphic form
- Improving your work through peer and self-evaluation
- Working collaboratively

Figure 8.19 lists a variety of possible portfolio elements and offers supporting examples. Portfolio elements that are asterisked are ones that may be accomplished by doing regular classroom assignments during the school year. You do not need to complete a portfolio contract for these. The portfolio elements that are not asterisked are ones that you may choose to do as independent projects. You will need to submit a contract for any independent project. This contract will ensure that independent projects will be appropriate for the portfolio. Your contract should include a description of the element and the method you will use to accomplish your task.

ASSESSING STUDENT PERFROMANCES AND ATTITUDES

An effective assessment strategy should be based on the philosophy or rationale of the course or unit that students are studying, as well as the intended learning outcomes of the experience. Advocating a curriculum based on science thinking skills and hands-on learning, but assessing outcomes using true-false and fill-in-the-blank tests is incongruent.

In this system, eight categories of intellectual skills or types of learning were identified and used to create a matrix of outcomes and assessments in Earth science, life science, and physical science. Let's take a look at the system, and then use it to develop test items for our science courses.

The eight categories of intellectual skills or types of learning were these:

1. Motor skills
2. Verbal skills
3. Discrimination
4. Concept learning
5. Rule learning
6. Problem solving
7. Cognitive strategy
8. Attitudes

As you can see, the first category describes psychomotor skills; categories two through seven cover cognitions and cognitive skills; and the final category identifies attitudes. Using this system enables you to take a systematic approach to developing effective assessment items for quizzes and tests. Take a moment to look at the table in Figure 8.20, which shows how the eight intellectual skills correlate to learning outcomes, human performance, and assessment items.

Let's look at some examples of assessment items given several learning outcomes. You can refer to these examples as model assessment items and make use of them as you design your own.

Figure 8.20 Active Learning Assessment System

Learning Skill	Learning Outcome (Action Word)	Human Performance	Assessment Example
1. Motor Skills	Manipulates	Executes a skilled motor performance	Weighs substance on a balance
2. Verbal Skills	Recalls	States a fact, makes a generalization, or gives a description	Lists minerals in Mohs' scale of hardness
3. Discrimination	Discriminates	Distinguishes objects or object features as the same or different	Tells whether photographs of galaxies are the same or different
4. Concept learning	Identifies or classifies	Classifies an object or a situation in accordance with a definition	Classifies granite as an igneous rock
5. Rule learning	Demonstrates	Applies a rule, law, or concept to a specific example	Determines the density of a mineral
6. Problem solving	Generates	Generates a solution to a novel problem	Determines the effect of velocity on erosion along a stream
7. Cognitive strategy	Originates	Originates a novel problem and solution	Gets an answer to "I wonder what would happen if . . ."
8. Attitudes	Chooses	Chooses a course of action and/or expresses a feeling toward a person, an object, or an event	Writes a letter to a Congressional Represent-ative supporting air-quality standards

Figure 8.21 Rock Chart

Characteristic	Color	Crystal Size	Hardness	Texture
Rock 1				
Rock 2				
Rock 3				

(Psycho)motor Skills

In an inquiry-oriented, hands-on science course, students will be involved in the manipulation of laboratory apparatus, scientific instruments, and the tools necessary to carry out investigations and activities. Although the assessment of motor skills, or chains, may seem to involve motor skills only, it's worth noting that cognitive skills are usually involved in any activity of this type. In any case, providing students feedback through psychomotor assessments is a powerful way to reinforce the importance of motor skills and learning in the science classroom.

Example: Motor Skills
Learning Outcome
Given a graduated cylinder, colored water, and an empty container and asked to put 40 mL of liquid into the empty container, the student manipulates the beaker and the graduated cylinder by measuring the 40 mL of the liquid and pouring this measured amount into the empty container.

Assessment Item
Here is a graduated cylinder, some colored water in a beaker, and an empty container. Pour 40 mL of the colored liquid into the empty container.

Cognitions and Cognitive Skills

As previously noted, there are six categories of assessment items that, when combined, provide measures of cognitions and cognitive skills. There is a hierarchy implied in the categories. In this section we present the six categories of cognitive thinking, along with examples of each.

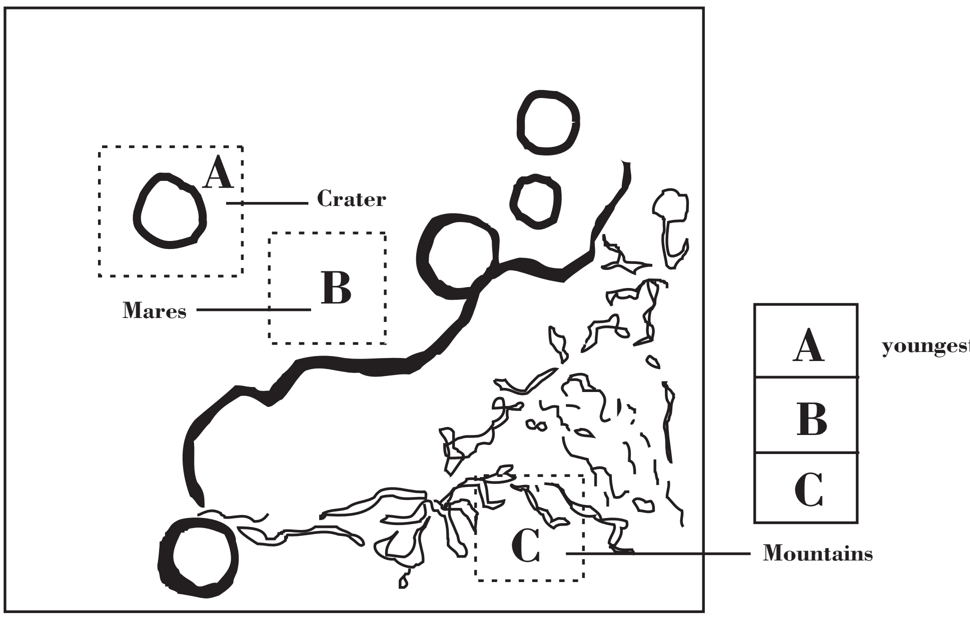
1. Verbal Skills
This form of thinking finds students involved in recalling information, either verbally or in writing. Correct answers indicate that the student knows the proper sequence of words in response to a request for verbal information. This category represents the lowest level of cognitive thinking—the recall of information.

Example: Verbal Skills
Learning Outcome
Given a volume of a liquid (melted paraffin) that is changing from a liquid to a solid, the student identifies the change by stating that the liquid is "freezing."

Assessment Item
When the liquid paraffin forms solid paraffin, what process has taken place?
(Answer: The process is called freezing.)

2. Discrimination
When students discriminate, they decide

Figure 8.22
Moon Map



whether or not things are identical. Discrimination does not imply, however, that students can identify the specific properties of the things that are the same or different.

Example: Discrimination
Learning Outcome
Given granite and a set of igneous rocks, the student discriminates between granite and other plutonic rocks.

Assessment Item
For each characteristic listed, indicate with a d or an s whether the rocks in the new set are the same as or different from granite (Figure 8.21).

3. Concept Learning
In concept learning, students do one of two things. (1) They recognize a class of objects, object characteristics, or events. In this case, students have learned the concept of class to the extent that they can classify examples by instant

Figure 8.23 Moon Problem

_____50-foot nylon rope
_____star map
_____5 gallons of water
_____box of matches
_____two 100-pound tanks of oxygen
_____food concentrate
_____life raft
____first-aid kit
____solar-powered heater
____magnetic compass
____signal flares
____case of powdered milk
____solar-powered FM walkie-talkie
____parachute silk

recognition. Recognition can involve any one or all of the senses—sight, touch, smell, taste, or sound (see Example 1). (2) Concept learning also involves classification per se. In this case, students use a definition to put something into a class (or to put some things into classes). Correct responses indicate that students know the parameters of the class or classes, and they can either verbalize them or use them when asked to do so (see Example 2).

Example 1: Concept Learning
Learning Outcome
Given the names of parts of a typical plant cell, the student draws a cell and names the given parts.

Assessment Item
Draw a plant cell with these parts shown and labeled.

a. Cell wall
b. Nucleus
c. Chloroplasts

Example 2: Concept Learning
Learning Outcome
Given a map of the moon with features labeled, the student classifies the labeled features according to age.)

Assessment Item
The map (see Figure 8.22) shows a region of the moon with three areas marked. In boxes to the right of the map, place the letters of the features in order of age, listing the youngest first.

4. Rule Learning
Rule learning engages students in applying specific concepts, rules, or procedures to a specific task. The key notion here is the process of applying rules. Indeed application is an important part of the learning cycle that has been developed throughout this book. Students need opportunities to apply what they are learning, and they need assessment feedback on their progress.

Example: Rule Learning
Learning Outcome
Given a hypothetical situation in which the student crash lands on the moon's surface and given a list of items that survive the crash, the student ranks those items in terms of their importance to reaching the safety of a moon base.

Assessment Item
Imagine that you are a member of a moon landing crew whose spaceship has just crashed on the lighted side of the moon's surface. Your survival depends on reaching a moon base some 5 miles away. Figure 8.23 shows 14 items left intact after the crash landing. Rank them in order of importance to reaching the moon base. Place a number 1 by the most important, number 2 by the second most important, and so on.

5. Problem Solving
When students use two or more rules, definitions, or concepts to solve a problem, they are generating ideas, solutions, and procedures. Like rule learning, problem solving involves the application of scientific concepts; however, it occurs at a higher level of cognitive functioning. Students benefit from many opportunities to solve problems and, by extension, from assessment strategies that test their problem-solving abilities.

Example: Problem Solving
Learning Outcome
Given a hypothetical situation describing an individual's energy requirements and given materials that model these needs, the student generates a system to fulfill the energy requirements.

Assessment Item
Imagine this situation. Your neighbors are planning to add a garage to their house. Their energy needs include lighting, heating, and power to run a motor for the garage door. The energy they have selected is electricity. You have been given a dry-cell battery, a light bulb, a piece of nichrome wire, and a small motor. Using any or all of these materials, make a system that shows how your neighbors can meet their energy needs.

6. Cognitive Strategy
Cognitive strategy ultimately refers to student creativity. The key notion here is originating a plan or an idea. Cognitive strategy means combining ideas to propose and solve problems. Students know the material sufficiently well to identify a problem area and organize the proper concepts and procedures to solve it. Many of the performance tasks that were introduced earlier in this chapter involve cognitive strategy.

Example: Cognitive Strategy
Learning Outcome
Given an organic and inorganic fertilizer, soil, containers, and seeds, the student designs and conducts an experiment to find out which fertilizer is more effective.

Assessment Item
(For individuals) You will find before you the materials you may use to carry out an experiment. You are to design the experiment yourself. Its purpose is to determine which fertilizer is better for making the plants healthier and able to produce more peppers.

(For groups) You will find before your team the materials you may use to carry out an experiment. You are to work together with your team members to design the experiment. Its purpose is to determine which fertilizer is better for making the plants healthier and able to produce more peppers.

Attitudes
Affective outcomes, like psychomotor and cognitive outcomes, can and should be assessed. In the model being presented here, "affects" are classified as "attitudes."

Attitudes involve, among other behaviors, choosing. If students make a choice, they are deciding to behave in a certain way. A student might choose to say that smoking is harmful, but

figure 8.24
Use this form to measure student attitudes.

Example 2: Attitudes

Science is	1	2	3	4	5	6	
Meaningful	______:	______:	______:	______:	______:	______	Meaningless
Bad	______:	______:	______:	______:	______:	______	Good
Useful	______:	______:	______:	______:	______:	______	Useless
Confusing	______:	______:	______:	______:	______:	______	Clear
Unimportant	______:	______:	______:	______:	______:	______	Important
Simple	______:	______:	______:	______:	______:	______	Complex

after school be seen smoking a cigarette. Similarly, a student might say that recycling is an important part of a family's responsibility to the environment, but not make use of trash stream separators at restaurants or in the school cafeteria.

Example 1: Attitudes
Learning Outcome
Given a list of endangered animal species and a statement that the animals are being killed in such numbers as to risk their extinction, the student chooses to speak in favor of protecting the animals.

Assessment Item
The bald eagle, blue whale, California condor, Everglades kite, red wolf, key deer, cougar, alligator, and whooping crane are all examples of animals in the United States that are endangered species. These animals may all become extinct, never again to be part of the Earth's ecosystem. What should be done about this problem?

There are other techniques that you can use to assess attitudes. One technique involves the semantic differential. To use the technique, you select a concept or an idea, then develop a set of relevant bipolar adjectives or adjective phrases. For example, suppose you wanted to assess your students' attitudes toward science. You could use the following semantic differential scale.

The students simply check a line along the continuum, indicating what their attitude is with respect to each bipolar pair. NOTE: You'll probably find it useful to summarize the class's responses first, then calculate a mean for each bipolar adjective pair. Of course, many other "concepts" can be assessed using this technique. You might, for example, assess student attitudes about the following:

- Chemistry
- Rocks
- Science course
- This unit
- Alcohol/drugs
- Space exploration

SUMMARY

Teaching science as inquiry behooves us to reconsider the way that student learning is assessed. The key concept in assessing student learning is the connection between the goals of science teaching and the expression of student learning. Not all student learning can be expressed in terms of answers on a multiple-choice test. In this chapter you were introduced to diagnostic, formative, and summative assessment tools and examples. Eliciting students' prior knowledge and understanding through discussion and talk helps us diagnose student learning. Formative tools such as observing students in group work, asking questions, using alternative types of questions, and performance assessments will help students learn and understand. Summative tools including student logs, portfolios, and open-ended questions help us assess student learning and make improvements in instruction.

PART IV CONSTRUCTIVISM IN THE BAG: ACTIVE SCIENCE LESSONS

Science As Inquiry has focused on the importance of establishing classroom environments in which students are active learners using inquiry as a way of knowing. Research has shown that regardless of the strategy being used by the teacher—questioning, cooperative learning, discrepant events (EEEPs), and so on, the most important element in fostering achievement and learning is an active student.

Chapters 9 through 12 contain thirty-one active science lessons organized into the following subject areas: Earth Science, Environmental Science, Life Science, and Physical Science. Every lesson includes Internet resources that complement the subject matter. Additionally, many of these lessons incorporate the use of the Internet into their design.

Developing the Lessons

The lessons you'll find here are based on sketches and outlines developed at teaching seminars conducted over several years.

In preparation for the seminars, a four-stage plan based on the Constructivist Learning Model (CLM) was developed. The four stages used are: Invitation, Exploration, Explanation, and Taking Action. Figure IV.3 outlines the key elements of the constructivist learning cycle.

In a session entitled "Constructivism in the Bag," teacher participants selected from a bag of science materials grouped into Earth, environmental, life, and physical sciences. An Earth science bag, for example, might contain a collection of rocks, a hand-held lens, and a metric rule. Physical science bags might contain lenses, batteries, motors, wire, light bulbs, Slinkys™, prisms, and/or mirrors; life science bags might contain animal replicas, shells, soil, and/or seeds (Figure IV.1).

The teacher teams then worked together on lesson sequences using the "Constructivism in the Bag" form (Figure IV.2) to guide their work. This form outlines the four key elements of the constructivism lesson (Invitation, Exploration, Explanation, and Taking Action). The task for the teams was to develop a lesson sequence as well as to design posters summarizing their work. Some of the posters are shown in Figure IV.4. As a final step, the teachers exchanged materials and shared ideas.

Invitation

Purpose: The CLM begins by engaging the student with an invitation to learn. The invitation stage helps spark interest and expose initial ideas students have about the topic.

Figure IV.1
Bags of science equipment as shown here were used by teachers to develop active learning and Web-based lessons in the activity "Constructivism in the Bag" in the author's seminars.

Figure IV.2

Constructivism in the Bag

The Design Team Activity

Creating Constructivist Science Lesson Sequences

Inquiry. This is an open-ended inquiry activity. You will work with your science curriculum design team and create a sequence of activities using a four-stage learning cycle. Obtain a "constructivist science baggie" and use it to frame your team's thinking and planning as you design a sequence of activities. Be prepared to mini-teach and/or share your product with others.

Topic of the Teaching Sequence

Key Preliminary Decisions

Grade Level and Subject

Big Idea

Fundamental Concept(s) That Your Team Wishes to Teach

Key Objectives/Goal

Grouping of Students

Materials

Key Elements of the Learning Cycle Sequence

1. Invitation. (Invite student ideas.) Describe how you will find out about students' prior knowledge, ideas, and beliefs about the concepts in your sequence.
   - Provocative Questions
   - EEEPs
   - Discrepant Events
   - T-charts
   - Interview Questions
   - Interesting Challenges
   - Demonstrations
   - Concept Maps

   Describe your activity or procedure:

2. Exploration. (Students explore phenomena through focused activity.) Describe at least one activity that you will use to assist your students in exploring the fundamental concept(s).
   - Inquiry
   - Writing to Learn
   - Hands-on
   - Observation
   - Data Collection
   - Data Interpretation
   - Asking Questions
   - Constructing Explanations
   - Communicating Ideas
   - Cooperative Groups

   Describe your activity:

   What are some questions you will be asking students to help them focus on fundamental concept(s)?

3. Explanation. (Help students propose and compare ideas.) Describe how the students will have the opportunity to hear differing views to talk aloud about their ideas to test ideas against the "the scientist's" ideas.
    - Small-Group Discussion
    - Debating Alternative Ideas
    - Large-Group Discussion
    - Displays of Concepts
    - Constructing Models
    - Journal/Log Writing
    - Active Reading
    - Collaborative Group Questioning
    - Explaining Ideas
    - Defending Models

    Describe how you will assist students to form explanations of the fundamental concepts:

4. Taking Action. (Students apply their knowledge.) Describe at least one activity that will assist students in taking personal and/or social action on issues related to the content of the concepts, or to assist them in applying the concepts to new situations.
    - Designing a long term research project
    - Writing letters
    - Making posters about the topic
    - Hands-on activities
    - Sharing knowledge
    - Journal/log writing
    - Concept maps
    - Seeking answers to their own questions

    Describe the plan to assist student in taking action:

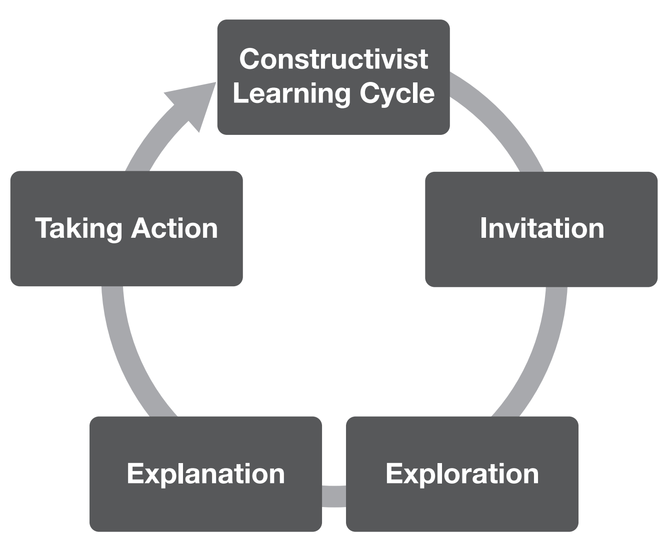


Figure IV.3
Constructivist Learning Cycle

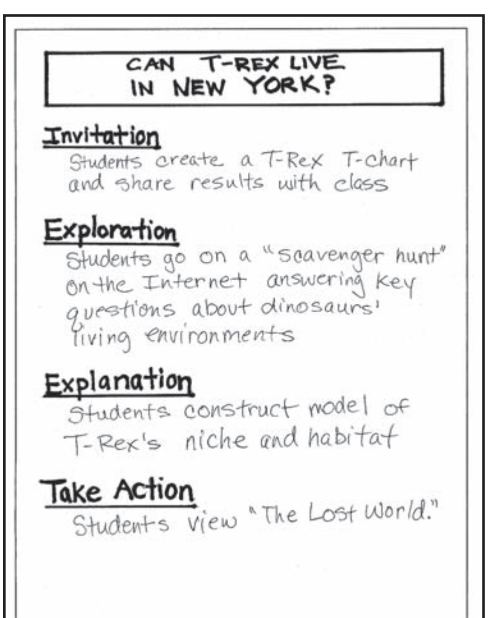
- Teacher establishes a context for learning and invites student to learn about a topic by:
- Asking provocative questions
- Conducting a demonstration of a discrepant even or an EEEP and asking students to ponder, think about, predict about the topic
- Asking students what they know and questions they have about a topic

Exploration

Purpose: To provide an opportunity for students to explore phenomena or concepts through focused activities.

- Teacher plans specific activities that enable students to test their predictions or initial ideas as well as engage in observation, data collection, and data interpretation experience.
- Students work in cooperative groups to brainstorm, test, discuss, and debate ideas.

Figure IV.4
To turn posters into lessons, the author collaborated with Daniel Whitehair, a science educator in New York and graduate student in science education at Georgia State University, to develop the 31 complete lessons that form the basis of Chapters 9 and 10.



Explanation

Purpose: To enable students to propose explanations based on their own activity and to help them construct new views of the concepts.

- Teacher plans activities that will enable students to communicate their ideas to each other as well as construct new explanations for concepts and phenomena.
- Students work in small groups, but share ideas with the whole class through displays of their work, poster reports, and class discussion.

Take Action

Purpose: To take action on what they learned.

- Teacher works with students to help them take personal and social action on issues related to the content of the concepts and phenomena.
- Students apply knowledge and skills, share information about the topic, ask new questions, make decisions, develop products, and write letters.

Using the Lessons

The lessons that follow can be used in any sequence. They integrate many of the strategies that are developed earlier in the book. Each lesson plan includes eight elements:

- Goal—Lesson objective(s)
- Overview—Description of student responsibilities
- Materials—listing of simple and easily obtainable supplies needed for the lesson
- Invitation—Stage 1 of Constructivist Learning Model, in which students' prior knowledge and ideas are identified
- Exploration—Stage 2, in which students explore the key phenomena in the lesson
- Explanation—Stage 3, in which students propose and compare ideas
- Taking Action—Stage 4, in which students take personal and/or social action on issues

related to the content of the lesson

- Internet Resources—Identification of relevant sites on the Internet.

Chapters 9 through 12 contain a collection of lesson plans that are based on a constructivist and inquiry approach to science learning. Each lesson is self-contained, and thus you can choose to use the lessons in whatever sequence that you wish. Each lesson also includes Internet sites that you might wish to use in the lessons. NOTE: All of the websites listed for the lessons in Chapters 9 – 12 can be found in in the Science As Inquiry website under the tab "Science Activities": http://www.science-as-inquiry.org/science-activities.html

Chapter 9 Earth Science Lessons

Earth Science Lessons

Lessons in this Chapter:

- Making a Cloud
- Igneous Rocks: Granite
- The Center of the Earth
- Rock Types: Igneous, Metamorphic, Sedimentary
- Geysers
- Mohs' Scale of Mineral Hardness
- Geology: Mohs' Scale
- Project River Watch: Investigating Water Quality

Making a Cloud

Goal: Students become more aware of cloud formations after completing this activity, which illustrates the principles involved in cloud formation. More specifically, students observe the importance of a nuclei-providing medium on which water vapor can condense, forming a "cloud." Lab skill, observation skills, and ability to deduce will be enhanced.

Overview: Initially, students will complete a T-chart on clouds. Groups of students then formulate a hypothesis on how clouds are formed. Groups make a cloud in a jar using simple equipment; they then formulate a new hypothesis on the formation of clouds. Students finish up by researching local weather and finding out how technology is used to predict weather patterns.

Materials: Bags containing a wide-mouth gallon pickle jar, a heavy-duty clear plastic bag, rubber bands, matches

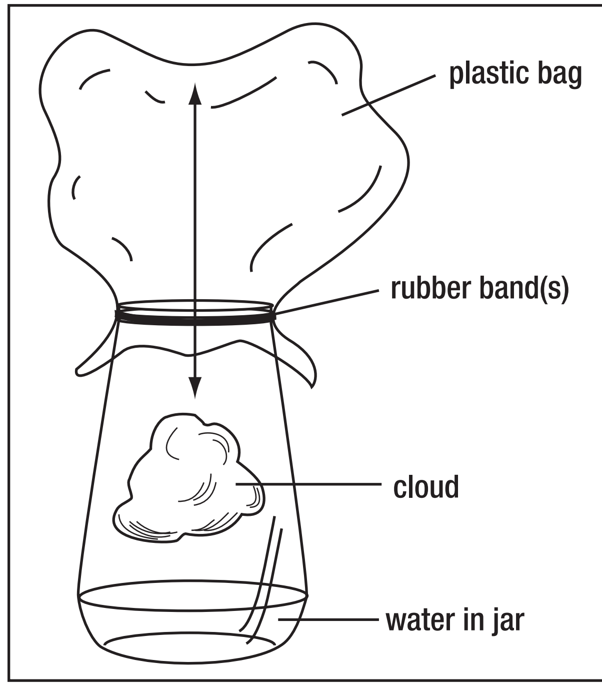
Invitation

Students complete a T-chart on clouds. One column should read "Things we know about clouds"; the other should read "Things we would like to know about clouds." Cloud formation should emerge as a topic in either column. Discussion focuses on a study of how clouds form.

Exploration

Students are divided into small cooperative learning groups. Each group should develop a hypothesis about how clouds are formed and record its ideas. Groups are given a bag containing the lab materials. Groups should then follow this procedure: Place 20 ml of water in a jar. Place a lit match into the jar. Quickly place a plastic bag over the mouth of the jar and secure it with (a) rubber band(s). Push the bag into the jar quickly, then pull the bag out. Observe and record what happens. Each group should formulate a new hypothesis on the formation of clouds.

Figure 9.1
Making a Cloud



Explanation

Groups present their hypotheses and observations to the class. The teacher presents the following hypothesis and asks for students if they have data that can support or refute the idea. The water produces high humidity in the jar and the smoke provides nuclei on which the water vapor can condense. As the bag is pushed in, the pressure and temperature in the jar increase, causing the jar to clear. Upon pulling the bag out, pressure and temperature drop, allowing water vapor to condense and produce a "cloud" inside the jar.

Take Action

Students could track local weather conditions for a few days and make predictions about cloud coverage according to conditions. Students could also contact and/or visit a local meteorologist, or research radar and other technology used in weather detection and forecasting.

Internet Resources
http://www.crh.noaa.gov/lmk/?n=cloud_classification
Cloud Classifier Home Page

http://www.usatoday.com/weather/wcirrus.htm
Cirrus Clouds

http://en.wikipedia.org/wiki/Cloud
Clouds

http://radar.weather.gov
National Weather Service Radar Site

Igneous Rocks: Granite

Goal: This activity, done in cooperative learning groups, challenges students' abilities to observe, examine, inquire, and conclude. Students become familiar with igneous rocks, their formation, and composition.

Overview: Students brainstorm about rocks and create a concept map based on their brainstorming. In groups, students examine a sample rock and try to deduce facts about its composition. Students share resulting observations/deductions with the class. Groups then reevaluate their initial concept map and modify it, if necessary. This concept map is to be turned in.

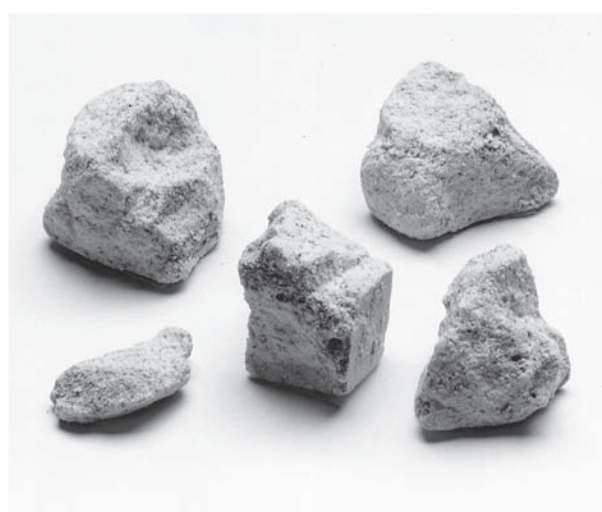
Materials: Bags containing a sample of granite, a small magnifying glass, newsprint, markers

Invitation
As a class, students brainstorm about rocks. Terms are written on the board/large newsprint by the teacher. Groups then create a concept map utilizing the terms on the board.

Exploration
Each group receives a bag containing a sample of granite. Groups examine the sample, make observations about the sample, and attempt to determine facts about its composition. Groups then answer questions such as the following: How many different substances make it up? What are some characteristics of those substances? What type of rock is it? What is it? All observations and deductions should be recorded on newsprint.

Explanation
Students share resulting observations/deductions with the class. Teacher intervention, if necessary, consists of informing the class that the sample is granite, an igneous rock composed of feldspar, quartz, and mica. The class discusses the characteristics of igneous rocks. Groups then reevaluate their initial concept map and

Figure 9.2
Granite



modify/change it if necessary. The concept map is turned in, along with observations.

Take Action

Students could conduct research on the other two types of rocks (sedimentary and metamorphic) and/or on feldspar, quartz, and mica. Students could also research the type of rocks found in their geographical area, then make conclusions about that area.Finally, students might investigate the rock cycle (figure 9.3).

Internet Resources

http://www.geosociety.org/index.htm
Geological Society of America

http://www.usgs.gov
United States Geological Survey (UCGS)

http://en.wikipedia.org/wiki/Geologic_map
Geologic Maps

The Center of the Earth

Goal: In this activity, students become familiar with the composition of the Earth. They learn to identify the Earth's four main layers, and the effects they may have on us. In cooperative learning groups, students apply knowledge and exercise their creativity.

Overview: Students read and discuss an excerpt from Jules Verne's Journey to the Center of the Earth. In groups, they create a small model of the Earth, revealing its composition. Students present their models to the class. Models are then displayed. As a final step, students investigate the composition of the moon and other planets for comparison with the Earth's composition.

Materials: Bags containing materials for making a model: small polystyrene foam ball, various colors of modeling clay, cotton, paper, etc.; colored pencils/markers; other basic supplies, as desired; copies of an excerpt from Journey to the Center of the Earth

Invitation

Students receive a copy of an excerpt from Journey to the Center of the Earth. They discuss the reading and Verne himself, answering such questions as: Would such a journey be possible? Did people in Verne's time believe that such a journey was possible? If it wouldn't be possible, why not?

Exploration

Students are divided into cooperative learning groups. In these groups, they research the composition of the Earth and design and create a small model. Accompanying this model should be a written summary of the group's work and its findings.

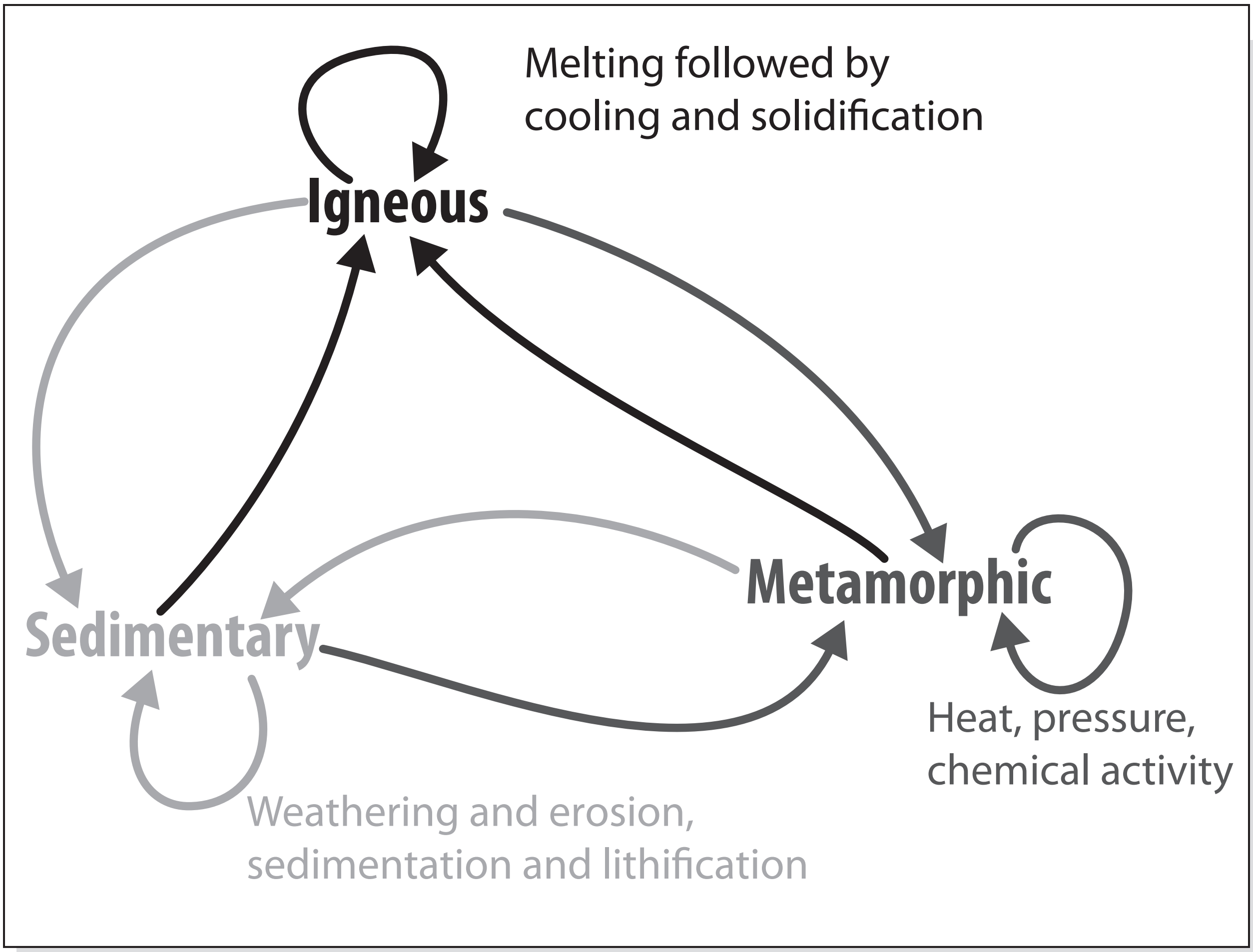
Explanation

Once the models and the reports have been completed, each group presents its final project (model and report) to the class. Final projects are then displayed. Teachers should use an alternative form of assessment to evaluate the model and teamwork.

Take Action

Students could review the questions they answered in the Invitation section, and compare their responses to those they would give now. They could also investigate the composition of the moon and other planets for comparison with the Earth's. Additionally, students could opt to read any of Verne's books and/or read about Verne.

Figure 9.3
The Rock Cycle.
New conditions, such as weathering and erosion, and heat and pressure cause rocks to change, and cycle from one form to another as shown in the cyclic diagram. Source: National Park Service.



Internet Resources
http://scign.jpl.nasa.gov/learn/plate1.htm
Structure of the Earth

http://en.wikipedia.org/wiki/A_Journey_to_the_Center_of_the_Earth
Journey to the Center of the Earth

Rock Types: Igneous, Metamorphic, Sedimentary

Goal: In this activity, students gain insight into the three different types of rocks and how each is formed. Observational, research, and inference-making skills are enhanced in this cooperative learning activity.

Overview: Students brainstorm about rocks. In groups, students make observations and inferences about a rock, utilizing as many of the terms from their brainstorming list as possible. Each group then conducts research to verify its inferences and presents its findings to the class. The class revises its initial brainstorming list. To finish up, students research types of rock from the local area.

Materials: Bags containing a rock and a magnifying glass (use different rock types in the various bags); books; computer(s) with Internet access

INVITATION
Students are asked to brainstorm about rocks. Teacher records all suggestions on the board/ newsprint. Students are then divided into groups and given a bag containing a rock and a magnifying glass. Groups observe their rock and make at least five inferences about it, using as many of the terms as possible from their brainstorming list. Observations and inferences should be recorded.

EXPLORATION
Groups research their rock in order to verify their five inferences. Utilizing the Internet can be a very fruitful and efficient way for student groups to conduct their research. Some informative sites that groups may want to access are listed under the Internet Resources section that follows. Teachers may need to assist the groups in determining what type of rock they have. Once the type has been determined, students' search can be facilitated.

EXPLANATION
Groups present to the class their rock, their five inferences, and their factual findings. After the final presentation, the class revisits its initial list and amends it to make it a more accurate and comprehensive list about rocks.

TAKE ACTION
Students could collect rock samples from their geographical area. The samples could be classified and certain inferences made about the geological history of that area. Visits to any local rock formations could be interesting as well.

Internet Resources
http://en.wikipedia.org/wiki/Igneous_rock
Igneous Rocks

http://en.wikipedia.org/wiki/Metamorphic_rock
Metamorphic Rocks

http://en.wikipedia.org/wiki/Sedimentary_rock
Sedimentary Rock

http://en.wikipedia.org/wiki/Rock_cycle
Sedimentary Rock

http://www.usgs.gov
United States Geological Survey (UCGS)

GEYSERS

Goal: Students participate in a hands-on cooperative activity giving them insight into how geysers function. In the process, they gain experience in laboratory work and hone their observational skills. At the end of the activity, students will be able to describe how a geyser works.

Overview: Students watch and discuss a video on Old Faithful. In groups, students theorize about the mechanism of a geyser. Groups then conduct an experiment that demonstrates geyser functioning. Groups record the procedure and results. To expand their knowledge, students can research geyser numbers and activity in their area, in the country, or worldwide.

Materials: Bags containing a funnel, a large coffee can or pot as tall as the funnel, a piece of plastic tubing (about 1 m); video on Old Faithful

INVITATION
Students watch a video about Old Faithful, located in Yellowstone National Park. As part of the discussion, any student who has seen a geyser can share his or her experience with the class. Students are then divided into small cooperative learning groups and theorize about the mechanism of a geyser. A member of each group records the group's theory.

Figure 9.4
Old Faithful Web cam
Old Faithful Geyser of Yellowstone National Park. This a picture taken from the webcam in the visitor center. To view the live webcam, go to http://www.nps.gov/yell/photosmultimedia/webcams.htm Source: National Park Service.

Exploration

Groups are given a bag containing the lab materials. Each group should conduct the following experiment recording each procedure and result: Fill the pot with water; set the funnel mouth down into the water; place the end of the plastic tubing under the rim of the funnel; blow. Groups then answer the following questions regarding their experiment: Describe what happened and relate this to what you know about the structures of geysers. Some geysers erupt every few minutes, while others erupt every few years—what could be causing this difference?

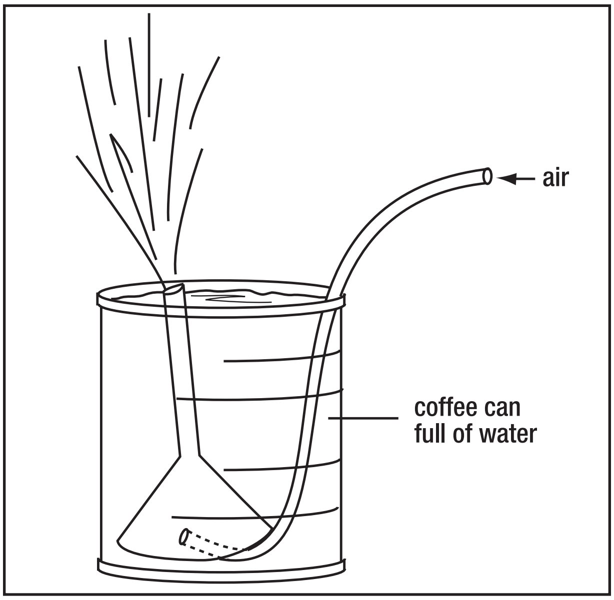
Explanation

Groups present their results and their answers to the class. As they do so, teachers can make a listing of answers on the board. A teacher-led discussion helps put the results in perspective and answer any remaining questions.

Take Action

Students could expand their knowledge by researching geyser numbers and activity in their area, in the country, or worldwide. Research on Yellowstone National Park would make for an excellent longer-term project.

Figure 9.5
Geyser



Internet Resources
http://www.yellowstone.net/geysers.htm
The Geysers of Yellowstone

http://www.eia.doe.gov/kids/energy.cfm?page=geothermal_home-basics
Geothermal Energy

MOHS' SCALE OF MINERAL HARDNESS

Goal: This lesson introduces students to Mohs' hardness scale and teaches them how it relates to the classification of minerals. Students create their own hardness scale using scientific and imaginative skills.

Overview: In groups, students answer questions related to the hardness of certain substances. Students then create a simple hardness scale using some of the items from Mohs' base scale. Student groups share their scales with the class. Further discussion and research might focus on some of the substances on Mohs' scale.

Materials: Bags containing substances from the scale: talc, gypsum, calcite, fluorite, apatite, feldspar, quartz, topaz, sapphire, diamond; small blackboards or items made of another slatelike substance; a chart with Mohs' scale; newsprint; markers

INVITATION
Teacher begins lesson by asking students thought-provoking questions such as these: "What are some differences between talc and diamonds?" "Why do we use chalk on blackboards?" "What if we used other substances on a blackboard?" "What is the principle behind the process of engraving?" "What is used to cut glass?" Questions should inspire discussion relating to the hardness of substances.

EXPLORATION
Groups of students receive a bag containing the lab materials. Groups test the hardness of the various substances in the bag, and make observations; small blackboards or items made of another slatelike substance are provided for scratching. Groups then design a simple scale of hardness—one appropriate for ranking not only the substances provided in the bag, but other substances as well. Groups create their scale on newsprint and present it to the class.

EXPLANATION
Teacher introduces Friedrich Mohs and his scale of hardness (see Figure 9.7). Class discussion focuses first on how Mohs' scale compares with the various scales designed by the students. Should there be questions about the ranking of the items, additional class tests can be run on any of the substances. Discussion then turns to why hardness is an important feature, and who might need to use Mohs' scale.

TAKE ACTION
Each group could choose one of the items from the scale and do additional research on that

Figure 9.6 Mohs' Hardness Scale

Hardness	Material
1	Talc—easily scratched by the fingernail
2	Gypsum—just scratched by the fingernail
3	Calcite—scratches and is scratched by a copper coin
4	Fluorite—not scratched by a copper coin and does not scratch glass
5	Apatite—just scratches glass and is easily scratched by a knife
6	Orthoclase—easily scratches glass and is just scratched by a file
7	Quartz—not scratched by a file
8	Topaz
9	Corundum
10	Diamond

substance. Research might focus on the answers to these (and other) questions: What is it used for? Why is it relevant? Why is its position in Mohs' scale important to its features and functions? Research might be carried out via the Internet. Each group could create a brief report on the selected substance and present it to the class.

Internet Resources
http://en.wikipedia.org/wiki/Mohs_scale_of_mineral_hardness
Mohs' Scale

http://www.minerals.net/
The Minerals and Gemstones

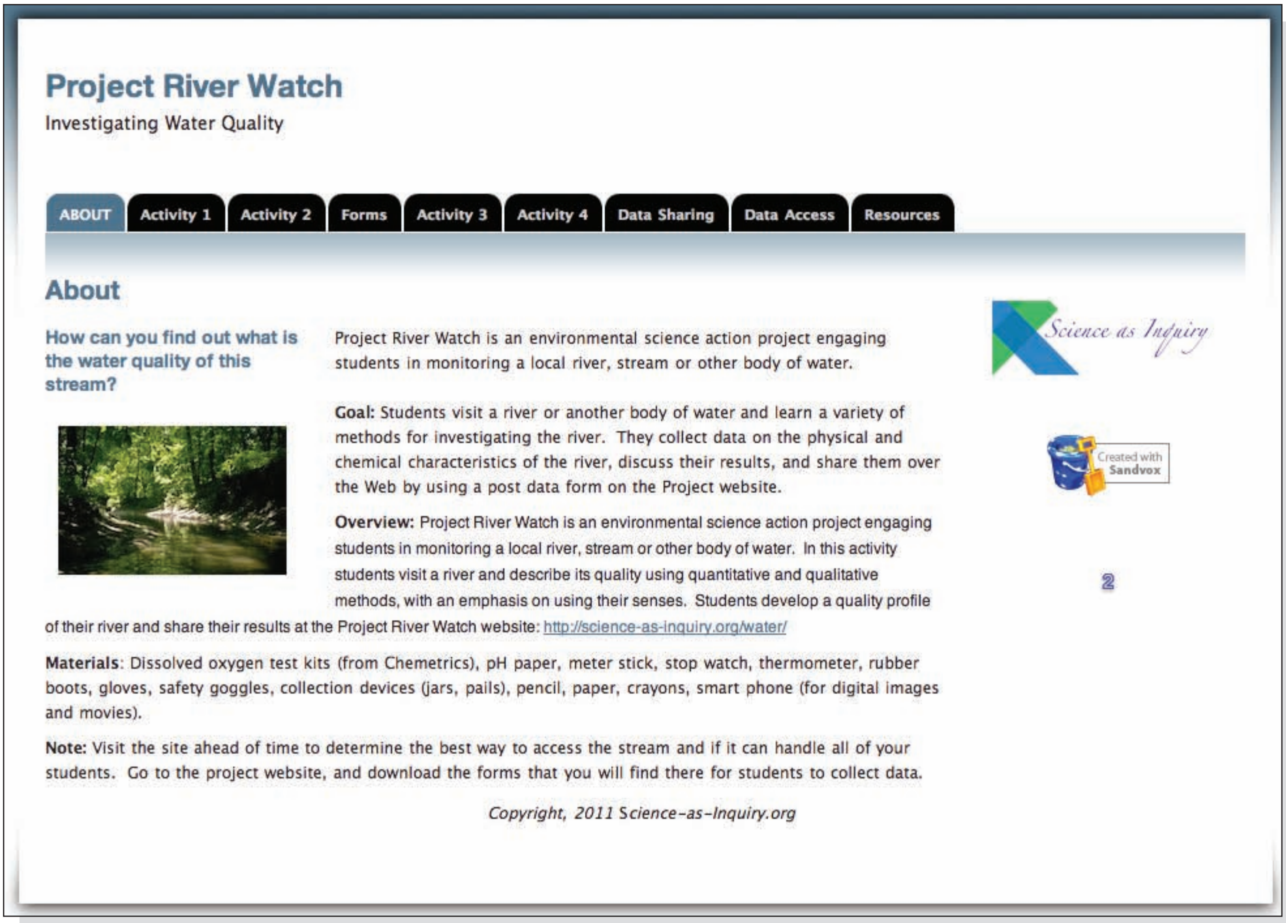
http://webmineral.com
Mineralogy Database

Project River Watch

Goal: Students visit a river or another body of water and learn a variety of methods for investigating the river. They collect data on the physical and chemical characteristics of the river, discuss their results, and share them over the Web by using a data form on the Project River Watch Web site.

Overview: Project River Watch is an environmental science action project engaging students in monitoring a local river, stream, or other body of water. In this activity students visit a river and describe its quality using quantitative and qualitative methods, with an emphasis on using their senses. Students develop a quality profile of their river and share their results at the Project River Watch Web site:
http://science-as-inquiry.org/water

Fig 9.7
Project River Watch Website:
http://www.science-as-inquiry.org/water



Materials: Dissolved oxygen test kits (from Chemetrics), pH paper, meter stick, stop watch, thermometer, rubber boots, gloves, safety goggles, collection devices (jars, pails), pencil, paper, crayons, and a smart phone (for digital images and movies).

Note: Visit the site ahead of time to determine the best way to access the stream and if it can handle all of your students. Go to the project website, and download the forms that you will find there for students to collect data.

INVITATION
Show students a digital video of the river or body of water that you are going to use for the activity. Ask the students to discuss in small groups how they would go about trying to find out about the quality of the water in this body of water. After reports from each group, explain that in this activity they will be collecting data on the river and the water in the river, and will be sharing their data with each other and with others by posting their results on the Internet. You might show the class the Project River Watch Web site (http://science-as-inquiry.org/water).

EXPLORATION
Organize your class into teams, each of which will be responsible for observing and collecting data on the physical and chemical characteristics of the river. Each team should work as an

independent unit, collecting data on the section of the river assigned to them. Have the teams gather the equipment and data forms they need to carry out their investigations.

Explanation

After the students have visited the river and collected data, upon return, each team should post their results on a large class chart that is based on the data form that they used to collect data. The chart should include (at a minimum) name of team, location of observations, date, weather, air temperature, water temperature, depth of water at observation, flow of water, dissolved oxygen, and pH.

Use the data table to invite the students to draw conclusions about the quality of water in the body of water they investigated.

Tell the students that, as a class, they will post one set of data representing an average for each type of data collected. Select the team to post the data on the Project Web site.

Ask the students to visit the Project Web site, and look at the data collected by other schools participating in the project. The data can be easily downloaded into Excel and used for analysis.

Students can also post comments on the Project River Watch Blog.

Take Action

Ask students to prepare a digital report that they can present to others, adults and students. Select a day for your students to present their digital reports to each other, as well as to another group (perhaps an elementary school class), if possible.

Chapter 10 Environmental Science Lessons

Environmental Science Lessons

Lessons in this Chapter:

- Acid Rain
- Rain Forest Deforestation
- Project Green Classroom
- Waste Disposal
- Clean Water
- Hydroelectric Power

ACID RAIN

Goal: This lesson provides students with a general awareness of what acid rain is, what it affects, and what is being done about this worldwide problem. Students will gain experience utilizing computers and the Internet. In the end, the lesson raises school consciousness about the pressing problem of acid rain.

Overview: Students brainstorm about and complete a T-chart on acid rain. In groups, students research via the Internet, one concept/question and write a one-page summary of it, which they present to the class. Summaries are compiled into a final Acid Rain Folder. To finish, students make informational posters about acid rain and post them around the school.

Materials: Posterboard, markers, resources on acid rain (Internet, books, pamphlets, etc.), computer(s) with Internet access

INVITATION

To spark a brief discussion of acid rain, ask students questions such as the following: "How do sulfur emissions from power plants in the United Kingdom affect Scandinavia?" "How do Canadian emissions (from cars) contribute to biodiversity in lakes in northeastern United States?" "Why does the Canadian government complain to the U.S. government about sulfur falling in eastern Canada?" Once class discussion leads to acid rain as the answer, a T-chart should be constructed with the following column headings: "What we know about acid rain" and "What we want to know about acid rain."

EXPLORATION

Teams select one of the questions/concepts from the T-chart for research. Teachers make resources available to the students, and involve themselves in students' research as needed. Each group should utilize at least one Internet resource in its research. That Web site should be properly read, referenced, and mentioned in the team's report (and Take Action posters). Each team prepares a final written report of its findings, which it hands in. Note: Teachers may want to assign one or two of the following Web sites to each team and have teams either use those sites to research their question/concept, or summarize each site and then share that information with the class.

Internet Resources
http://www.epa.gov/acidrain
EPA Acid Rain Program

http://www.epa.gov/acidrain/education/site_kids/index.htm
Acid Rain Kids

http://en.wikipedia.org/wiki/Acid_rain
What is Acid Rain

http://www.epa.gov/acidrain/effects/materials.html
Effects of Acid Rain

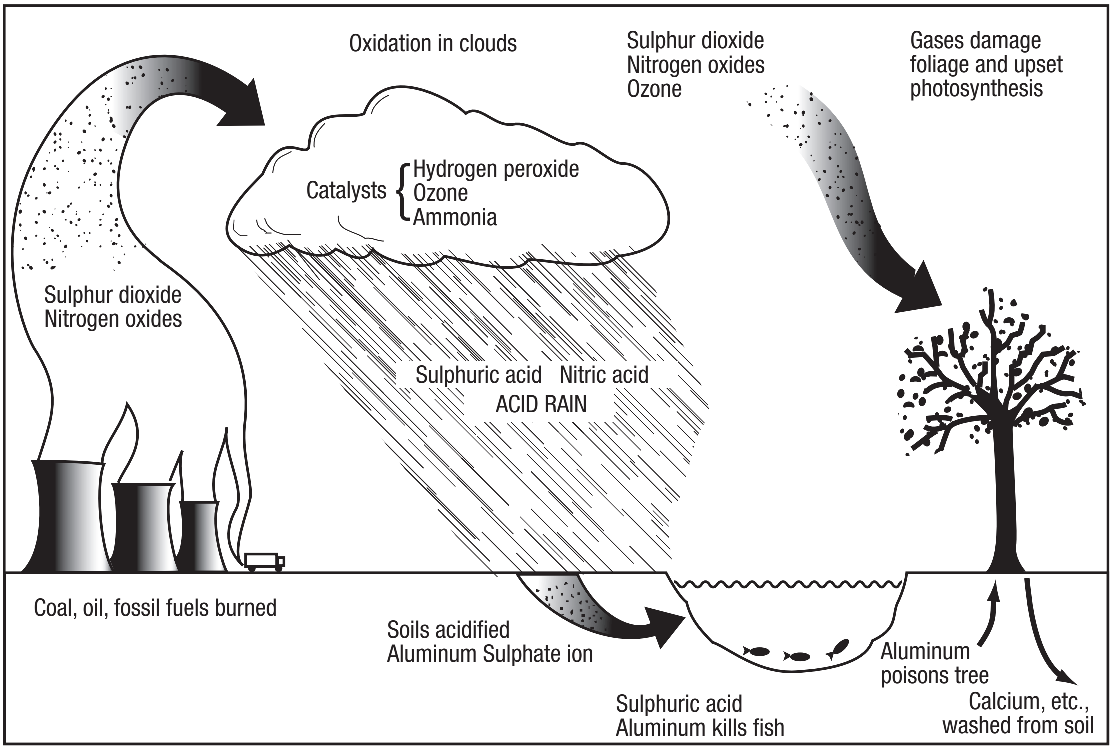
EXPLANATION

Each team briefly shares its report with the class. It should be clear from the report what question/concept the team selected, and their findings on that issue. Following the presentations, groups turn in their written reports, which are compiled into an Acid Rain Folder, and placed in the school library as a resource.

TAKE ACTION

Each team should make one to three posters about acid rain. By hanging up posters around the school, students help to make other students aware of the acid rain problem. Be sure students understand that the posters are to be informational and aimed at raising school consciousness. Each individual student could also research and prepare a one-page report on legislation regarding acid rain. This one-page report could be included in the Acid Rain Folder, along with any newspaper articles on the subject. Consider evaluating the folder with a rubric.

Figure 10.1
Acid Rain



Internet Resources
http://unfccc.int/2860.php
Climate Change Convention

http://www.epa.gov/acidrain/education/experiments.html
Acid Rain Experiments

http://www.epa.gov/acidrain
U.S. Environmental Protection Agency — Acid Rain

http://www.epa.gov/docs/acidrain/ardhome.html
EPA Acid Rain Program

http://www.ns.ec.gc.ca/aeb/ssd/acid/acidfaq.html
FAQ's on Acid Rain

http://www.beakman.com/acid/acid.html
Acid Rain

Rain Forest Deforestation

Goal: Students learn how the deforestation of the rain forest relates to the greenhouse effect. Students observe changes, record data, and conduct research utilizing the Internet. In the end, student awareness of deforestation and the greenhouse effect is raised.

Overview: Students are asked to speculate on how the clearing of land in Brazil can affect the temperature in Siberia. Students share their theories with the class; discussion of the greenhouse effect follows. A class experiment/demonstration shows the release of carbon dioxide from forest fires. The relationship between deforestation and global warming is verified and further research is conducted via the Internet.

Materials: 10-gallon fish tank with lid, sand/gravel, wooden matches, limewater (calcium hydroxide), two small glass beakers or jars, water, fireplace matches; computer(s) with Internet access

INVITATION

Ask students, working in cooperative learning groups, to hypothesize about how clearing land in Brazil for crops and livestock can affect the temperature in Siberia. Have each group share its theory with the class. Note theories on the board/newsprint.

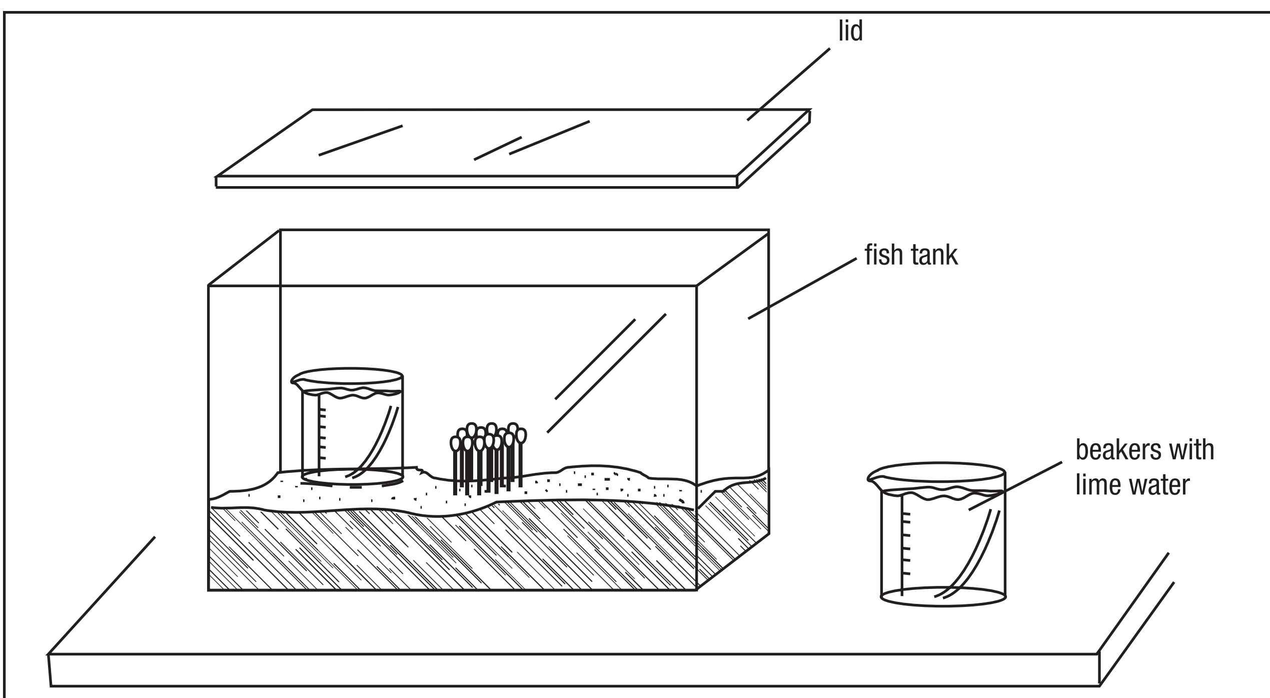
EXPLORATION

Tell students you are going to use limewater (calcium hydroxide) as an indicator to demonstrate how the burning of a forest releases carbon dioxide; in the presence of carbon dioxide, limewater will turn cloudy in color and a white sediment (calcium carbonate) will collect at the bottom of the beaker. Each team is to observe the experiment and record its observations. Cover the bottom of the fish tank with 8 cm of sand/gravel, and place 30 to 40 matches in a tight circle in the center of the tank. Fill the two beakers with limewater and place one inside the tank and the other just outside the tank. Light the matches using one of the fireplace matches and immediately seal the tank. The matches will burn and give off billows of smoke, soot, and ash. Leave the lid on the tank. Have students observe the beakers of lime water and record their observations. Students should continue to make observations for the next two to three days.

EXPLANATION

At the conclusion of the experiment, each group should revise its theory (as needed) about the relationship between the clearing of land in Brazil and temperature changes in Siberia. As part of this activity, groups should research global warming/deforestation on the Internet, utilizing the Web sites listed below. This information should be used to refine theories and/or develop new theories. Have students share their theories with the class (if they have changed). Inform students that

Figure 10.2
Deforestation Experiment/Demonstration



deforestation by fire emits carbon dioxide, which is a greenhouse gas. Greenhouse gases absorb and redirect heat down to Earth, thus causing global warming.

http://topics.nytimes.com/top/news/science/topics/globalwarming/index.html
Global Warming

http://www.epa.gov/climatechange/
Climate Change

http://environment.nationalgeographic.com/environment/global-warming/gw-overview.html
What is Global Warming?

http://www.ucsusa.org/global_warming/
Global Warming: Union of Concerned Scientists

Take Action

Students might opt to do one of several things: make a list of steps they can take to help prevent rainforest deforestation; or investigate other gases that pollute the air; or research the long-term effects of global warming. Students might also write letters to their U.S. Senators and Representatives regarding deforestation.

Internet Resources
http://en.wikipedia.org/wiki/Deforestation
Deforestation

http://www.cybercom.net/~faculty/rainforest/pictures.html
The Virtual Rainforest

http://www.bagheera.com/clasroom/spotlite/sprain.htm
Tropical Rain Forests

http://www.mat.auckland.ac.nz/~king/Preprints/book/diversity/cathed.html
Deforestation

http://www.ran.org/ran/info_center/whysave.html
Why Save the Rainforest?

http://ceps.nasm.edu:2020/CEPSDOCS/AMAZON/amazon.html
Amazon Deforestation

Project Green Classroom

Project Green Classroom Goal: Students will monitor and evaluate the environment in their classroom. They will share their data on the Science-As-Inquiry network, then compare and contrast their observations with other schools who choose to participate in the project.
Project Green Classroom Website:
http://www.science-as-inquiry.org/green

Overview: How would you rate the environmental quality in your school? your classroom? What kinds of observations can you make to help you answer this question? How do the conditions in your classroom compare with those in other classrooms around the world? In this activity, students investigate some of the factors contributing to the environmental quality of their classroom, and compare their results with those obtained in other classrooms.

Project Green Classroom is an example of one way to differentiate instruction in a science lesson. It is broken down into five independent investigations to be performed by different teams of students. Divide the class into teams of four or five students, and remind them to assign and rotate roles during the project.
Materials: thermometer, sling psychrometer, light meter, measuring tapes, hand lenses, mm-ruled graph paper, bathroom scale, paper sacks, microbiology reference books, particulate collectors, nutrient agar plates

Invitation

Open the lesson by asking the students how they would rate the level of environmental quality in their classroom. What criteria are they using to make their evaluations? Brainstorm as a class a list of factors that might contribute to the level of environmental quality in your classroom. Write these suggestions on a piece of chart paper and display them in the classroom.

Show the students the Project Green Classroom Web site and explain that all of the details of their work are found here, and that they will use the site to share the data the class collects on their classroom, and will also access data from other schools.
Project Green Classroom Website:
http://science-as-inquiry.org/green

Exploration

Explain to the students that they are going to conduct a survey to examine the environmental quality of their classroom. Each team will have a different task and will contribute to the final class report. Give each team a task and allow time for the students to complete the surveys. Remind team members to use their roles, so everyone has a chance to participate.

Team Assignments

- Weather Team
- Air Quality Team
- Physical Plant Team
- Population Team
- Microorganism Team
- Trash Team

Students can post data on a class chart, and then this data can be posted on the Project Green Classroom Web site.

Explanation

After each team has compiled its results, the communicator should report the data according to the report format shown at the bottom of their team's data sheet, and enter it into a class data chart. When all the teams have reported, return to the question that opened this activity. How would the students evaluate the environmental quality of their classroom now? What evidence can they bring to bear that was not available before? What new questions do they have? What ideas do they have for improving the environmental quality of their classroom? Have the communicators from each group meet together to summarize the class discussion in a classroom environmental profile.

Taking Action

After teams have had a few minutes to look over the data, instruct them to write down at least five questions they could answer using the data they have available. Help each team select one question and prepare a report for the class in which they state their question, present relevant data, and draw conclusions based on the data. Give teams time to use the computer to make graphs and complete appropriate analyses. This report should be prepared in the form of a poster to be presented to the rest of the class

Internet Resources

http://www.greenschools.net
Green School Initiative

http://www.epa.gov/greenbuilding
Green Buildings

http://www.nesea.org/k-12/greenschoolshealthyschools
Healthy Schools

Waste Disposal

Goal: Students learn about terms and concepts associated with waste disposal and other pollution problems. Students also conduct research on this topic utilizing the Internet, raising student awareness of waste management in the process.

Overview: Students are asked to brainstorm about waste disposal. In teams, students research, via the Internet, one of the concepts identified during the brainstorming. Teams present their findings to the class.If you did the Green Classroom activity, you can use the data collected on trash and relate to this activity.

Materials: Computer(s) with Internet access

Invitation

Ask students to brainstorm about waste disposal. Encourage them to list as many terms, concepts, procedures, methods, and so on, related to waste management as they can. Encourage the brainstorming by providing background information, such as the following:

> *Did you know that hogs used to act as garbage disposals in New York City? Long ago there were no garbage trucks or city dumps. In the 1700s, people threw their garbage out of their houses into the streets. Hogs roamed the streets eating garbage. Times have changed. Today, 90 percent of solid waste is currently disposed of in landfills. Several common methods are used to dispose of garbage. They range from burning to burying it in sanitary landfills. The current design of landfills does not promote the breakdown of wastes but does help to reduce their environmental impacts. In New York State, all new landfills have a plastic and clay liner at least 10 feet thick under the garbage, and a 4-foot-thick cover over the top. These layers minimize the immediate environmental impacts of landfills but exclude the water, air, and temperature changes needed to degrade waste. Still, some degradation takes place over time, and leachate must be collected. Each modern landfill in New York State has a leachate collection system to help keep the leachate from polluting groundwater and surface water supplies.*

Exploration

Divide students into groups. Each group should select a term, concept, or method from the brainstorming list. Each group then conducts research, via the Internet, on what it has selected (see Web sites at the end of this lesson).

Explanation

Each group presents to the class its findings on the concept it researched. The report should have an oral component as well as a written/ printed or Internet component. Reports should draw heavily on the Web sites used to research the concept. If possible, printed versions of the sites should be included in the reports. Time permitting, the class can create a concept map using terms from the initial brainstorming. Should any major concepts have been omitted, the teacher can request additional Internet research.

Take Action

Students could research local waste disposal systems, including those in their home, school, community, city, and state. This lesson also lends itself to school and community involvement through waste awareness, recycling, disposal, and other activities. Be creative and allow the students to be creative!

Internet Resources

http://www.learner.org/interactives/garbage/solidwaste.html
Interactive Solid Waste Website

http://www.epa.gov/osw/
EPA Waste Site

http://www.wm.com/index.jsp
Waste Management

http://www.nrc.gov/waste.html
United States Nuclear Regulatory Commission

CLEAN WATER

Goal: This lesson provides a hands-on, cooperative learning activity related to water filtration. Students gain an awareness about water supply, filtration, and purification in their community.

Overview: Student groups are challenged to create and test a filter system using only a handful of items made available. Each group shares its filter and its results with the class. The teacher shares a successful model that uses all of the items that make sense. Filtration is discussed. As a final step, students research local water filtration systems.

Materials: Bag containing cups, sand, rocks, cotton balls, carbon chunks, filter paper, and some random materials (marbles, pencils, etc.); a faucet water filter; dirty water in a large container (Dirty water = water, soil, and vinegar)

INVITATION

Show students a container full of dirty water. On a table have the sand, rocks, cotton balls, carbon chunks, filter paper, faucet water filter, and random materials (marbles, pencils, etc.). Ask students to name which of the items on the table they would use to clean the dirty water. Allow time for a few students to propose some ideas (record these on the board). Isolate the sand, the cotton, the rocks, and the carbon chunks. Briefly discuss these items, then inform students that their challenge is to create a filtration system using some or all of these items.

EXPLORATION

Have students work in groups. Present each group with a bag containing the lab materials. Student teams should create a filtration device using any or all of those items. They should then test their filters and summarize their results.

EXPLANATION

Each group presents its filter to the class and shares the results of its test. After all presentations are complete, the teacher shares/presents a model utilizing all of the materials except the random ones. Discussion should focus on the reasons for the filter's success and the various items it is composed of. The teacher's role is to lead the discussion and intervene as needed.

TAKE ACTION

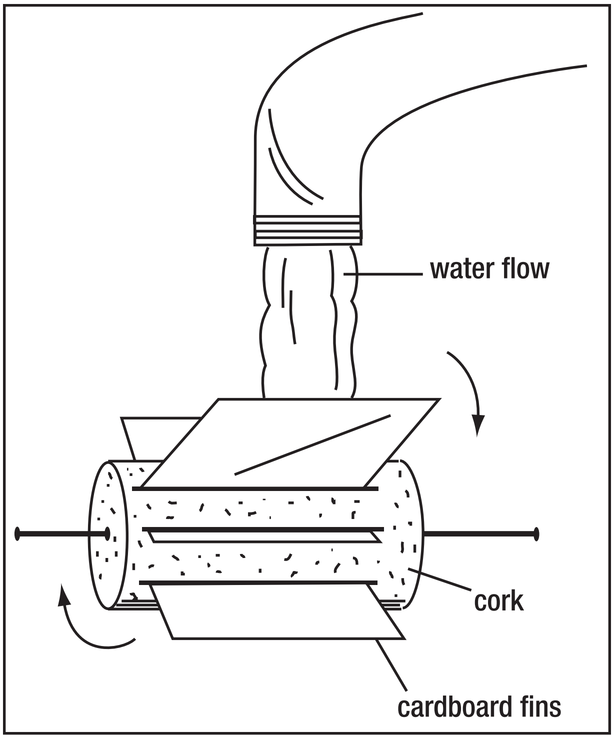
Students could watch an informative video about water purification. They could also learn how home water purification systems work. Finally, students could research and visit a local water purification plant and/or conduct research on the cleanliness of the local water supply. Students could even get involved in a community-based project. Be creative—this lesson lends itself to a great many activities.

Internet Resources
http://www.cleanwateraction.org
Clean Water Action

http://www.charitywater.org
Charity Water

http://www.nrdc.org/water
National Resources Defense Council

Figure 10.3
Water turbine



HYDROELECTRIC POWER

Goal: This activity raises student awareness of the various sources of energy available to humans. Students come to recognize that water is a renewable resource that is an important source of electricity. Creativity, experimentation, and cooperative learning are enhanced in the process.

Overview: Students brainstorm about the various energy sources available to humans. In groups, they design and build their own basic small water turbine, which are tested and presented to the class. Final models and summaries are displayed.

Materials: Bags containing pins, cork, cardboard, tacks (and other potential building materials); scissors; tape; paper; other basic supplies

INVITATION

Students brainstorm about the various energy sources available to humans. In groups, students determine the pros and cons of each of the energy sources. A few of these are shared with the class. This leads into a discussion of the pros and cons of hydroelectric power, and the basic principle behind a hydro-powered turbine.

EXPLORATION

Groups receive their bags containing the building materials. Each group designs and builds its own basic small water turbine. Models should be tested under running water from the faucet. Each group records its design notes, observations, and so on.

EXPLANATION

Each group presents its model and summary to the class. Class discusses models and, by extension, issues involving hydro-powered plants. Final models and summaries are displayed in the classroom or in the school. By now, it should be clear to students that the potential energy of water is harnessed to produce mechanical energy, which can be used directly or indirectly to generate electricity.

TAKE ACTION

Students could investigate their local source of electricity. They could also make posters about alternative sources of energy—ones that are environmentally friendly—and place them in their school to raise awareness.

Internet Resources
http://www.calpoly.edu/~ashan/
Hydroelectric Power

http://www.energy.ca.gov/html/hydro.html
Hydropower in California

http://www.his.com/~mesas/loren1.htm
Hydropower in India

http://h20.usgs.gov/public/watuse/wuhy.html
Hydroelectric Water Use in the United States

http://www.hooverdam.com/workings/
main.htm
Hoover Dam

CHAPTER 11 LIFE SCIENCE LESSONS

Life Science Lessons

- Endangered Species
- Dinosaur Biographies
- Dinosaur Defense
- Life in a Seashell
- Fossils
- Fossilization: Making a Plaster Mold
- Classification Systems

ENDANGERED SPECIES

Goal: This activity raises student awareness of endangered species. Students become aware of the needs of such animals by doing a practical, cooperative, and fun activity that encourages creativity and hones research skills, including those involving the Internet.

Overview: Students are asked to discuss endangered species and what is being done to protect them. In groups, students research an endangered species and design a habitat in which that species could live in captivity, for the purpose of reproduction. Projects are shared with the class.

Materials: Bags containing a picture of an endangered species (a different endangered species in each bag); books; computer(s) with Internet access

INVITATION

On the board make two columns, one labeled "Yes" and the other "No." Without telling them why, ask students to name some animals. List any animal that is endangered in the "Yes" column, and any nonendangered animal in the "No" column. Challenge students to guess how the animals are being categorized. This should lead to a general discussion of endangered species and what is being done to save them.

In preparation for their research, let students know that many interesting Web sites can be used to obtain excellent information on endangered species. One of these is the SeaWorld/ Busch Gardens Animal Information Database site.

EXPLORATION

Divide students into groups. Each group receives a bag with one endangered species inside. Groups research their species in-depth and design an enclosure, or a habitat, in which that species can mate in captivity. Habitats should reflect student knowledge of and sensitivity to the animal's needs. Students prepare a final written report, that includes drawings, images, models, and so on. The report should be digital: a slide show, web page, contribution to a blog. Creativity should be encouraged. NOTE: To give students ample time to research and be creative, it may be beneficial to allow two to three days for this lesson.

EXPLANATION

Each group presents to the class its endangered species, including the species' current condition, chances of survival, particularities, etc. The groups should also present their designed habitats. NOTE: It may be a good idea to create a rubric, such as the one shown in Figure 11.1 and allow students to evaluate their classmates' presentations and created habitats.

TAKE ACTION

Students could contact local zoos or animal organizations and find out what, if any, steps they are taking to save endangered species from extinction.

Internet Resources

http://www.endangeredspecie.com
Endangered Species Dot Com Species Links

http://www.earthsendangered.com/index_s.asp
Earth's Endangered Species

http://www.fws.gov/endangered
U.S. Fish & Wildlife Endangered Species

http://www.worldwildlife.org/species
World Wild Life Fund

http://en.wikipedia.org/wiki/Endangered_species
Endangered Species

Figure 11.1 Rubric

Criteria	3 Points	2 Points	1 Point
Presentation	Clear, structured, and varied presentation. All members were involved. It kept my attention.	Presentation was structured yet not too clear. Had some variety. Most of the members were involved.	Group may have learned the material well, but it only incorporated it fairly simply into the project and did not expand on it.
Content Material	Group displayed clear mastery of scientific material and expanded upon it in its project.	Imagination was clearly in evidence, yet project lost its feeling of reality and seemed fantastical.	The group was very organized, but the project was not well structured. Project had an objective, but no clear method.
Use of Imagination	Project showed a great deal of imagination, while maintaining a realistic focus.	Presentation was confusing and uninteresting. There was little variety or order to it. Not all members were involved.	There was only a superficial mastery of scientific scientific material. It was incorporated very generally into the project.
Organization	The group was very organized, and the project was well structured from concept to method.	Project was replicative as opposed to original. It had a few novel ideas, but the general scope was not novel.	The group lacked organization, and the project was not fluid. The project had an objective, but it was not carried into method.

Dinosaur Biographies

Goal: This lesson has students think back to an earlier time on Earth. In the process, they learn about dinosaurs and utilize cooperative learning and inquiry skills.

Overview: Students watch a portion of Jurassic Park. As a class, students create a list of questions they would like to ask a dinosaur, if they could. Then, in groups, students "interview" one specific dinosaur to discover how it lived. Groups then present their interview results and findings to the class orally and as a digital report. The group reports are uploaded to a class Web site.

Materials: Bags containing a plastic dinosaur (put a different dinosaur in each bag), paper, markers, binding materials (staples, string, rings, etc.); the video *Jurassic Park*, books, computer(s) with Internet access

Invitation

Play the portion of *Jurassic Park* with the friendly dinosaurs. Have students suggest questions they would like to ask the dinosaur if it could speak. On the board, write down five to fifteen questions. Divide the class into groups and distribute the bags containing dinosaurs. Have each group identify its dinosaur (this may require access to the Internet). Write the dinosaur names on the board.

Exploration
Instruct each group to "interview" its dinosaur. Groups should choose five questions to ask their dinosaur (they can create their own questions or use questions on the board). To answer these questions, they must conduct research (on the Internet). They then make a digital report of their findings that will become a part of a Web report that integrates all of the groups. Encourage students to be creative and to treat the report as if they had actually interviewed the dinosaur to obtain the responses. The Internet can be an excellent source of information on dinosaurs. In addition to the site in Figure 11.1, see the sites listed at the end of this activity.

Explanation
Student groups present their dinosaur to the class, including the questions they asked it and the responses they received. The report should be in digital form, such as a PowerPoint® Presentation or an html file that can be attached to a class Web site on Dinosaurs.

Take Action
Once the reports are finished, groups of students work on preparing a class website that includes all the groups' digital reports, including text, images, and video.

Internet Resources

http://ageofdinosaurs.com/
Age of Dinosaurs

http://www.ucmp.berkeley.edu/diapsids/dinolinks.html
200+ Great Links

http://edtech.kennesaw.edu/web/dinopage.html
Very Large Listing of Dinosaur Links

http://paleo.cc/paluxy/ovrdino.htm
Dinosaur Tracks and Tracking

http://www.skeletaldrawing.com/artgallery/artgallery.html
Dinosaur Drawings

http://dsc.discovery.com/dinosaurs
Dinosaur Central

Dinosaur Defense

Goal: This lesson introduces students to dinosaurs while it teaches them about sound scientific inquiry. It implements active cooperative learning methods and exercises observational and inference-making skills.

Overview: In groups, students make observations about different dinosaur models. Each group shares with the class the feature it feels was most significant to the dinosaur's survival. The class engages in a teacher-assisted discussion about each dinosaur. As an extension, students make inferences about other animal features.

Materials: Bags containing a model/image of a dinosaurs; newsprint, markers, access to the Internet

Invitation
Begin by holding a brief discussion on the following: "What is indirect investigation?" This should lead nicely to a discussion of this question: "How do scientists study dinosaurs . . . or other subjects that are not available for direct study?"

Exploration
Teacher divides students into groups by having them select pieces of paper with the names of dinosaurs written on them. All those with the same dinosaur are on the same team. The bags containing the corresponding model dinosaurs are passed out. Each group works to list as many features as it can about its dinosaur during a 3-minute period. The bags are rotated and

Figure 11.2
Visit Discovery Channel's Dinosaur Central to view video highlights of 3D graphics of dinosaurs:
http://dsc.discovery.com/dinosaur

work commences for the next 3-minute period, and so on.

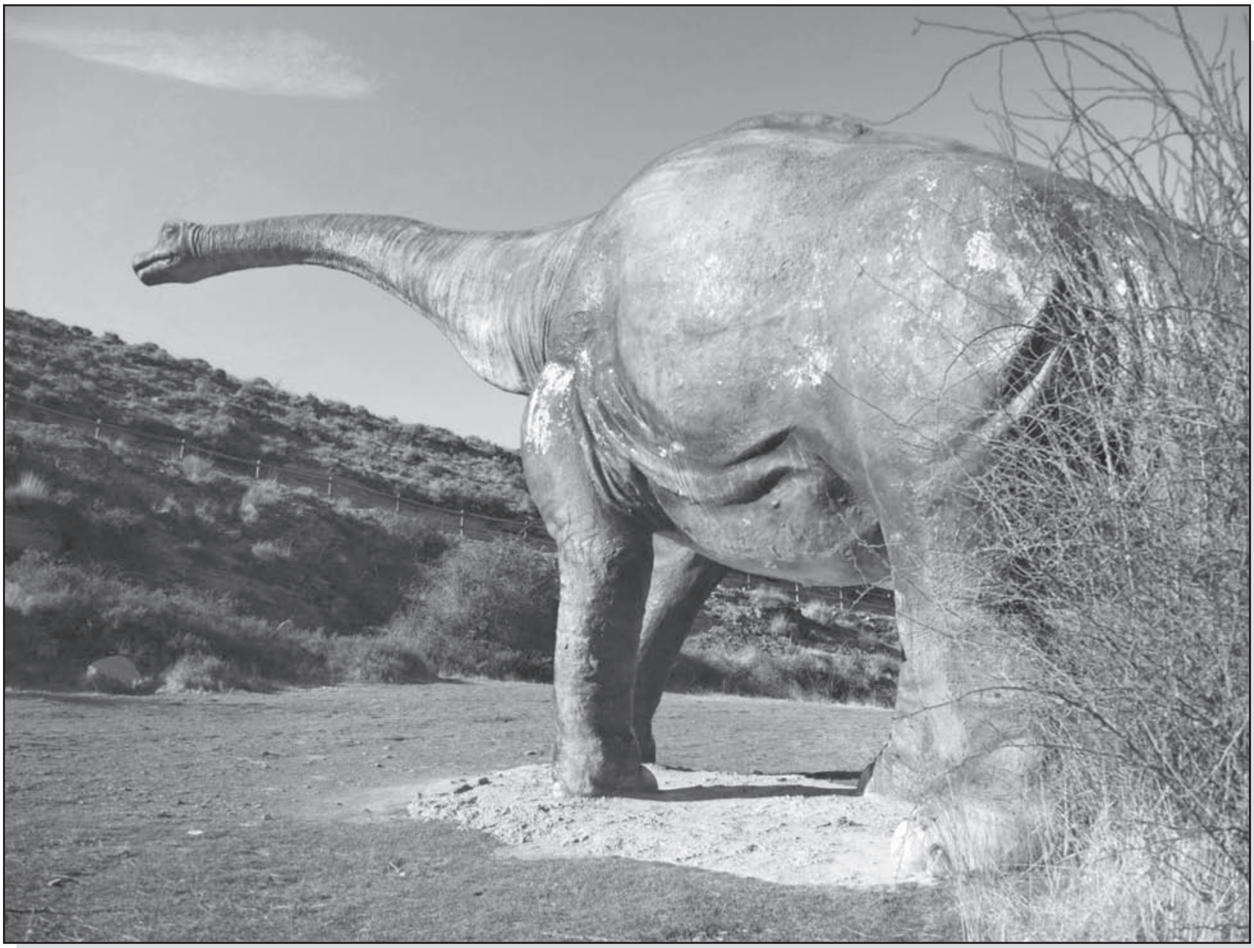
Explanation

Each group selects the feature it feels was most important to each dinosaur's survival. On newsprint or chalkboard at the front of the class (one sheet/grid per dinosaur), a representative from each group writes down the feature selected for each dinosaur. The class then discusses each dinosaur and the teacher expands on/corrects the features as needed. The Internet sites listed at the end of the lesson can be integrated into this stage as explanatory resources. Alternatively, certain sites can be assigned to each team, with the teams doing additional research on their respective dinosaurs. Research on themes such as extinction, the Earth's history, carnivores vs. herbivores, and the like should prove profitable.

Take Action

Students could be given photos of other animals, archaeological finds, bones, remains, and so on. from which they make additional inferences. Encourage inferences about the animals' habitat, food source, social habits, and so on, depending on the item/photo analyzed. Endangered animals might also be researched.

Figure 11.3
Link to "The Dinosauria" at the U.C. Berkeley to find answers to most of your dinosaur questions: http://www.ucmp.berkeley.edu/diapsids/dinosaur.html



Internet Resources
http://www.amnh.org/exhibitions/dinosaurs/display/
Dinosaurs at the American Museum of Natural History

http://www.dinosaurfact.net/
Dinosaur Facts

http://dsc.discovery.com/videos/dinosaurs-stegosaurus-built-for-defense.html
Dinosaur at Discovery Videos

LIFE IN A SEASHELL

Goal: This lesson aims to familiarize students with seashells and the types of animals that live in shells. The activity also gives students an opportunity to make observations and inferences, and thus to learn about indirect means of study.

Overview: In groups, students make inferences about the animal that lived in the shell they are examining. Each group selects the observation and inference they feel is the most accurate. One by one, groups present their observations and inferences to the class. Teacher then leads an informative discussion on each shell.

Materials: Bags containing one shell and one small ruler; also, newsprint and markers

Invitation

Teacher asks students to name ways in which scientists conduct research. The brainstorming should lead to indirect means of study, such as that relying on fossils, remains, bones, habitats, and so on. Teacher records brainstorming ideas on newsprint. Invitation phase ends with the introduction of the idea of using a shell to make inferences about the animal that lived in it. Teacher then explains the activity and distributes the materials.

Exploration

Students are divided into groups. Each group receives a bag containing one shell and a small ruler. Each member of the group makes one observation about the shell, which should be recorded on newsprint by a group member. After each student has had a turn, each student makes a second observation. Based on his or her observation(s), each student then makes one inference about the animal that lived in the shell. The group reviews all of the inferences and selects the observation-inference pair it feels is most significant/accurate. Final observations and inferences should be recorded on newsprint as well.

Explanation

Each group makes a brief class presentation, sharing its shell and the final observation-inference it selected (in their presentations, groups may mention some of the other observations and inferences as well). In a teacher-led discussion, information about that shell and its inhabitant is shared, discussed, and related to the groups' observations and inferences.

Take Action

Teacher hangs up the newsprint from the initial brainstorming session. All the items listed that deal with indirect means of study should be highlighted. Students could then be asked to research one of these methods or another method involving indirect observation.

Internet Resources

http://en.wikipedia.org/wiki/Seashell
Seashells

http://www.seashell-collector.com
Seashell Collector

Fossils

Goal: This lesson gives students an overview of how fossils are used to make hypotheses about prehistoric life. Students learn about and utilize indirect methods of investigation, utilizing computers and the Internet.

Overview: Students discuss archaeology as a means of solving a mystery from a set of clues. In teams, students make observations and inferences about a fossil, and share them with the class. Students then prepare a factual short report (using the Internet as a resource), which they share with the class. As an extension, students search the Internet for means of dating fossils and for the names of pioneering archaeologists.

Materials: Bags containing a fossil; a mystery-type "Who Done It?" picture; informational sheets about each of the fossils; newsprint and markers; textual resources; computer(s) with Internet access

Invitation

In teams, students are given a "Who Done It?" picture (picture of a crime scene with clues). Team members discuss the clues in the picture and propose a solution. As a class, students discuss their solutions and then professionals other than detectives who "solve mysteries." Teacher-led discussion leads to archaeology as a means of solving some types of mysteries.

Figure 11.4 Table of Inferences

Observation 1	Observation 2	Inference
Shell has a hole.	Shell has ridges.	Animal was consumed.
Shell has several colors on outer covering.	Color pattern resembles camouflage.	Animal had predators.

EXPLORATION

Each team receives a bag containing a fossil. Teams make observations and inferences about their fossil, using a two-column format. For every observation in column 1, they should make at least one inference/hypothesis in column 2. After sufficient time, each group shares its observations and inferences with the class.

EXPLANATION

Teams are given a factual information sheet about their fossil, including its site of extraction, life form that made it, age, and so on. Teams prepare a short report to share with the class about their fossil. In it, they should include some ideas about how that factual information was inferred/hypothesized from the fossil. After discussion of fossils, if time permits, groups can conduct research, via the Internet, using the following Internet sites. Students might initiate specialized searches by theme or participate in scavenger hunts within these sites. Findings can be summarized and shared by the students.

TAKE ACTION

As an extension, students could search the Internet or the library for means of dating fossils, for the various types of fossils that we know of, or for information about pioneering "mystery-solving" archaeologists. Teams could also research any local fossil activity that would be of particular interest.

Internet Resources

http://en.wikipedia.org/wiki/Fossil
Fossils

http://www.fossils-facts-and-finds.com
Fossils Facts and Finds

http://www.fossilmuseum.net
Virtual Fossil Museum

http://www.bbc.co.uk/nature/fossils
Fossils: The Natural History Museum, London

http://www.cruzio.com/~cscp/index.htm
Fossil Evidence: Human Evolution

http://en.wikipedia.org/wiki/Fossil_collecting
Fossil Collecting

http://www.halcyon.com/rdpayne/jdfbnm.html
Fossil Beds National Monument

http://www.uh.edu/~jbutler/anon/histpal.htm
Paleontology Resources

http://www.paleoportal.org
Paleontology Portal

http://www.paleosoc.org
The Paleontological Society

Fossilization: Making a Plaster Mold

Goal: This lesson introduces students to the process of fossilization. Using the Internet and laboratory procedures, students discover how fossils are used to learn about history, adaptation, ancestry, and so on. Observational and indirect inquiry skills are enhanced.

Overview: Students compare a fossilized snail with a modern snail. This comparison leads to a discussion of how fossilization occurs, and how fossils are used by scientists. Students then make a fossil out of plaster of Paris. To finish, students discuss other forms of preservation.

Materials: Bags containing a fossilized snail shell and a "modern" snail shell, a small amount of plaster, containers and utensils for making plaster, plastic containers for making molds; also, newsprint and markers; computer(s) with Internet access

Invitation

In groups, students are given a bag containing a fossilized shell and a modern shell. Groups compare and contrast the two shells, recording their observations on newsprint. Groups then make inferences about each shell, again recording these on the newsprint. Students should focus on the similarities and differences between the two samples.

Exploration

The various observations and inferences are discussed as a class. Discussion should include the process of fossilization and the importance and use of fossils. Internet-based research can be conducted on how fossilization occurs and how fossils are studied. If time permits, you might involve students in a virtual scavenger hunt wherein they discover how and where major dinosaur fossils have been found, who found them, and how they have been utilized by scientists. For example, students might conduct an Internet search of the Yellow River in Wyoming to discover why the conditions of the river have led to such amazing fossilized specimens (see the Web sites listed at the end of the lesson).

Explanation

The groups make a fossil out of plaster. Various materials can be placed on the item to be fossilized to simulate pressure-inducing layers of rock. A crystallized sugar sample might be used to make the fossil; that way, when heated and/or submerged in water, it will disappear, leaving only its "fossil" markings.

Take Action

Students could discuss other forms of preservation, such as amber or ice, or gather information about the "Ice Man." Students might also inquire into short-term preservation, such as organ/blood preservation.

Internet Resources

http://science.howstuffworks.com/environmental/earth/geology/fossil.htm
How Fossils are Made

http://paleobiol.geoscienceworld.org/
Paleobiology

http://www.ucmp.berkeley.edu/exhibits/geologictime.php
Tour of Geological Time

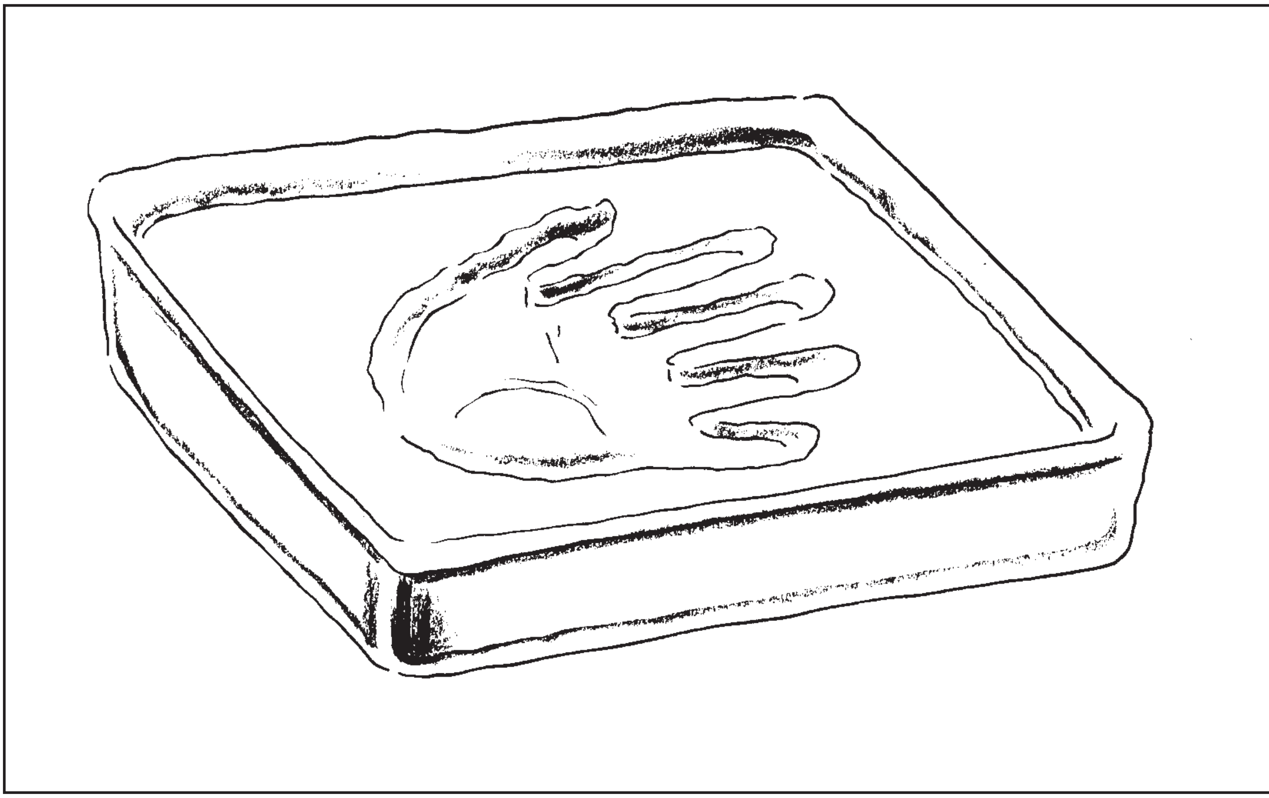
http://www.amnh.org/exhibitions/amber/
The World of Amber and Fossilization

Classification Systems

Goal: Students are introduced to classification systems to learn why such systems are necessary and their place in our lives.

Overview: Student teams compete to locate certain buttons from various sets of classified (and

Figure 11.5
Making Fossils



unclassified) buttons. Students share their experience and discuss how the classification system, or lack thereof, affected their performance. Students then create their own classification system for the buttons, which they share with another group. Teams brainstorm about scientific and everyday classification systems.

Materials: Bags containing many different kinds of buttons (one bag should contain buttons that are all mixed up; the other bags should have smaller bags within, with buttons classified by random categories, such as color, size, shape, number of holes, material, etc.); newsprint and markers

INVITATION

Students are divided into small teams. One team receives a large bag full of buttons in no order whatsoever. The other teams receive a bag containing smaller bags of classified buttons (see above). All teams are challenged to locate specific buttons (e.g., a red button with four holes). After five to ten searches, teams discuss the ease with which they located the buttons and in what way the button classification system that they inherited affected the process.

EXPLORATION

Student teams create their own classification system for the buttons they receive. They detail their system on newsprint. Teams then trade newsprint sheets. One team applies the other team's system to its buttons and provides an analysis.

EXPLANATION

Teams pair up with their partner team to share their experience and analyze the other team's system. As a class, students discuss their experience in the initial button search and in

Figure 11.6
Button Classification Scheme
Use this classification system to classify any set of buttons.

SHAPE	○								□								△							
COLOR	Blue Green				Yellow Red				Blue Green				Yellow Red				Blue Green				Yellow Red			
SIZE	Big		Small		Big		Small		Big		Small		Big		Small		Big		Small		Big		Small	
HOLE (H) OR NO HOLE (NH)	H	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	NH

creating a classification system. Teacher-led discussion should uncover the advantages and importance of classification systems in science and in our lives, in general. Examples abound, including the periodic table, animal/plant kingdoms, matter (solid, liquid, gas), rock types, musical instruments (wind, percussion, etc.), grocery store shelves (canned, frozen, etc.), and clothing sizes.

Take Action

Students could be asked to observe their activities for one week and note how many classification systems they encounter. They should analyze and critique those systems for functionality and adequacy. New systems could then be proposed. Student teams might also research a scientific classification system and prepare a brief report for the class.

Internet Resources

http://en.wikipedia.org/wiki/Category:Classification_systems
Classification Systems

http://www.kidsbiology.com/biology_basics/classification/classification1.php
Classification of Living Things from Kids Biology

http://en.wikipedia.org/wiki/Taxonomy
Taxonomy

Chapter 12 Physical Science lessons

Physical Science Lessons

Physical Science lessons include

- Electromagnetism
- Power: Watts in the Water
- Pendulum Variables
- Gravity
- Mixtures: Iron in Cereal Flakes
- Evaporation Is Cool
- Magnetic Fields
- Surface Tension: The Stress H_20 Feels
- Water and Air Surface Interactions: Bubbles
- The Visible Spectrum: A Rainbow

ELECTROMAGNETISM

Goal: Students gain insight into the relationship between electricity and magnetism. Working in cooperative groups, they conduct a hands-on inquiry experiment in which they use basic laboratory equipment.

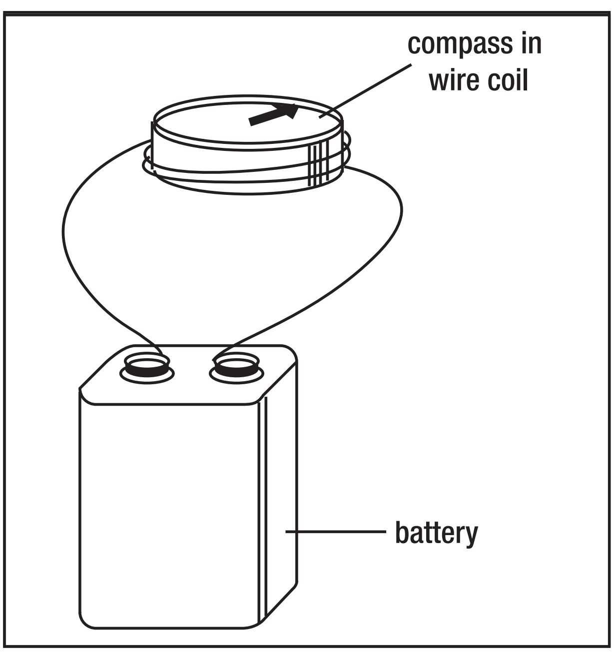
Overview: In groups, students are challenged to create a scenario in which a compass needle wouldn't point north. Each group then investigates how an electric current affects the direction of the needle on a compass. Groups share their results. Students extend their knowledge by investigating electric cars.

Materials: Bags containing a 6-volt battery, wire, and a compass

INVITATION

Students are divided into groups. Groups are challenged to write about a situation in which the needle of a compass would not point North. Groups should be given just a few minutes for this activity. Each group briefly shares its scenario. The teacher comments on the ideas, then mentions that another method (if not already mentioned) exists.

Figure 12.1
What happens to the compass needle when a wire, connected to a battery, is wrapped around the base of the compass?



EXPLORATION

Bags are distributed to the groups. Groups are challenged to find a way to alter the direction of the compass needle using the contents of the bag. Each group records, with drawings, each of its attempts and the results.

EXPLANATION

After sufficient time, any group that discovered a means of altering the direction of the needle with the battery and wire presents its findings to the class. Teacher involvement at this stage consists of providing the class with an explanation (in the form of a hypothesis) (wrapping the wire around the compass), as needed. After the presentations, the remaining groups should be given a short time to test the correct setup.

TAKE ACTION

As an expansion activity, students could conduct research on electric cars. What are their benefits? their drawbacks? Are there any in the United States? How much do they cost? Are they being used more extensively outside the United States? How do they benefit the environment? How do they work?

Internet Resources

http://www.afdc.energy.gov/afdc/vehicles/electric.html
Alternative and Advanced Vehicles

http://en.wikipedia.org/wiki/Electric_car
Electric Car

Power: Watts in the Water

Goal: In this activity, students gain insight into power and work by actually measuring it in a cooperative activity. Activity requires data collection and mathematical calculation, as well as creativity.

Overview: Students are asked to propose ways in which the human body's power can be measured. In groups, students test their power by raising the temperature of water. Calculations are made to determine the power each group emitted. As an extension, an inquiry into the cost of power is made.

Materials: Bags containing a one-stopper standard-sized test tube and a thermometer

Invitation

Students are asked to suggest ways to test/measure the power of a human body. Ideas are recorded by the teacher on the board. With each suggestion, the units in which human power would be measured should also be given. By the end of the discussion, the teacher should introduce or highlight using temperature as a means.

Exploration

Students are divided into groups. Each group receives a bag containing a test tube and a thermometer. Students should pour 10 to 20 mL of water into the test tube. The initial temperature and mass of the water (1 mL = 1 gram) should be measured. When the signal is given, one

Figure 12.2
Pendulum Terminology

Heat/Power Terminology

Calorie: Unit of heat; defined as the amount of heat necessary to raise the temperature of 1 gram of water by 1 degree Celsius

Work: Force applied to an object in a certain direction; measured in Joules
Work + Force (Newtons) x Distance (meters)

Power: The rate at which work is being done; measured in Watts
Power + Work (Joules)/time (seconds)

Joule: Unit of work; defined as 1 Newton-meter; 4.19 Joules/calorie

Watt: Unit of power; defined as 1 Joule/second

Steps to Calculate Power from the Change in Temperature of Water in Tube

1. Convert temperature change, which is in degrees Celsius, to Heat, measured in Calories. (number of degrees Celsius) x (grams of water in tube) = (number of Calories)

2. Convert Heat, which is in Calories, to Joules of Work. (number of calories) x (4.19 Joules/Calorie) = (number of Joules)

3. Convert Joules to watts to obtain measurement of Power. (number of Joules)/(number of seconds it took to raise water temperature) = (number of Watts)

student in each group begins doing whatever he or she has decided to do in order to warm up the test tube. Students can shake it, rub it, blow on it—whatever they want, so long as they use only their body. After 5 minutes, time is up! Take and record the final temperature of the water. Repeat as many times, with as many different students, as time allows.

EXPLANATION

Each group calculates the power it generated. The temperature change is converted into calories by multiplying each degree gained by the number of grams of water. If 10 g of water gained 8 degrees, then 80 calories of heat was added to the water. The work done in raising the temperature of water can be found by multiplying the calories added to the water by 4.19 joules. Power in watts can then be calculated from the work (joules/second). Each group should calculate its total power and share it with the class. One group should emerge as the winner!

TAKE ACTION

Students could contact their local power company to inquire into the cost of a kilowatt hour of power. They might then review their figures and place a dollar value on the power they generated.

PENDULUM VARIABLES

Goal: Students learn to identify pendulums at work around them. By designing a basic experiment and presenting their results, they recognize how a change in one of the pendulum's features affects its motion.

Overview: Students brainstorm about different types of pendulums, including their motion and their function. In groups, they design a basic pendulum and test a variable. They present their experiment to the class. In an extension activity, students gather information about a specific pendulum in operation today.

Materials: Bags containing string, many washers of all sizes, a ruler, a stopwatch (if available); chalkboard/newsprint

INVITATION

Have students brainstorm and come up with a list of different types of pendulums that exist in the world around them (clocks, swings, cranes, The Flying Dutchman amusement ride, tree tire swing, etc.). Using one of these examples, ask the class questions related to length and weight: What would happen if you shortened the length of the rope?" "What would happen if twice as many people got on the swing?" Allow students to suggest answers to such questions without verifying what is correct. Write two to four of the questions on the board.

EXPLORATION

Divide students into groups of four or five. Distribute the bags containing the laboratory items. Instruct students to build a basic pendulum and then design a basic experiment testing one of the pendulum's features. Suggest features such as length of string, weight on the end of the string, release point, period of time, and so on. Circulate about the room and assist groups on experimental design, as needed.

EXPLANATION

Each group prepares a written report that includes its pendulum design, variable tested, method used, number of tries, measurements, results, conclusions, and so on. Each group shares its findings with the class in a brief oral report. After the presentation, ask the students as a class to answer the questions you first asked them in the Invitation portion of the lesson. Alternatively, assign this as homework.

Figure 12.3
Pencils & Washers Pendulum

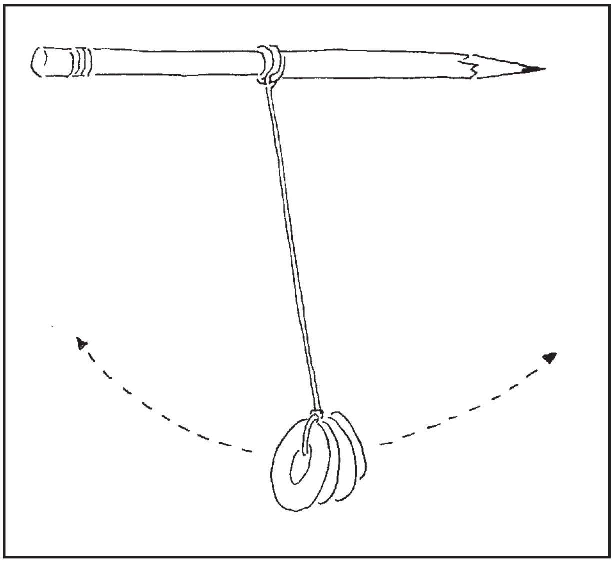


Figure 12.4
Pendulum Terminology

Pendulum Terminology

Speed: Rate of change of position, or the distance over time

Velocity (v): Speed + direction (a vector quality)

Acceleration: The rate of change of the velocity

Weight (w): The force of gravity upon a body times the quantity of its mass

Mass (m): Equivalent to the inertia of a body (the amount of work necessary to move it or to stop it, without regard to gravity)

Work: Force times distance

Kinetic energy (***k***): The energy a body (of mass ***m***) has by virtue of being in motion (at velocity ***v***). The quantity of work ***k*** can perform is $k = {}^{1}/_{2}mv^2$.

Potential energy (***p***): The "potential to do work" a body (of weight ***w***) has by virtue, for instance, of its position (***h***) within a gravitational force field: $p = w \quad h$

The total energy of a dynamical system (E) is the sum of its kinetic and potential energy:

$E = k + p$ or $E = ({}^{1}/_{2}mv^2) + (w \quad h)$

In a pendulum, raising the ***h*** of the weight increases its ***p***. This injects energy into the pendulum. Releasing the bob creates an oscillating relation between ***p*** and ***k***. As ***h*** decreases to 0, ***v*** increases to a maximum; as ***h*** increases to a maximum, ***v*** decreases to 0. Here, ***k*** and ***p*** are in direct inverse proportion.

Take Action

Students could select one of the real-life pendulums from the list on the board and prepare a brief report explaining a few of the following: function, principle feature, how it works, size, weight, designer, cost, maximum capacity, and so on.

Internet Resources

http://www.wired.com/science/discoveries/news/2009/01/dayintech_0107
Foucault Pendulum

http://en.wikipedia.org/wiki/Pendulum
Pendulum Physics

http://www.worsleyschool.net/science/files/pendulum/pendulum1.html
Pendulum Experiments

Figure 12.5
Experimental Planning

Experimental Planning

Independent variable: Factor or condition being tested

Dependent variable: Factor that responds to the change in the independent variable; its response is measured as data

Controlled variables: All other factors that are kept constant during the experiment

GRAVITY

Goal: This lesson introduces students to the concept of gravity, including the concepts of acceleration and mass. Students experience the principles of gravity in a hands-on cooperative activity that requires measurement and data collection.

Overview: Students, working in groups, make predictions about how quickly different objects will reach the ground when dropped from the same height. Tests are run and results are analyzed with respect to gravity, acceleration, and mass. The groups are then challenged to apply their knowledge to other scenarios and conduct further tests.

Materials: Bags containing a tennis ball, a baseball, a sponge ball (such as a Nerf™ ball), a marble (can be any four different objects), a stopwatch, a meterstick

INVITATION
Students are divided into groups of four or five. Each group is asked to predict the order in which the four balls (tennis ball, baseball, Nerf ball, marble) will hit the ground when dropped from the same height. Each group writes a brief statement containing the group's prediction and the reasoning behind that prediction.

EXPLORATION
Each group tests its prediction by dropping the four balls and recording each time of fall—dropping the balls first individually and then simultaneously—and the height. Each group summarizes its results and discusses them.

EXPLANATION
The teacher leads a class discussion focusing on the experiment. Each group briefly presents its prediction and its results. The teacher should keep a master tally of the groups' predictions and results on a chalkboard or chart in front of the class. The class goes on to discuss the results, touching on such concepts as mass, gravity, force, and acceleration. The teacher's role is to reinforce correct predictions with factual information and untangle incorrect predictions by discussing common misconceptions.

TAKE ACTION
Groups could research a real-life scenario involving gravity, mass, and/or acceleration. Examples might include parachuting, escape velocity from the Earth's atmosphere (space shuttle), a penny falling from atop a tall building, hail, and so on.

Figure 12.6 Recording the Falls

TIME OF FALL (SEC)

Item Dropped	First Drop from 5 Feet	Second Drop from 5 Feet
baseball	.37	.30
tennis ball	.32	.29
marble	.22	.38
sponge ball	.42	.49

Internet Resources
http://en.wikipedia.org/wiki/Gravitation
Gravitation

http://en.wikipedia.org/wiki/Escape_velocity
Escape Velocity

http://www.virgingalactic.com/
Virgin Galactic: Travel into Space

http://www.nasa.gov/home/index.html
NASA

http://physics.info/falling/
Falling Bodies, Galileo and Physics

MIXTURES: IRON IN CEREAL FLAKES

Goal: This lesson reviews the properties of mixtures and helps students to understand that the components of a mixture retain their own identities. Students use a physical method to separate a mixture, in the process gaining insight into the difference between physical and chemical changes.

Overview: Students brainstorm about the composition of a cereal flake. Substances and physical properties are identified. Students then physically remove iron from wet, crushed cereal with a magnet. As an extension, students discuss and research water pollution.

Materials: Bags containing a bar magnet, $^1/_2$ cup iron-fortified cereal in a sealable plastic bag, tissues, magnifying glass; water

INVITATION

Students are asked to reflect on the following question: "What is in a cereal flake?" Teacher should record students' ideas on the board and lead the class to include iron as a component. Teacher should ask for physical properties of the substances students list. Ideally, iron will emerge as a component and magnetism will eventually emerge as a physical property. Teacher-led discussion of physical properties of mixtures should generate student interest in the possibility of separating iron from cereal with a magnet, thereby proving one basic feature of mixtures: individual components retain their identities. To expand your

Invitation-stage discussion, distribute a copy of the side of a cereal box (Figure 12.7) and discuss the contents and how they are combined in every flake.

EXPLORATION

Small groups receive a bag containing the laboratory materials. Cereal should be crushed in the bag until it is a fine powder. Water should be added to the bag, and the mixture stirred with the bar magnet for 5 minutes. At the end of this time, the bar magnet should be removed, allowed to drip, and then carefully wiped on a white tissue. Examination of the tissue with a magnifying glass should reveal the presence of small dark specks: iron. Groups should record their procedure, observations, and results.

EXPLANATION

Each group briefly presents to the class a summary of its results and any problems encountered during the activity. A teacher-led class discussion should reinforce the idea that each component in a mixture retains its identity. Discussion should inspire students to suggest other ways to separate other mixtures.

TAKE ACTION

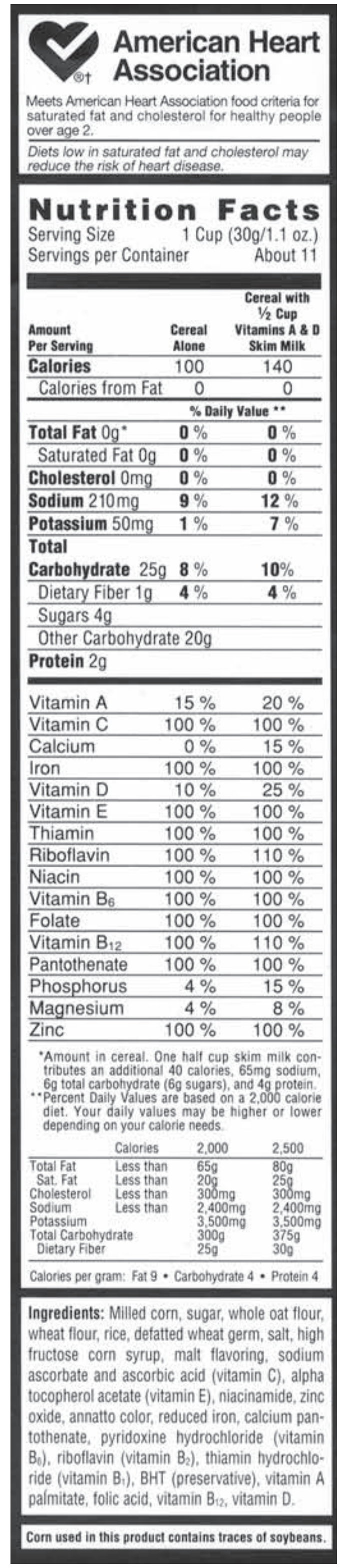
As an extension, students might discuss and research water pollution, water purification systems (local and home), and what can be done about any home, local, or global issues of water purification that emerge. The ocean might also be studied in the context of its properties as a mixture/solution.

Internet Resources

http://www.chem4kids.com/files/matter_solution.html
Solutions and Mixtures

http://www.chem4kids.com/files/matter_mixture.html
Mixture Basics

Figure 12.7
Nutritional information
Courtesy Kellogg's Product 19



American Heart Association

Meets American Heart Association food criteria for saturated fat and cholesterol for healthy people over age 2.

Diets low in saturated fat and cholesterol may reduce the risk of heart disease.

Nutrition Facts

Serving Size 1 Cup (30g/1.1 oz.)
Servings per Container About 11

Amount Per Serving	Cereal Alone	Cereal with ½ Cup Vitamins A & D Skim Milk
Calories	100	140
Calories from Fat	0	0
	% Daily Value **	
Total Fat 0g*	**0** %	**0** %
Saturated Fat 0g	**0** %	**0** %
Cholesterol 0mg	**0** %	**0** %
Sodium 210mg	**9** %	**12** %
Potassium 50mg	**1** %	**7** %
Total Carbohydrate 25g	**8** %	**10**%
Dietary Fiber 1g	**4** %	**4** %
Sugars 4g		
Other Carbohydrate 20g		
Protein 2g		
Vitamin A	15 %	20 %
Vitamin C	100 %	100 %
Calcium	0 %	15 %
Iron	100 %	100 %
Vitamin D	10 %	25 %
Vitamin E	100 %	100 %
Thiamin	100 %	100 %
Riboflavin	100 %	110 %
Niacin	100 %	100 %
Vitamin B_6	100 %	100 %
Folate	100 %	100 %
Vitamin B_{12}	100 %	110 %
Pantothenate	100 %	100 %
Phosphorus	4 %	15 %
Magnesium	4 %	8 %
Zinc	100 %	100 %

*Amount in cereal. One half cup skim milk contributes an additional 40 calories, 65mg sodium, 6g total carbohydrate (6g sugars), and 4g protein.
**Percent Daily Values are based on a 2,000 calorie diet. Your daily values may be higher or lower depending on your calorie needs.

	Calories	2,000	2,500
Total Fat	Less than	65g	80g
Sat. Fat	Less than	20g	25g
Cholesterol	Less than	300mg	300mg
Sodium	Less than	2,400mg	2,400mg
Potassium		3,500mg	3,500mg
Total Carbohydrate		300g	375g
Dietary Fiber		25g	30g

Calories per gram: Fat 9 • Carbohydrate 4 • Protein 4

Ingredients: Milled corn, sugar, whole oat flour, wheat flour, rice, defatted wheat germ, salt, high fructose corn syrup, malt flavoring, sodium ascorbate and ascorbic acid (vitamin C), alpha tocopherol acetate (vitamin E), niacinamide, zinc oxide, annatto color, reduced iron, calcium pantothenate, pyridoxine hydrochloride (vitamin B_6), riboflavin (vitamin B_2), thiamin hydrochloride (vitamin B_1), BHT (preservative), vitamin A palmitate, folic acid, vitamin B_{12}, vitamin D.

Corn used in this product contains traces of soybeans.

http://water.epa.gov/learn/kids/drinkingwater/watertreatmentplant_index.cfm
Water Treatment Process

http://en.wikipedia.org/wiki/Water_treatment
Water Treatment

Evaporation Is Cool

Goal: This activity gives students a hands-on opportunity to discover why we sweat. Students work in cooperative groups to learn that the evaporation of liquid from skin cools the skin. In the process, heat stroke awareness may also be raised.

Overview: Students brainstorm about the idea of utilizing heat in order to cool. Groups then experiment with a few materials to show how the human body utilizes heat in order to cool. Groups reach one final observation, which they share with the class. Teacher expands on how the human body cools by heating.

Materials: Bags containing cotton balls, small containers of isopropyl alcohol, small containers of water

Invitation

Ask students to consider the following puzzle: "I utilize heat in order to cool, what am I?" Working in groups, students brainstorm for ideas and decide on a possible solution. Solutions should be shared with the class, but no final conclusion arrived at.

Exploration

Teacher tells the student groups to experiment with the materials in the bag in order to solve the puzzle. Teacher then instructs the students to use the cotton balls to rub the back of one hand with alcohol and the back of the other with water, to wait a few seconds, and then to record their observations. Group members should share their observations with each other, and each group should arrive at one final observation.

Explanation

Each group shares its final observation with the class. The class then revisits the initial puzzle. The teacher provides the final solution— "the human body"—as needed. He or she goes on to explain that the hand rubbed with alcohol will feel cooler because alcohol evaporates faster than does water. Heat from the skin provides the energy for the evaporation of liquids such as perspiration. When heat is used this way, it is removed and the body becomes cooler.

Take Action

Students could research animals, such as pigs, that do not have sweat glands. Alternatively, they could research heat stroke and methods of cooling that humans have devised in extremely hot areas of the world. Students might also make a pamphlet or handbook on avoiding heat stroke and distribute it within the school.

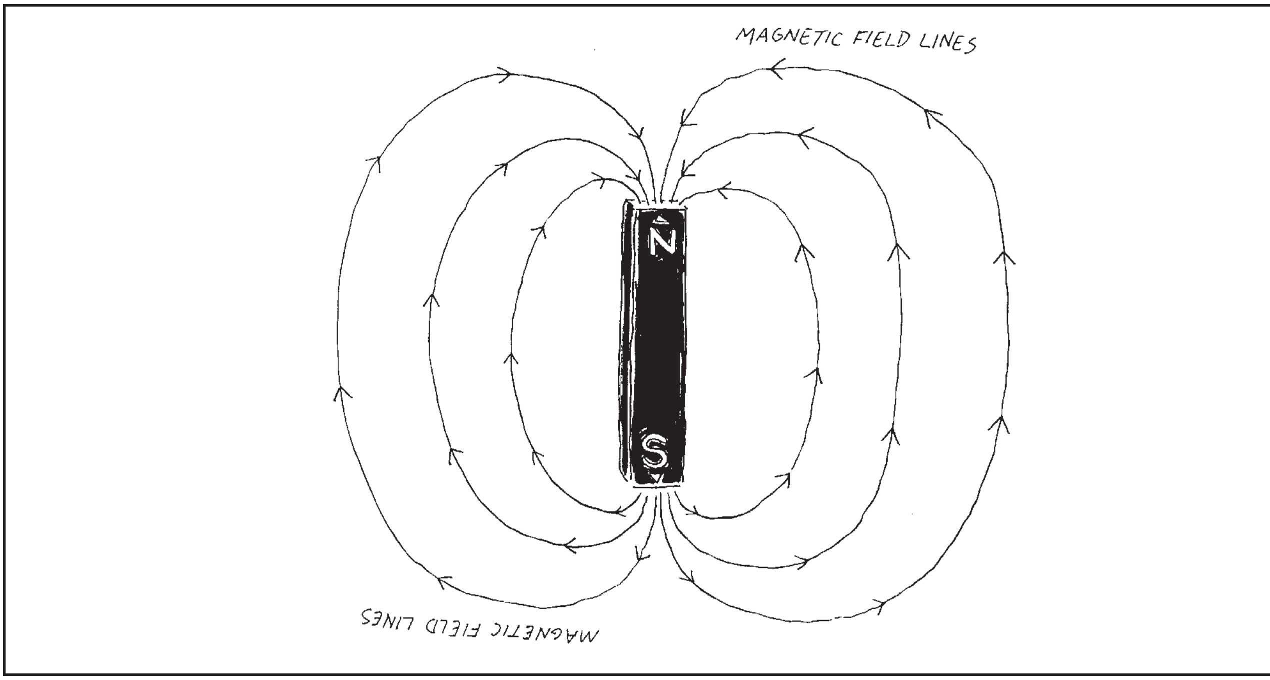
Internet Resources

http://www.nlm.nih.gov/medlineplus/sweat.html
Sweat Medicine

http://en.wikipedia.org/wiki/Perspiration
Perspiration

http://en.wikipedia.org/wiki/Deodorant
Deodorant & Human Biology

Figure 12.8
Magnetic Fields



MAGNETIC FIELDS

Goal: Students directly observe and come to understand the direction of a magnetic field. Students work in cooperative learning groups and gain experience in making and recording observations.

Overview: In groups, students make predictions about a magnetic field. Groups then discover the shape of a magnetic field by utilizing iron filings on a plate. Groups record their observations and present their predictions and results to the class. As an extension, the concept of magnetic fields is related to issues such as solar activity and electricity production.

Materials: Bags containing a few magnets, a plate, iron filings, a compass, chart paper, newsprint, markers

INVITATION

Students are divided into groups. Each group receives a bag containing the laboratory materials. Using only the magnets from their bags, groups make predictions about the magnetic field, including direction, shape, and relationship to the magnet's poles. They can manipulate the magnets to assist the prediction-making process. On a sheet of newsprint labeled "Prediction," each group describes its prediction (diagrams strongly encouraged).

EXPLORATION

Groups now use the remaining materials from their bag to make predictions about magnetic fields. The iron filings should be spread out on the plate. By placing magnets underneath, above, on, and around the plate, the directions of the magnetic field of each magnet will be revealed by the filings. Each group should record its findings and make a Results poster that includes descriptions and diagrams.

EXPLANATION

Groups present to the class their Prediction poster followed by their Results poster. After each brief presentation, small discussions can be held, in which questions are asked and answered. The teacher provides any corrections or information that may be needed to properly explain magnetic fields. Posters are displayed in the classroom.

Take Action

Students could research the effect of magnetic fields on our lives. Examples include the following: the relationship between electricity and magnetic fields (including the direction of electron flow), the purpose of magnets in televisions and speakers, solar activity due to the sun's magnetic field—and its results (sunspots, flares, solar wind, comet tails, auroras, etc.), the Earth's magnetic field, and so on.

Internet Resources

http://www.engineerguy.com/index.htm
Engineer Guy: Dr. Bill Hammond

http://en.wikipedia.org/wiki/Magnetic_field
Magnetic Fields

http://en.wikipedia.org/wiki/
Geomagnetic_reversal
Magnetic Field Reversals of Earth

http://en.wikipedia.org/wiki/Compass
Compass

http://www.exploratorium.edu/learning_studio/
auroras/
Auroras

Surface Tension: The Stress H_2O Feels

Goal: This lesson provides students with a hands-on, cooperative learning experience in which they investigate water surface tension. Students utilize scientific inquiry and experimental design as they create their own experiment.

Overview: Students are introduced to water surface tension with a striking class demonstration. In groups, they test surface tension by designing and conducting their own experiment. The results are shared with the class.

Materials: Bags containing diverse lightweight objects (paper clips, wires, cardboard, pennies, plastic chips, etc.) and containers of various sizes; water (cold and hot)

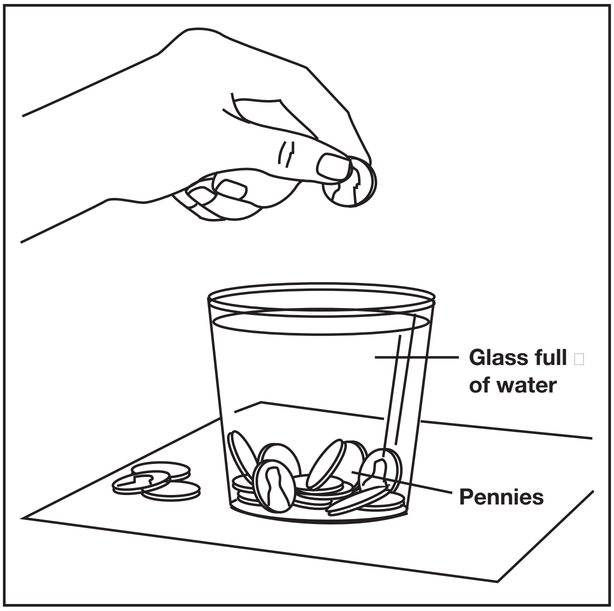
Invitation

Students are asked to guess how many pennies will fit into a full cup of water without causing the water to spill over. Student guesses are recorded on the board. The teacher then begins to drop pennies into the cup of water, one by one. Once the cup overflows, the teacher leads
a discussion focusing on why things happened as they did. The concept of surface tension is introduced.

Exploration

Students are divided into teams. Each team receives a bag of laboratory materials. Each team designs an experiment utilizing the lightweight objects and any of the containers available. The experiment should in some way test water tension. (Suggestions: placing objects on top of the water, hot water vs. cold water, shape of container, depth of water, placing objects on water surface and in glass, etc.) Experiments should be recorded as they are carried out.

Figure 12.9
Surface Tension



EXPLANATION

Groups prepare a brief presentation of their procedure and results and share it with the class. Each group should arrive at one final conclusion regarding surface tension, which they should write on the board/newsprint. After the presentations, the teacher leads a discussion about the results, the final conclusions, and water tension in general.

TAKE ACTION

As an extension activity, the class could research the local water supply, or the condition of local lakes or rivers. Pollution, water supply, water distribution, water towers, and so on, might be looked at specifically, depending on the area.

Internet Resources
http://www.epa.gov/owow/NPS/kids/surfacetension.html
What is surface tension?

http://web.mit.edu/nnf/education/wettability/index1.html
Fundamentals of Surface Tension/Wettability

http://www.groundwater.org/
Ground Water

WATER AND AIR SURFACE INTERACTIONS: BUBBLES

Goal: This activity demonstrates surface interactions between water and air. Students work in cooperative groups to discover properties of water and air. Observational and recording skills are enhanced.

Overview: In groups, students are asked to speculate on how it might be possible to make a raisin or a grape rise to the top of a glass of water, without touching it. Groups are given materials with which to conduct an experiment showing that the object may rise in carbonated water. Results are shared, and the class discusses the relationship of the air bubbles to the rising raisins and the grapes.

Materials: Bags containing raisins and grapes, a clear carbonated beverage, 2 beakers; tap water

INVITATION

Ask students in groups to speculate on how it might be possible to make a raisin or a grape rise to the top of a glass of water, without touching it. Have each group propose a plan and briefly share it with the class.

Variation: Many teachers have successfully utilized a scenario in which students are initially told they will be studying a species of sewer lice, a variation that seems to truly engage the students in the activity. The sewer lice are being studied, students are told, because they are very efficient at cleaning dirty water, including sewer water. Show the students a beaker containing (dark) cola and yellow raisins. Inform the students that they are looking at dirty water with a few sewer lice in it. Then show students a beaker containing a cola/clear cola mixture and some yellow raisins. Tell the students that the lice have been in that beaker for a week; make the observation that the water is clearly cleaner. (The raisins should be rising and falling in the liquid periodically.) Finally, show the class a beaker containing clear cola and yellow raisins. Tell the class that the sewer lice have been in that beaker for 3 weeks; observe that it is perfectly clean. You can even drink some of the "water" to prove how clean it is. Give the students a small beaker with dark cola and some raisins in it, and ask them to make observations that they have actually seen eyes and tiny legs on the sewer lice. Now you can go ahead and inform the students that they are really observing yellow raisins in cola. Following a short de-briefing, move into the explanation-stage discussion of the phenomena observed.

Exploration

Distribute the bags. Have each group fill its two beakers, one with water and one with carbonated water. Instruct the groups to place raisins, grapes, and/or peeled grapes in one or both of their containers. Each group should record its observations.

Explanation

Once all groups have completed their test, each group should present its observations to the class. A teacher-led class discussion provides a forum in which groups attempt to explain the phenomena they observed. The teacher should inform the students that in a carbonated beverage, the raisins and the unpeeled grapes will periodically rise to the surface, "riding" on the bubbles, and then fall. The peeled grapes do not rise because the bubbles cannot adhere to their surface. From here, discussion can turn to the properties of air and/or water.

Figure 12.10
Prism

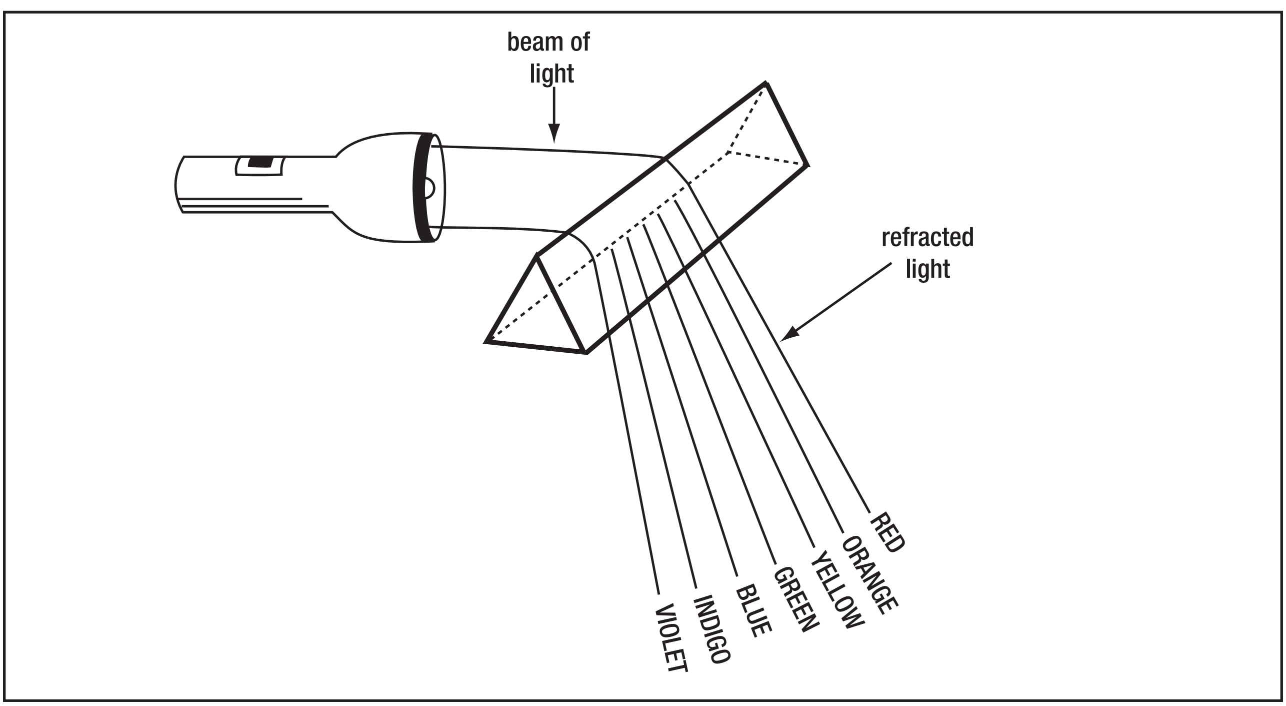
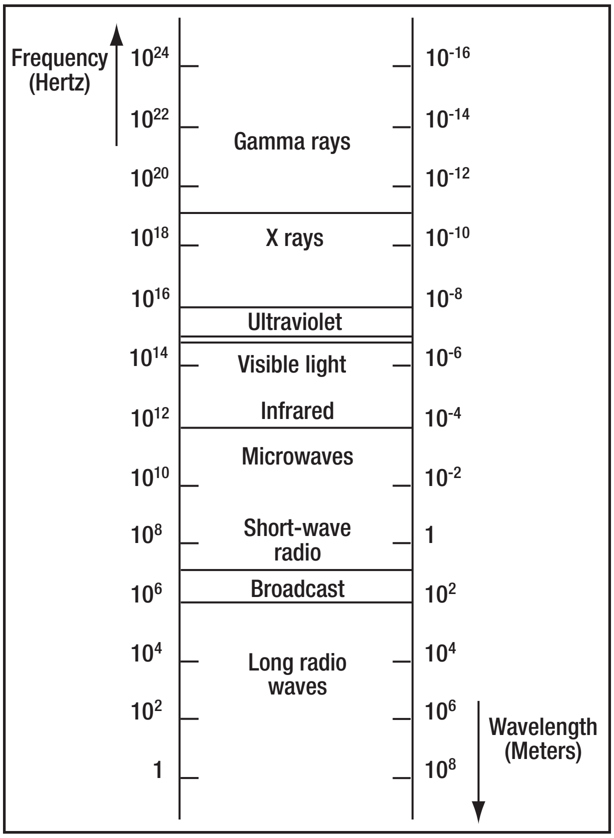


Figure 12.11
Visible spectrum



TAKE ACTION
Students could research the dangers involved in scuba diving, and how these relate to the properties of air and water.

Internet Resources
http://en.wikipedia.org/wiki/Carbonated_water
Carbonated Water

http://en.wikipedia.org/wiki/Scuba_diving
Scuba Diving

http://scuba-doc.com/nitronarc.html
Nitrogen Narcosis

http://en.wikipedia.org/wiki/Nitrogen_narcosis
Nitrogen Narcosis

THE VISIBLE SPECTRUM: A RAINBOW

Goal: Students become familiar with the diffraction of light through a prism. They come to understand that different colors have different wavelengths and that white light consists of all the colors combined. Students use scientific inquiry and observational skills to complete this activity.

Overview: In groups, students are challenged to describe how a rainbow is formed. Each group records its ideas and shares one with the class. Groups then test light by passing it through a prism and a glass of water. Results are recorded and shared. The class reaches a consensus on the formation of rainbows.

Materials: Bags containing a prism, flashlight, white cardboard, drinking glass; water

INVITATION
In groups, students are challenged to describe how a rainbow is formed. Each group records its ideas with diagrams. It selects the idea it feels is most accurate and shares it with the class. The various explanations are recorded by the teacher on the board or on newsprint.

EXPLORATION
Groups receive a bag containing the lab materials. Groups test light by passing it from the flashlight through the prism and/or the glass of water, onto the white cardboard. Students record their results with drawings and explanations.

EXPLANATION
Each group shares its findings with the class. Teacher-led discussion clarifies the separation of the different wavelengths of light. The class then reaches a consensus on the formation of rainbows, comparing its latest ideas with those originally proposed.

Take Action

Students could study the entire electromagnetic spectrum and see where visible light fits in. Research into other forms of electromagnetic waves might focus on X rays, UV light, infrared light, radiowaves, and so on; students could learn about the functionality and importance of these invisible waves.

Internet Resources

http://imagine.gsfc.nasa.gov/docs/science/know_l1/emspectrum.html
Electromagnetic Spectrum

http://imagine.gsfc.nasa.gov/docs/features/movies/groovie_movie.html
X-ray Sources Near and Far

http://missionscience.nasa.gov/ems/05_radiowaves.html
Radio Waves

http://www.physicsclassroom.com/class/refrn/u14l4a.cfm
Dispersion of Light by Prisms

The resources presented here are organized into the four Parts of the book, including The Tools of Inquiry, Teaching Strategies and assessment Tools, The Internet, and Science Activities.

All of the references listed here are posted as hyperlinks on the Science As Inquiry Website, and you can find them here: http://www.science-as-inquiry.org/ and then click on Research and Publications.

The Tools of Inquiry

Aikenhead, Glen S. (2006). *Teaching Science for Everyday Life: Evidence-Based Practice*. New York: Teachers College Press

Duschl, Richard A., Schweingruber, Heidi A., and Shouse, Andrew W., Editors (2007). *Taking Science to School: Learning and Teaching Science in Grades K–8*. Washington D.C.: The National Academies Press

Gillies, Robyn M. (2007). *Cooperative Learning: Integrating Theory and Practice*. Thousand Oaks, CA: Sage Publications, Inc.

Michaels, Sarah, Shouse, Andrew W., and Schweingruber, Heidi A, Editors. (2008). *Ready, Set, Science!: Putting Research to Work in K-8 Classrooms*. Washington D.C., The National Academies Press

O'Brien, Thomas (2010). *Brain-Powered Science: Teaching and Learning with Discrepant Events*. Alexandria, VA: National Science Teachers Association.

Smithenry, Dennis W. and Gallahher-Bolos, Joan A. (2009). *Whole-Class Inquiry: Creating Student-Centered Science Communities*. Alexandria, VA: National Science Teachers Association.

Teaching Strategies and Assessment Tools

Bell, Philip, Lewenstein, Bruce, Shouse, Andrew W., and Feder, Michael F. (2009). *Learning Science in Informal Environments: People, Places, and Pursuits*. Washington D.C.: National Academies Press.

Donovan M. Suzanne and Bransford, John D., Editors. (2005). *How Students Learn: Science in the Classroom*. Washington D.C., National Academies Press

Fenichel, Marilyn and Schweingruber, Heidi A. (2010). *Surrounded by Science: Learning Science in Informal Environments*. Washington D.C.: National Academies Press

Hassard, Jack and Dias, Michael (2009). *The Art of Teaching Science: Inquiry and Innovation in Middle School and High School, 2nd Edition*. New York: Routledge.

Keeley, Page (2008). *Science Formative Assessments: 75 Practical Strategies for Linking Assessment, Instruction, and Learning*. Alexandria, VA: National Science Teachers Association.

Keeley, Page (2005). *Uncovering Student Ideas in Science, Volume 1: 25 New Formative Assessment Probes*. Alexandria, VA: National Science Teachers Association

Keeley, Page (2011). *Uncovering Student Ideas in Life Science, Volume 1: 25 New Formative Assessment Probes*. Alexandria, VA: National Science Teachers Association.

Llewellyn, Douglas (2007) *Teaching High School Science Through Inquiry: A Case Study Approach*. New York: Corwin Press.

Singer, Susan R., Hilton, Margaret L., and Schweingruber, Heidi A., Editors (2006). *America's Lab Report: Investigations in High School Science*. Washington D.C.: National Academies Press.

Young, Sarah (2011). *Gourmet Lab: The Scientific Principles Behind Your Favorite Foods*. Alexandria, VA: National Science Teachers Association.

Internet Resources

Berger, Pam and Trexler, Sally. (2010). *Choosing Web 2.0 Tools for Learning and Teaching in a Digital World*. Englewood, CO: Libraries Unlimited.

Berry, Barnett (2011). *Teaching 2030: What We Must Do for Our Students and Our Public Schools…Now and in the Future*. New York: Teachers College Press

Hassard, Jack. (2011). *Science As Inquiry Website: http://science-as-inquiry.org/*

Tachell, Peter (2004). *Science Encyclopedia: Usborne Internet-Linked Discovery Program*. London: Usborne Publishing

Zucker, Andrew A. (2008). *Transforming Schools with Technology: How Smart Use of Digital Tools Helps Achieve Six Key Education Goals*. Cambridge, MA: Harvard Education Press.

Science Activities

Fullager, Paul D., and West, Nancy W. (2011). *Project Earth Science: Geology, Revised 2nd Edition*. Alexandria, VA: National Science Teachers Association.

Frederick, J. Adam, Blake, Robert W., Haines, Sarah, and Lee, Stephanie Colby (2010). *Inside-Out: Environmental Science in the Classroom and the Field, Grades 3 – 8 (e- book)*. Alexandria, VA: National Science Teachers Association.

Hansen, Thor, and Slesnick. (2006). *Adventures in Paleontology: 36 Classroom Fossil Activities*. Alexandria, VA: National Science Teachers Association

Herr, Norman (2010). *The Sourcebook for Teaching Science, Grades 6 – 12: Strategies, Activities, and Instructional Resources*. San Francisco: Jossey-Bass.

Holt, Geoff, and West, Nancy W. (2011). *Project Earth Science: Astronomy, Revised 2nd Edition*. Alexandria, VA: National Science Teachers Association.

Walker, Pam and Wood, Elaine (2007). *Hands-On General Science Activities With Real-Life Applications: Ready-to-Use Labs, Projects and Activities for Grades 5-12, 2nd Edition*. San Francisco: Jossey-Bass

Walker, Pam and Wood, Elaine (2006) . *Science Sleuths: 60 Activities to Develop Science Inquiry and Critical Thinking Skills, Grades 4-8*. San Francisco: Jossey-Bass.

Acknowledgements

A special thank you to Dr. Frank Koontz, Director of Programs, The Bureau of Education and Research, who invited me to design a science seminar on cooperative learning to be presented to science teachers grades 6 –12. With Dr. Koontz's support, I developed a book for the seminar entitled Enhancing Your Science Teaching Through Cooperative Learning. For the next 12 years, I presented three additional seminars for the BER on different topics including active learning, project-based teaching, and the Internet. For each seminar, I designed a handbook full of practical activities and lessons that science teachers could use in their classes. The constructivist theory and content of these seminars also became the underlying theory of the TEEMS science teacher education program that I developed and designed at Georgia State University for mathematics and science teachers.

The content of this book, Science As Inquiry, is due then to my experiences conducting seminars for the BER and my work as a professor of science education at Georgia State University. All of the activities and projects in the book have been used with many teachers and students, and they in turn used them in the context of grades 6–12.

I want to thank Daniel Whitehair, who worked with me to develop the activities that comprise Part IV of *Science As Inquiry*. Daniel was a student in the TEEMS science teacher education program, and now teaches in New York. Grateful acknowledgement to many of the TEEMS students who wrote Fuzzy Situations that you will find in Chapter 3. I've identified the author of each Fuzzy Situation, and I wish to thank each of you for granting me permission to use these creative stories.

When the first edition of the book was published with Good Year, my editor in chief was Roberta Dempsey, who guided me through the entire process and made key decisions in the design and content of the book. Thank you, Roberta, for help on *Science As Inquiry*, and for the other books that you edited for me.

There are many educators who have been an inspiration to me over the years, and whose ideas and thinking resonated with me, and are surely found in the pages of Science As Inquiry. Firstly is my friend Joe Abruscato, who I met in graduate school, which led to lifetime of work and friendship. Joe will always be a part of me, and I treasure the time that I had with him. Special debt of appreciation to Roger Cross, professor extraordinaire, and friend, and author of many books on science education; Marlene Hapai, colleague and friend, and one of the most influential science educators and scientists in Hawaii; and Sergei Tolstikov, a long time colleague and friend from Moscow, Russia.

I also wish to thank those of you who used the first edition of *Science As Inquiry*. The book was purchased by individual teachers, used as a text in science education methods courses, and also used in staff development workshops around the country. I hope you will find this Second Edition of *Science As Inquiry* worthy of your interest and support.

Since the first edition of *Science As Inquiry* was published, Good Year Books has gone through several changes in ownership, but is now a Division of Social Studies School Service. I want to thank Dr. Aaron Willis, Chief Education Officer of Social Studies School Service, for asking me to do this revision of *Science As Inquiry*. Bill Williams, Senior Editor of the Social Studies School Service, shepherded my book through the revision stage, and I thank him for his support. Thank you to Will Slattery, science editor for Good Year Books, who edited the revision.

This book relied upon the contributions of science teachers and science education researchers who have led the way in pioneering efforts to improve science teaching, and to document and uncover new truths about science teaching. I have tried to reference their work in *Science As Inquiry*. However, the view and interpretation of science teaching presented in this book, one that promotes a humanistic and inquiry-oriented approach, is my own.

Jack Hassard, Marietta, Georgia, 2011

Abilities in Science Chart, 17–18
Air Pollution Data, Real-Time, 150
Air Quality Chart, 149
Assessing Performance in Science, 163–195
Assessment
  Multiple Methods of, 164
  System, 190
Attitudes, 189–195
  Examples, 195

Biodrama Project, 100
Biology Portfolio, 184–189
Books
  Online and Internet, 257
  Science Activity, 258
  Tools of Inquiry, 257
Bureau of Education and Research, 259

Chlorofluorocarbons (CFCs), 132–154
Circle of Knowledge Structure, 25, 30–34
  Lesson Plan: Mystery at the Ringgold Roadcut, 30–35
Clay Boats Project, 102
Cognitions and Cognitive Skills, 191
Cognitive Strategy, 194
  Example, 194
Collaborative Inquiry Strategy, 10–16
  Lesson Plan: The Footprint Puzzle, 11
Constructivism in the Bag, 197–203
  Design Team Activity, 200–202
Constructivist Learning Cycle, 5, 198, 201
Constructivist Learning Model, 198–201
Cooperative Inquiry Roles, 11–12
Cooperative Learning Lesson Plans
  Footprint Puzzle, 11–16
  Whirlybirds, 18–23
Cooperative Learning Strategies, 10–42
  Collaborative Inquiry Strategy 10–16
  Individual Accountability and, 10
  Positive Interdependence and, 10
Concept Learning, 189–193
  Examples, 193
Concept Mapping, 72–73
Cretaceous Period, 13
Crinoid Task Cards, 31–35

Design-an-Organism Project, The, 101
Dirty Water Project, 100
Discrimination Skills, 192
  Example, 192
Drifting continents, 77–78

Earth Science
  EEEPs, 46–49
  Fuzzies, 63–65
  Lessons, 206–216
  Projects, 97–100
Earth Science and Environmental Science
  Lessons, 205–229
Earth Science Lessons
  Center of the Earth, The, 209–210
  Geology: Classifying Rocks, 215–216
  Geysers, 211–213
  Igneous Rocks: Granite, 208–209
  Making A Cloud, 207–209
  Mohs' Scale of Mineral Hardness, 213–214
  Rock Types: Igneous, Metamorphic, Sedimentary, 210–211
EcoBadge, 132, 135
EEEPs (Exciting Examples of Everyday Phenomena), 44–53
    Activity sheet, 47
    Earth Science EEEPs, 46–49
    Life Science EEEPs, 49–50
    Physical Science EEEPs, 50–53
E-groups, 112–113
E-mail, 111–112
Environmental Protection Agency, 225
Environmental Science Lessons
  Acid Rain, 219–220
  Clean Water, 225–226
  Hydroelectric Power, 226-227
  Rain Forest Deforestation, 220–222
  Waste Disposal, 224–225
EPals, 117
Erathosthenes Project, the, 98–99

Feederwatch Project, 101
Footprint Puzzle, The, 11–16
  Recording Sheet, 14
Fossil crinoid stems, 30–31
Fuzzy Situations, 56–66

Assessing prior knowledge, 56
Definition, 56
Earth science, 63–65
Environmental science, 65–66
Life science, 59–62
Physical science, 62–63
Using, 57

Games, 84–89
Disaster Game, 84–88
Earth science, 89
Environmental science, 89
Life science, 89
Physical science, 89
Geoblock, The, 77–79
Geoblock model, 79
Global Classrooms, 132
Global Lab Program, 110, 115
Ground-Level Ozone, 133
Guided Imagery, 81–82

Hydrocarbons, 140

iEARN, 127–129
Igneous Rock Expert Sheet, 39
Information Collection and Analysis
Information Exchanges, 119
Pooled Data Analysis, 119
Information Exchanges, 116, 119
Inquiry questioning, 73–74
Insect Project, The, 101
Internet, 98–110
E-mail, 112
Scavenger Hunt, 139
Tools of the, 113–119
Interpersonal Exchange Activities, 115–132
Global Classrooms, 115, 132
Keypals, 115, 132
Question-And-Answer Services, 128
Interpersonal Tools, 111–114
Interviews with Teachers, 106–109

Jigsaw Strategy, 36–42
Lesson Plan: Jigsaw Rocks, 37–42
Journals, 164

Keypals, 115–117
K-W-L Strategy, 77–80
Lesson Plan: Earthquakes, 81

Life Science
EEEPs, 49–50
Fuzzy Situations, 59–62
Projects 100–101
Life Science Lessons
Classification Systems, 239–240
Dinosaur Biographies, 232–233
Dinosaur Defense, 233–235
Endangered Species, 231
Fossilization: Making a Plaster Mold, 238–240
Fossils, 236–237
Life in a Seashell, 235–236
Log, student, 179–181
Organization, 181–182
Use of, 181–182
Lunar Project, 100

Mars Egg Drop Project, 97
Mars, Problem on the Way to, 24–29
Data Recording Sheet, 28
Metamorphic Rock Expert Sheet, 41
Mindspring, 110
Mooncards, 26–27
Multiple Abilities Strategy, 17–23
Multiple Choice, alternative, 171
Multiple Intelligences, 17–18
Mystery at the Ringgold Roadcut, 30–35

National Park Project, 100
NASA, 25, 63, 97–98, 114
Scorecard, 29
Nitrogen Oxides, 140
Numbered Heads Together Strategy, 23–25
Lesson Plan: Problem on the Way to Mars, 24–25

Observing
Hands-on/Minds-on Behavior, 168
Social Behavior, 168
Old Faithful geyser, 212
Onion lab, 75–77

Online and Internet Resources, 260–261
Online Classroom, 105–130
Anticipating Problems, 108–110
Creating, 108
Open-Ended Questions, 172
Designing, 173
Examples, 174–177
Heating the Air, 177
Plant-in-the-Jar, 175–176
Scoring Rubric, 173
Ozone
Certificate, 160
Community, ozone in your, 143–148
Definition, 132–133
Depletion, 137
A Global Project, 148–151
Goals of Project, 133
Good and the Bad, 133–138
Hole, 133
Introduction to, 132
Layer, 132–133
Mini-Learning Log, 155–159
Monitoring Card, 144
Observation Chart, 146
Portfolio, 154
Shield, 133
Submission Form, 151
A Web-Assisted Project, 131–160
Web Site, 133–134

Paper Tower Project, 101
Performance Tasks
Characteristics, 174
Examples, 178
Photochemical Reactions, 142
Photons, 140
Physical Science
EEEPs, 50–53
Fuzzy Situations, 62–63
Projects, 101–103
Physical Science Lessons
Electromagnetism, 243
Evaporation Is Cool, 250
Gravity, 247–248
Magnetic Fields, 251–252
Mixtures: Iron in Cereal Flakes, 248–250
Pendulum Variables, 245–247
Power: Watts in the Water, 244–245
Surface Tension: The Stress H_2O Feels, 252–253
Visible Spectrum: A Rainbow, The, 255–256
Water and Air Surface Interactions: Bubbles, 253–254
Pooled Data Analysis, 119, 132
Portfolio
Basic, 184–185
Biology/Life Science, 185–189
Ozone, 154
Pre-assessment Strategies, 68–72
Concept Mapping, 72–73
Cushioning/Underexplaining, 72
Interviews, 69
Surveys, 69
T-charts, 68–69
T-chart template, 70
Problem on the Way to Mars, 24–29
Problem Solving, 193
Examples, 193
Projects, 119–131
Social Action Projects, 132
Earth Science Projects, 97–100
Life Science Projects, 100–101
Physical Science Projects 101–103
Problem-Solving Projects, 126–129
Project-Based Science Teaching, 92–103
Definition, 92
Evaluating, 93–96
Rationale, 93
Rubric for, 96
Steps for, 95
Shifting paradigms, 94
Types of, 93
Project Ozone: A Web-Assisted Science Unit, 131–160
Psychomotor Skills, 189
Examples, 189

Q-M-S Strategy, 75–77
Question-and-Answer Services, 132
Questioning, collaborative, 73–75
Inquiry questioning, 74

Questions
Asking, 168
Open-Ended, 172
Probe, 168
Redirect, 168
Variety, 168
Wait Time, 168

Rocks, 38–42
Rocky Writing, 171–172
Round Table Strategy, 24–29
Lesson Plan: Problem on the Way to Mars, 24–29
Rule Learning, 193
Example, 193

Science Activities, 258
Science Teaching Resources, 257–258
Sedimentary Rock Expert Sheet, 40
Self Reflection Form, 185
Scavenger Hunt
Ozone, 139
Shadows Project, 99
Smog, 132, 138
Social Action Projects, 132
Spaghetti Cars Project, 103

Talk
Student, 169
T-Chart Conversations, 169
T-charts, 68–69, 169
Rocks and Minerals, 169
T-chart template, 70
Testing the Waters Project, 100
Think Aloud Pair Problem Solving Strategy, 35–36
Lesson Plan: Boston Harbor, 36
Lesson Plan: Foreign Language, 35

Verbal Skills, 191
Example, 192
Video Conferences, 112
Virtual Classroom, 125–126
Virtual Field Trip, 119–124, 132, 140
Virtual Learning, 119
Visualizations: Guided Imagery, 81–84
Creating your own, 84
Lesson Plan, 82

Web Resources for Science Teachers, 121–129
Access Excellence, 124
Classroom FeederWatch, 101
Global Thinking Project, 109, 113, 127
GLOBE, 113–114
Whirlybirds, Lesson Plan, 18–23
Template, 20
Group Mini-log, 21–22
Wind-Powered Vehicles Project, 102
Writing
As an Assessment Strategy, 170–171
Rocky, 171