Visiting Geoscientists
An Educational Outreach Guide for Geoscience Professionals

Developed by the American Geological Institute and The American Association of Petroleum Geologists
Bob Krantz  
AAPG Youth Education Activities Committee  
Ed Roy  
Trinity University  
Laura Zahm  
AAPG Youth Education Activities Committee

Ann Benbow  
American Geological Institute

Colin Mably  
American Geological Institute

Laura Middaugh Rios  
American Geological Institute

Jason Betzner  
American Geological Institute

**Dedication:**

We dedicate this volume to one of our co-authors, Dr. Ed Roy, who passed away while we were completing the handbook. Dr. Roy inspired us and many others through his tireless support of Earth science education, and as a champion for K-12 Earth science excellence.

**Photo Credits:**

Top cover photo, Gold Panning Courtesy Beth Stettner USGS

Earth, Ed Roy: Earth Science World Image Bank

Blue Marble Image p. 7 NASA Visual Earth

Hurricane Isabel p. 10: Earth Science World Image Bank © MODIS NASA

Children taking water samples, p. 11: Earth Science World Image Bank © Tim McCabe, NCRS

Geologist in a classroom, p. 14: The Missouri Department of Natural Resources

Muddy Shallow water p.38: USGS

Swamp p. 38: Earth Science World Image Bank © Chris Keane

Fish, Sandy Bottom p. 38 Courtesy Rob Pederson, EPA

Coral Reef fish p. 38, Open Source image

Rocky beach p. 38 Courtesy David Siscon, NOAA

Nautilus p. 38 Courtesy J. Baecker, Open Source image

Unidentified earthquake damage image p. 41 NOAA

Collapsed Interstate 680 in California p. 41 USGS

Damage to a second kitchen in a townhouse near the Northridge Fashion Center p. 41 USGS

Wooden structure that shifted on its foundation during the 1989 Loma Prieta earthquake. p. 41 Courtesy C. Stover, United States Geological Survey

1988 Armenian earthquake p. 41 Courtesy USGS Earthquake Hazards Program

Collapse of apartment building over garage in Reseda following the 1971 San Fernando earthquake, p. 41 USGS

A paleontologist removing fossil bones from a cliff: p. 48 Earth Science World Image Bank Courtesy NPS

A paleontologist is excavating fossils in Colorado's Dry Mesa Quarry: p. 48 Earth Science World Image Bank © Michael Collier

This paleontologist at Utah's Dinosaur National Monument is relieving the shoulder bones of a large Stegosaurus: p. 48 Earth Science World Image Bank Courtesy NPS

This skull is being prepared for study by National Park Service and visiting paleontologists at Utah's Dinosaur National Monument: p. 48 Earth Science World Image Bank Courtesy NPS

This paleontologist is excavating fossils in Colorado's Dry Mesa Quarry: p. 48 Earth Science World Image Bank © Michael Collier

A paleontologist is studying the jaw of an Antrodemus fossil: p. 48 Earth Science World Image Bank Courtesy NPS

The Rock cycle images p. 54 Courtesy NASA

Tyrannosaurus p. 58 Courtesy North Dakota State Government

Apatosaurus p. 58 Courtesy Wikipedia Commons

Triceratops p. 58 Courtesy Wikipedia Commons

Stegosaurus p. 58 Courtesy Wikipedia Commons

Velociraptor p. 58 Courtesy Wikipedia commons

Earth System Diagram p. 68 American Geological Institute
# Table of Contents

<table>
<thead>
<tr>
<th>Title</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Introduction</td>
<td>4</td>
</tr>
<tr>
<td>Chapter 1: Modern Science Enrichment</td>
<td>5</td>
</tr>
<tr>
<td>What is Enrichment?</td>
<td>5</td>
</tr>
<tr>
<td>The Opportunity for Outreach</td>
<td>6</td>
</tr>
<tr>
<td>Why Earth Science Matters to Everyone</td>
<td>7</td>
</tr>
<tr>
<td>Chapter 2: How Children Learn</td>
<td>11</td>
</tr>
<tr>
<td>Chapter 3: Earth Science in 21st Century Curricula</td>
<td>14</td>
</tr>
<tr>
<td>Chapter 4: How to Get Into (and Out of) the Classroom</td>
<td>19</td>
</tr>
<tr>
<td>Chapter 5: Investigations for Different Age Levels</td>
<td>24</td>
</tr>
<tr>
<td>Chapter 6: Resources</td>
<td>81</td>
</tr>
</tbody>
</table>
Introduction

We wrote this guide to inspire geoscience professionals and assist them in helping to provide Earth science enrichment for students, especially in school programs at the K-12 level. We have grown increasingly aware of the tremendous opportunities for enrichment and the equally large resource represented by professional geologists and geophysicists. We hope to reach scientists working in resource and environmental companies, research institutes, state and federal agencies, and even college and university departments. We also hope to connect with teachers and help them make the most of the volunteers they meet.

In short, we want to encourage all Earth scientists to join us in making science education more inspirational and effective. To do this, we need to understand the modern classroom setting, including the challenges faced by teachers and other education professionals. We also want to make the most of the limited time and resources we have to apply.

We know that many geoscience professionals already visit classrooms, lead student field trips, and even involve K-12 students in research, and we strongly applaud their efforts. We hope this handbook can offer them some additional ideas and resources to enhance their experience. For those who have yet to face a group of curious students, we want to encourage that first step, and make the initial encounter as fun and effective as possible.

Chapter 1 begins with a discussion of what effective modern enrichment can be like, including key components and why Earth science enrichment matters. Chapter 2 discusses how K-12 students learn science best, with an emphasis on discovery and inquiry. In Chapter 3, we review the current state of Earth science in K-12 education, from curriculum issues to science frameworks and standardized testing. Chapter 4 provides ideas to help get into (and out of) the classroom, and how to make the most of the time spent there. Chapter 5 provides some sample activities, material lists, and other resources. Finally, Chapter 6 provides valuable resources that you may use to supplement your outreach experience.
Chapter 1: Modern Science Enrichment

Imagine you are back in school, say, in seventh grade. You are in science class, and in the middle of a module that includes volcanoes. When you arrive for class you notice a strange adult talking with your teacher at the front of the room. After the bell rings, your teacher announces that the class has a special guest, a geologist who came to talk with the class. Wow—a break from routine! Maybe this will be a good day after all.

The geologist starts talking about the kinds of volcanoes, something you covered in class last week. He then lists the kinds of volcanic rocks and the minerals they contain. Some of the names are kind of long and complicated. He reaches into a box and takes out five pieces of rock and places them on the table in front. One at a time, he holds them up and repeats the minerals each one contains. On the board he makes a list with the names in some kind of order, and says something about the kind of eruptions that each type comes from. The other students around you are getting restless and fidgety. The geologist starts to draw shapes of volcanoes and again holds up the rocks one at a time and uses some more complicated words. Your teacher makes a comment that time is running out…

Let’s rewind and start over. Imagine that after the teacher introduces the visiting geologist, he stands up, shakes a bottle of soda, puts it into a shallow tub on the front table, and asks, “If we open the top now, what will happen?” Several of your classmates call out that it will splurt out and make a mess. Will he do it? Yes! He twists off the top, and out comes a fountain of soda followed by lots of laughs and loud comments from the class. He asks about what happened and writes down a few ideas from the class on the board. He then takes out a bottle of juice, shakes it, and again puts it in the tub. Again he asks the class to predict what will happen, opens the top, and writes down ideas from the class. The discussion gets into what made the soda erupt—something about gas dissolved in liquid under pressure.

The geologist flips open his laptop, already plugged into the digital projector, and shows some cool videos of erupting volcanoes. Some are exploding ash and glowing lava, on others the lava just flows out and runs down hill. Now it makes sense what is happening, and the class explains how gas drives some eruptions more than others. He passes out piles of rocks to each table group and asks how you might tell from the cooled lava rocks which ones came out in different ways. You get to work with a magnifying lens and… all too soon the class is over.

Which experience would you enjoy more? These may be extreme examples, but the key difference is that the second version allows students to investigate and discover on their own, and to help lead the investigation. In essence, they are learning about science by doing science. If we want to promote science learning and appreciation, we have to offer enrichment opportunities that can inspire all the students.

What Is Enrichment?

Enrichment adds to the learning experience by offering additional content, excitement, and opportunities. When geoscience professionals visit a class or otherwise interact with students, they offer both personal science experiences and can provide role models that inspire career interests. Good enrichment makes the best of very limited classroom time to help teachers meet diverse instructional objectives.

Good enrichment contains as many of these key ingredients as possible:
Chapter 1: Modern Science Enrichment

Inquiry
Science by doing
Process more than fact

Data
Observing, measuring, testing
Recording and organizing
Manipulating, graphing

Synthesis
Interpreting
Drawing conclusions
Independent thinking and team work

Reporting
Distilling important results
Presenting and defending

Fun
Excitement and inspiration
Rewarding self-discovery

Relevance
Teacher and district goals and frameworks
Grade-level appropriate
Kid accessible
Links to other disciplines

Students learn science by doing science, reinforcing both content and method. Good science includes opportunities for discovery and exploration, data collection and analysis, and conclusions that must be communicated (and defended!). Of course, these components must be presented at age-and grade-appropriate levels, but even the youngest students can do all these tasks.

Good enrichment integrates other classroom goals, ranging from individual teacher curriculum plans to school district and state science education standards (see Chapter 3). A visiting science professional needs to know what these other goals are and how to help achieve them.

Like science itself, the enrichment content should be objective. While much of what people learn comes from biased sources, science offers rational methods for recognizing and evaluating that bias. Even if existing opinions seem one-sided, strongly advocating the opposing viewpoint can very quickly turn off students and teachers.

The Opportunity for Outreach
Why take the time and effort to provide science enrichment, especially with all these complicating issues? Most obviously, if working professionals do not, then few others that can offer the same insights will. Some teachers have strong science backgrounds, others do not. Some teachers love science, others might be intimidated by it. Most teachers will welcome the interaction, and almost all kids will be excited when someone special comes to class. Most science professionals find the experience equally rewarding, and even inspirational.

Geoscience professionals have extensive academic training and applied experience. We can provide both the factual answers and “back-story” to answer questions from students, and the skills to help guide students in conducting their own investigations. We can bring Earth materials to the class, or take the class outside to experience the Earth close-up. We can help discuss
Chapter 1: Modern Science Enrichment

practical Earth resource issues, and connect modern lifestyles with critical resource issues. We know that gasoline does not come from the pump, that floods do not strike randomly, and that money spent on water witching goes down the drain. We also know how to obtain and evaluate data that can help people make wise practical and even political solutions.

Earth science in particular needs support at the K-12 level. In many school districts, formal Earth science content is last covered in middle school (see Chapter 3). Many college-educated US citizens (i.e. voters) had their last formal exposure to Earth resource and hazard-related science in seventh or eighth grade. Despite the practical implications, many educators still view Earth science as less rigorous than physics or chemistry.

Why Earth Science Matters to Everyone

Because We Live on Earth

Not so long ago, we had the first view of our planet from space. We were startled to see how beautiful and how fragile our home appeared, “a pale blue dot” said Carl Sagan, very different from the other planets in our solar system. Our home—blue with water, white with clouds, green with life—is a planet unique in our solar system and probably rare in the universe.

Nearly everything we do each day is connected in some way to Earth: to its land, oceans, atmosphere, plants, and animals. The food we eat, the water we drink, our homes and offices, the clothes we wear, the energy we use, and the air we breathe are all grown in, taken from, surround, or move through the planet.

By 2025, eight billion people will live on Earth. If we are to continue extracting resources to maintain a high quality of life, then we, as individuals and citizens, need to know more about our planet—its processes, its resources, and its environment. And only through Earth science education can students understand and appreciate our complex planet. The future lies in the hands of students, parents, grandparents, teachers, school administrators, school board officials, and politicians at all levels of government. The future of Earth science literacy—indeed, the future itself—lies in your hands.

Earth Science Benefits Everyone

Our lives and civilization depend upon how we understand and manage our planet—Earth processes affect us all. Weather patterns influence the availability of water resources and the potential for forest fires; Earthquakes, volcanic eruptions, hurricanes, and floods can kill large numbers of people and cause millions or even billions of dollars in property damage.

Just as Earth systems directly affect each of us, we – as individuals, communities and nations— affect our planet. Expanding technologies and growing populations increase demand on natural resources. As we extract and use these resources, we have an impact on Earth today, which will in turn affect those who come after us. To enhance our stewardship of the environment, we must proceed into the future with a sound understanding of Earth systems.

Earth science knowledge enables us to think globally and act locally— to make sound decisions about issues important in our lives as individuals and citizens. People who understand how Earth
systems work can make informed decisions about where to buy or build a home out of harm’s way. They can debate and resolve issues surrounding clean water, urban planning and development, national security, global climate change, and the use and management of natural resources.

An informed society, conscious of our complex relationships with our planet, recognizes the importance of and insists on Earth science education at all grade levels—elementary, secondary, and adult education. When we emphasize Earth science education, everyone benefits.

**Earth Science Creates Informed Citizens**

If we intend to live on—and with—this planet, we truly need to understand how it works, and to understand the interactions of the many components that make up the Earth. The Earth sciences provide an integrated and interdisciplinary approach to a true understanding of our planet. Earth science includes and applies knowledge from biology, chemistry, physics, ecology, and mathematics to tackle complex interdisciplinary issues.

Earth science education also improves critical thinking skills. It offers a historical perspective and improves our ability to predict future events. To understand Earth processes that affect us now and tomorrow, geoscientists look for evidence of what happened in the past. This connects students to the past, as well as challenging them to think about the future.

Earth science poses questions that are exciting as well as practical to children and adults alike: Why is California prone to Earthquakes? Why is the beach eroding and what can we do about it? Why isn’t a floodplain a good place to build a house? Where will we get the fuel to power our cars and planes in the future? Where will we get fresh water to drink? How can I help to protect the environment? Earth science problems and issues are ideally suited for an inquiry-based education approach—an educational process that most closely resembles the reality of scientific endeavor.

**Earth Science Builds Careers for Life**

The role of Earth science in meeting society’s needs continues to grow in importance. Earth science develops skills that help students become better problem solvers, including three-dimensional analysis and comprehension of time and scale. Earth scientists use these skills to ensure a supply of clean water, explore for oil, gas, and coal, map the oceans, track severe weather, and discover the Earth materials we need to build our homes and roads, and the minerals and nutrients we need to farm the land.

Earth scientists work for a wide range of organizations, including petroleum companies, environmental firms, mining companies, and construction companies. They work in local, state, and federal government agencies and teach in our schools, colleges, and universities. Earth scientists also work in non-traditional industries such as telecommunications and financial planning, assisting their organizations to address Earth-related issues that affect their activities.

More than 800 colleges and universities in the United States offer degrees in the Earth sciences. Nearly half of these colleges offer a Masters Diploma, the professional degree for pursuing a career as an Earth scientist. However, training in the Earth sciences builds a foundation for work in other fields, and nearly half of those graduating with Earth science degrees establish careers in fields as varied as engineering, law, systems analysis, and financial management.

Earth science provides a strong background for many career paths and instills an understanding of how the Earth system influences the many and varied aspects of human activity. However, many students graduate from high school unaware of the contributions that Earth scientists make to society and the unique problem solving skills that Earth science instills. We must make Earth science education a priority at all levels if we, as a society, are to meet the increasing demands of the future.
Chapter 1: Modern Science Enrichment

Earth Science: Make It Happen

Earth science has been part of the curriculum in American schools for more than 100 years. Yet many people still think that biology, chemistry, and physics constitute a complete science education. In the 21st Century, that attitude is changing.

The National Science Education Standards and the Benchmarks for Science Literacy (AAAS, 1993) define science literacy and reaffirm the centrality of Earth science in education. The Standards promote the idea that Earth science should be taught in parity with biology, chemistry, and physics as part of the country’s national strategy for science literacy. Earth science education enhances our understanding and appreciation of critical issues that affect every state, so it is imperative that students in every state graduate with a thorough understanding of Earth science.

In recent years, 49 states have established science learning standards—outlining what students must know and be able to do. In every case, these standards emphasize the importance of Earth science in producing well-rounded literate citizens. State science frameworks across the country note that Earth science is necessary for all students and that schools should include Earth science topics in the curriculum from kindergarten through grade 12. Nearly fifty percent of all states include Earth science content in state-mandated high school exams, and thirty-seven states count Earth science courses towards high school graduation requirements.

[This section is adapted with permission from Why Earth Science?, a six-page publication of the American Geological Institute (2004). You may want to incorporate some of the information in this section into your classroom visits, as appropriate. (Why Earth Science? is downloadable from the AGI web site at www.agiweb.org/education/WhyEarthScience/Why_Earth_Science.pdf. It is available in both English and Spanish.]

What We Wish Everyone Knew (about Earth)

Think about the most fundamental concepts of modern Earth science, and the key learnings from the past hundred years. What could you outline on a single page that matters most, and that everyone should know? Here is our list:

1. The Earth has a long history.
   The immense stretch of geologic time is hard for us humans to grasp.
   Some geologic processes happen very slowly.

2. The Earth is always changing.
   We live on a very active planet.
   Some changes are fast, others slow, but nothing is forever.

3. Understanding present Earth processes is the key to unraveling the past.
   We look for the results of past process in the rock record to reveal Earth’s history.
   In turn, the rock record helps us understand the present (and future).

4. Modern society exists at the whim of Earth processes.
   We depend on Earth resources, and are at the mercy of Earth hazards.
   We don’t need to save the planet, but we might save ourselves.
Connecting Current Events and Local Interests

No matter where you live or interact with students, you can focus enrichment activities on local Earth science issues. Coastal areas likely include eroding beaches or sea cliffs. Students in seismically active areas will certainly have questions (and ideas) about Earthquakes. Regions with strong Earth resource industries present plenty of opportunities for issues that affect local families. By including topics that students already care about and have discussed before, you are sure to gain more interest—but be prepared for lots of strong pre-existing ideas.

We can also focus enrichment on recent national or global Earth events. Tsunamis, Earthquakes, Earth science discoveries in the popular press, and even geologic content in films can all provide the sparks for student curiosity.

To help students connect their knowledge of the Earth with “practical” issues, we can emphasize economic and political factors. Younger grades need to understand that fuels and consumer goods do not come from neighborhood gas stations and stores. Older grades can tackle more quantified dollar impacts as well as the critical inputs on complex and even controversial policy decisions.
Chapter 2: How Children Learn

As you plan your classroom visit, it can be helpful to understand how children of different ages learn, so that you challenge your audience, but don’t turn them off by using overly sophisticated language or introducing science concepts that are beyond their abilities to understand.

Studying how children learn has gone on for over a century. One of the most respected researchers in this area was Jean Piaget (1896 – 1980), a child psychologist from Switzerland. Over many years, he observed and questioned children (including his own three) as they manipulated objects, made drawings, listened to and told stories, and made judgments. He was able to get children to describe their thought processes, and he related these processes to the children’s behavior and language. From his observations and analyses, he identified four sequential stages of intellectual development in children. These are defined as:

- **Sensorimotor stage** (birth to approximately age 2). During this stage, children, starting with their innate motor reflex actions, progressively learn to cope with their world through sensory stimuli. At this stage, their intelligence is not linked to language.

- **Preoperational stage** (approximately age 2 to age 7; nursery school and pre-Kindergarten to grade 2). Children in this stage respond to and use language as part of their thinking, but are unable to use logical thinking or operations. They are highly egocentric and they think in the "here and now". They learn best by direct experiences, such as handling and manipulating objects. They can begin to classify objects and events, and begin to think of things that are beyond their direct observations.

- **Concrete operational** (approximately age 7 to age 11; end of grade 2 to early grade 6). In this stage, children start to use logic as they reason. They also understand **conservation**, which means that elements such as area, weight, and substance do not change if their positions change. They also understand the inverse of actions they may take (**reversibility**). They are able to see something from another's point of view. However, they are largely restricted in their thinking to "concrete" objects and events. They cannot think in terms of overall principles, theories, or abstractions. They are limited by the "what is" and cannot focus on the "what could be."

- **Formal operational** (after approximately age 11; late grade 6 and beyond). At the formal operational stage, children can begin to reflect on their own thinking processes. They can now reason in abstract terms, and generalize about principles. For example, where, in earlier developmental stages a child might think "that person's behavior is bad and he should be punished", they can now think more abstractly and say "all bad behavior is wrong, but sometimes it can be justified for other reasons."

The key point of Piaget's theories is that the four stages of development are sequential. Children cannot reach a new stage until they have gone through and have come to terms with the experiences of the preceding stage. At the same time, it is important to note that some children...
Chapter 2: How Children Learn

reach stages at an earlier or a later age than those indicated. Children act upon new objects, events, experiences, and ideas using the prior experience they already have in a process that Piaget calls assimilation. In acting upon the results of these new stimuli, Piaget says they are accommodating these results by learning and incorporating new ideas and behaviors. The relationship between assimilation and accommodation, which has its origins in biology, is at the heart of Piaget's theories of intellectual development. Years later, it remains at the heart of what is today termed constructivism. Although subsequent researchers have added to and refined Piaget’s stages, they have still held up over time.

Here’s what these developmental stages mean to you as you plan and carry out classroom visits with different ages of children: In the earlier grades (K - 2), most children are still preoperational. This means that the science experiences they have must take into account that the children see the world as "me-focused". They need a great many hands-on experiences using simple, everyday objects and materials such as magnifiers, containers of various volumes, non-standard measuring tools, building blocks, rocks and minerals, fossils, water, and sand. It is important that you choose or create science experiences for preoperational children so that they have ample time to explore items, as well as to talk about their discoveries. In this way, you can help them to understand such ideas as: liquids are conserved no matter what the size of their container; or that it is possible to group objects in many different ways.

Older children, those at the concrete operational level, are able to investigate a number of simple science questions, but should do these using as many direct experiences as possible. Such experiences should involve measuring tools, simple laboratory equipment, plants and animals in the classroom, everyday objects, field experiences, videos, and many more. Having children work in collaborative groups as they investigate gives them the opportunity to talk about what they are investigating and what they have found out. In this way, they begin to recognize patterns and relationships in data - an important step along the path to the formal operational level.

While most older elementary children are in the concrete operational stage, you may encounter some who have some formal operational abilities. Children at this level are ready to learn about hypothesis-testing as a way of investigating science questions. They may be able to understand that scientific theories are based upon the results of many experiments, and can be used as the starting points for further experiments.

A number of instructional approaches have built upon the work of Piaget and other researchers. One of the most widely used of these approaches is called the Learning Cycle. There are variations to the steps of the Learning Cycle, but one version consists of these steps:

- **Engaging with a concept**: This is the "grabber" step of the Learning Cycle where you can capture children’s interest about a topic. This can happen with a demonstration, video, interesting samples, cartoon, story, going outdoors, or many other methods. It is important in this step to link the concept to the children’s experiences and knowledge base.

- **Exploring a concept**: One of the best ways of having children explore ideas is by hands-on experiences. If you are teaching about Earth history during your visit, for example, get samples of fossils into the children’s hands as soon as you can. Get them started on asking questions about the fossil samples and looking for patterns and relationships between them.

- **Explaining a concept**: After the children have time to explore, your explanation can help them to focus on the key concepts you want them to understand. This is a good time to let the children ask questions of you and each other, and seek for explanations together.

- **Applying a concept to a new situation**: So that you feel confident that the children you are working with "get it", give them an opportunity to apply their knowledge to a new situation. For example, if you are having them learn to identify a set of minerals, give them a couple of new...
samples to try identifying later in the lesson.

- **Expanding a concept:** This is a "what next" stage. Children think about other questions on the concept they could investigate. This helps them to expand their understanding of the concept. Classroom teachers often use free-standing Learning Centers to enable interested children to explore these "what next" questions.

During a relatively brief classroom visit (45 minutes or so), you may only get to the Explanation Stage of the Learning Cycle. The classroom teacher can then follow up with the later stages. If possible, provide him or her with activities that help children make those "next steps" after your visit. It is important to remember that the steps of the Learning Cycle put into clear and simple language what are really a series of complex intellectual processes for both children and their teachers.

The Learning Cycle is just one research-based approach used in science teaching. The lessons in Chapter 5 use a modified Learning Cycle approach to help students learn science through inquiry. The inquiry aspect of the lessons is based upon the body of research which supports the definition of **inquiry** in the *National Science Education Standards* and in the *Benchmarks for Science Literacy*. Students who learn science through inquiry may begin with their own question to investigate, or someone else's question, but, eventually they need to find answers that:

- Fit with their existing understanding and developmental level
- Make sense
- Are scientifically correct (even if only at a very simple level)
- Help them to understand their world
- Lead to new questions

Note that inquiry is more than just hands-on; good inquiry is "hands-on, minds-on". As a visiting instructional leader, you can both promote and guide the discovery and inquiry process. Rather than answer student questions directly, you can help them find their own answers, which again helps them experience the scientific process.

While hands-on, minds-on experiences are a vital part of the inquiry method, children also need to draw upon the information they can find in books, videos, the Internet, CD-ROMs, magazines, field trips, experts (including you and their teacher), and each other. You can work with the classroom teacher to craft or select experiences for children that allow them to investigate science questions in a rich and supportive atmosphere. This includes giving children time to explore science; as well as giving them access to information technology; interesting items to investigate; opportunities to discuss and share; and the chance to investigate their own questions.
Chapter 3: Earth Science in 21st Century Curricula

Earth Science in the Curriculum - or Not

As someone who is deeply engaged in Earth science, you know how vital the geosciences are to living in today’s world. Students and their parents receive daily reminders in the form of news headlines about natural disasters, energy crises, technological advances, and global climate controversies. No matter who you are, the importance of this discipline is clear.

Yet many educational systems are turning their backs on Earth science. Public schools are dropping Earth science from the curriculum. Geoscience enrollments at higher education institutions are faltering, and some colleges and universities are closing relevant departments. As a result, not only are citizens ill-informed on key issues, but our nation’s economic and geopolitical standing is threatened by a critical lack of expertise in the public and private sectors. Geoscientists are failing to make the case — to students, parents, education officials, and key decision makers — that Earth science ranks among the most important science subjects for young people to study.

Why? Federal mandates, such as the No Child Left Behind (NCLB) legislation, have led public schools to limit the scope of curriculum and instruction. Much of the academic focus has been on subjects (primarily reading and mathematics) that appear on standardized tests. However, in 2007, NCLB mandates that science is to be tested once a year in each of the three grade bands: 3-5, 6-9 and 10-12. This new testing requirement may make school districts more amenable to visiting geoscientists as a resource to both students and teachers, but only if Earth science is considered as much as of a “core science” as biology, chemistry and physics. If your community is like many others, education decision makers may be scaling back or eliminating Earth science offerings.

Maybe your local school principal is discouraging spending classroom time on the subject or your school board is excluding it from the district’s required curriculum. State legislators could be minimizing Earth science content in academic standards and testing and/or nearby colleges and universities could be dismantling geology departments or folding them into other departments that downplay geoscience.

As we write this, some states are increasing the science requirements for high school graduation. For example, Texas has increased the number of years of science classes from three to four. Although no firm decisions have been made, at least this presents an opportunity for a core class that focuses on or includes Earth science. Other states currently have local districts with Earth science courses or components in their curricula. As a whole, however, in most of the United States, students will spend their high school years with little or no exposure to Earth science.

On the other hand, virtually every state requires strong Earth science courses or components in middle school. While this seems like good news, consider that middle school science course vary in depth of content and scientific thinking. Many middle school science teachers, while talented and dedicated, lack formal instruction in Earth science. And 6th grade is a long time ago for most
of us—but it serves us to remember that most adults (and voters), will at best have a middle school level appreciation for Earth science issues.

You, however, can make a difference by becoming involved in your local schools. With your geoscientific expertise and ties to the community, you’re in a perfect position to point out the importance of Earth science to students, teachers, school administrators and parents. To help your efforts, the American Geological Institute has created the Pulse of Earth Science web site (www.agiweb.org/education/statusreports/2007/index.html) with state by state information on the status of Earth science education. Look up the data for your state to see if Earth science is an endangered subject for grades 6 – 12 students. If Earth science is under threat, follow the advice in the Advocacy Guide located at www.agiweb.org/education/statusreports/advocacy/index.html. The guide has information on how educational policy is made, what you can do to influence that policy and what your expected results might be.

Above all, be visible as an enthusiastic and involved representative of the geosciences in your local schools. Bring as much content, critical thinking, and applied analysis as you can when you visit middle school classes (and think of the students as future voters). Write your state and local school boards in support of rigorous Earth science classes as core parts of high school graduation requirements. Remind them of how critical it is for the citizens of your state to understand local Earth resources or geologic hazards. Work with educators to integrate Earth science in classes to cover science standards and prepare for state-wide exams. Do you know your local science frameworks and tests, right?

The National Science Education Standards come from the National Academies of Science. Project 2061, from the American Association for the Advancement of Science, produced two landmark reports: Science for All Americans and Benchmarks for Science Literacy. These provided input to the national science content standards released by the National Research Council in 1996. You can read the contents of the report at a web site hosted by the National Academies Press at http://books.nap.edu/html/nses/html/.

Here are the content standards for K-4 from the National Science Education Standards:

**PROPERTIES OF EARTH MATERIALS**

- Earth materials are solid rocks and soils, water, and the gases of the atmosphere. The varied materials have different physical and chemical properties, which make them useful in different ways, for example, as building materials, as sources of fuel, or for growing the plants we use as food. Earth materials provide many of the resources that humans use.
- Soils have properties of color and texture, capacity to retain water, and ability to support the growth of many kinds of plants, including those in our food supply.
- Fossils provide evidence about the plants and animals that lived long ago and the nature of the environment at that time.

**OBJECTS IN THE SKY**

- The sun, moon, stars, clouds, birds, and airplanes all have properties, locations, and movements that can be observed and described.
- The sun provides the light and heat necessary to maintain the temperature of the Earth.

**CHANGES IN THE EARTH AND SKY**

- The surface of the Earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and Earthquakes.
- Weather changes from day to day and over the seasons. Weather can be described by measurable quantities, such as temperature, wind direction and speed, and precipitation.
Chapter 3: Earth Science in 21st Century Curricula

- Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The moon moves across the sky on a daily basis much like the sun. The observable shape of the moon changes from day to day in a cycle that lasts about a month.

Here are the content standards for 5-8:

**STRUCTURE OF THE EARTH SYSTEM**
- The solid Earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core.
- Lithospheric plates on the scales of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as Earthquakes, volcanic eruptions, and mountain building, result from these plate motions. ([www.nap.edu/readingroom/books/neses/html/6d.html#csf58](http://www.nap.edu/readingroom/books/neses/html/6d.html#csf58))
- Land forms are the result of a combination of constructive and destructive forces. Constructive forces include crustal deformation, volcanic eruption, and deposition of sediment, while destructive forces include weathering and erosion.
- Some changes in the solid Earth can be described as the "rock cycle." Old rocks at the Earth's surface weather, forming sediments that are buried, then compacted, heated, and often recrystallized into new rock. Eventually, those new rocks may be brought to the surface by the forces that drive plate motions, and the rock cycle continues.
- Soil consists of weathered rocks and decomposed organic material from dead plants, animals, and bacteria. Soils are often found in layers, with each having a different chemical composition and texture.
- Water, which covers the majority of the Earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from the Earth's surface, rises and cools as it moves to higher elevations, condenses as rain or snow, and falls to the surface where it collects in lakes, oceans, soil, and in rocks underground.
- Water is a solvent. As it passes through the water cycle it dissolves minerals and gases and carries them to the oceans.
- The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has different properties at different elevations.
- Clouds, formed by the condensation of water vapor, affect weather and climate.
- Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate, because water in the oceans holds a large amount of heat.
- Living organisms have played many roles in the Earth system, including affecting the composition of the atmosphere, producing some types of rocks, and contributing to the weathering of rocks.

**EARTH'S HISTORY**
- The Earth processes we see today, including erosion, movement of lithospheric plates, and changes in atmospheric composition, are similar to those that occurred in the past. Earth history is also influenced by occasional catastrophes, such as the impact of an asteroid or comet.
- Fossils provide important evidence of how life and environmental conditions have changed. ([www.nap.edu/readingroom/books/neses/html/6d.html#csc58](http://www.nap.edu/readingroom/books/neses/html/6d.html#csc58))

**EARTH IN THE SOLAR SYSTEM**
- The Earth is the third planet from the sun in a system that includes the moon, the sun, eight other planets and their moons, and smaller objects, such as asteroids and comets. The sun, an average star, is the central and largest body in the solar system. ([www.nap.edu/readingroom/books/neses/html/6b.html](http://www.nap.edu/readingroom/books/neses/html/6b.html))

American Association of Petroleum Geologists and The American Geological Institute
The Geoscience Professional's Science Enrichment Handbook
Most objects in the solar system are in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses. Gravity is the force that keeps planets in orbit around the sun and governs the rest of the motion in the solar system. Gravity alone holds us to the Earth's surface and explains the phenomena of the tides. The sun is the major source of energy for phenomena on the Earth's surface, such as growth of plants, winds, ocean currents, and the water cycle. Seasons result from variations in the amount of the sun's energy hitting the surface, due to the tilt of the Earth's rotation on its axis and the length of the day.

And finally, here are the content standards for grades 9-12:

**ENERGY IN THE EARTH SYSTEM**

- Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the Earth's original formation.
- The outward transfer of Earth's internal heat drives convection circulation in the mantle that propels the plates comprising Earth's surface across the face of the globe. (www.nap.edu/readingroom/books/neses/html/6e.html#csb912)
- Heating of Earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.
- Global climate is determined by energy transfer from the sun at and near the Earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the Earth's rotation, and static conditions such as the position of mountain ranges and oceans.

**GEOCHEMICAL CYCLES**

- The Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid Earth, oceans, atmosphere, and organisms as part of geochemical cycles.
- Movement of matter between reservoirs is driven by the Earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.

**THE ORIGIN AND EVOLUTION OF THE EARTH SYSTEM**

- The sun, the Earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. The early Earth was very different from the planet we live on today.
- Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed.
- Interactions among the solid Earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the Earth system. We can observe some changes such as Earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years.
- Evidence for one-celled forms of life—the bacteria—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the Earth's atmosphere, which did not originally contain oxygen.

**THE ORIGIN AND EVOLUTION OF THE UNIVERSE**

- The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a
hot dense state; according to this theory, the universe has been expanding ever since.
(www.nap.edu/readingroom/books/nses/html/6e.html#csa912 )

- Early in the history of the universe, matter, primarily the light atoms hydrogen and helium,
clumped together by gravitational attraction to form countless trillions of stars. Billions of
galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of
the visible mass in the universe.
- Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium.
  These and other processes in stars have led to the formation of all the other elements.

However, these are just the content standards. Each grade level also includes standards for
inquiry, understanding relevant or enabling technology, social contexts, and how different
sciences (and other academic disciplines) integrate. The more familiar you are with these
standards and with the science frameworks established by your state and local school district, the
more effective you can be in helping teachers meet required goals.

Finally, just by being in the classroom you demonstrate how rewarding an interest and even a
career in Earth science can be, and inspire students to reach beyond any curriculum limits.
Chapter 4: How to Get Into (and Out Of) the Classroom

This section will provide you with step-by-step advice for how to contact teachers, plan appropriate and worthwhile experiences for students, and carry these out in the classroom. More detailed information on specific activities is in Chapter 5.

Get Ready.

1. Contact the teacher well in advance.

You can make contact with teachers in a number of ways. You might have a child or grandchild in the school, have been a science fair judge, know the principal or science supervisor, or have a relationship already established with the school system by your company, survey or university.

If you have none of these, you might find it easiest to make contact through your school system’s supervisor of science (usually based at the District office or Board of Education). Once you have made contact, be sure to set up a meeting with the teacher at least a month in advance of your visit.

2. Meet with the teacher to plan your visit.

It’s always a good idea to meet with the teacher in his or her classroom, either after school or during a planning period (usually about a 45-minute time slot). That gives you a chance to find out the following essential information:

- How much time will you have?
- How early should you arrive to set up?
- How many and what type of students will you be addressing?
- Do students usually work in groups, pairs or as individuals?
- Will they have name badges or name tents?
- What is the classroom setting like (tables and chairs, desks, lab tables)?
- What should the science topic(s) be and what curriculum, if any, are the students using?
- What immediate and long-term curriculum goals does the teacher have for this section (and what framework goals)?
- What science equipment, water and electricity are available?
- What are the science safety rules?
- What are the school safety rules?
- What AV you can use, or bring with you?
- What are the school dress code requirements?
- Where should you park? (Avoid bus loading zones!)
- Where should you go when you enter the school to sign in? (Many schools now require visitors to show ID and to wear badges during their visits.)
- What is the teacher’s contact information in case of emergencies, especially his or her cell phone number (leave your contact information as well, including your cell phone).

You can also plan your respective roles during your visit. One way to divide this up is that the teacher is responsible for classroom management and you are responsible for the
Chapter 4: How to Get Into (and Out Of) the Classroom

lesson delivery. You may also want to co-teach. The teacher could introduce your concept and you take over from there. No matter which way you plan the visit, the teacher should always be in charge of managing the students and should not leave the room with you in charge. He or she has a legal responsibility for the students.

You might also find the opportunity to help a curious teacher learn more background material, and start a long-term relationship about Earth science.

3. Start slowly!

If you have never made a presentation that includes a hands-on investigation to a school audience before, you might want to start with just one class – preferably a class of very highly motivated students. Once you get your “sea legs,” you can plan for lengthier visits with a wider range of students.

4. Plan your presentation.

From your visit with the teacher, you should be able to tailor an experience for the students that fits with their curriculum, is exciting, draws upon your expertise and leaves them wanting you to return. Students will really like hearing stories about your work, as long as you keep these pretty short. If you use a PowerPoint presentation, make sure that you keep the vocabulary on the students’ level and keep to very few slides. Use LOTS of photographs, include helpful diagrams, and even cartoons if they can best illustrate ideas you are presenting.

Chapter 5 of this handbook has lesson plans and investigations that fit a variety of geoscience topics. Additional investigations are on the AGI web site at www.Earthsciweek.org/forteachers/classroomactivities.html. Be sure to allot time for introductions, any AV pieces you have, distribution and collection of materials, investigations and questions and answers. Most class periods are 45 minutes and the time really does fly. If possible, try to visit during a double period in grades 6 – 12, if these exist in the school. Also, self-contained elementary teachers often have more flexibility in scheduling their days than middle or high school teachers do. Here’s a skeleton of what your visit could include (just one example):

- **Step 1:** Introduce yourself and explain what you do – be enthusiastic!

- **Step 2:** Show any tools of your trade, if you brought these along.

- **Step 3:** If you’re doing an investigation, let students know that up front. They’ll be more attentive if they know they are going to be handling “real stuff.”

- **Step 4:** Show a short video (AGI’s *Why Earth Science?* DVD, which is included in this Handbook) or a PowerPoint presentation about what geologists do in general, or what you do in particular.

- **Step 5:** If you’re using a handout with an investigation, give it out and walk through it with the students. (Make sure you have enough for everyone.)

- **Step 6:** With the help of the teacher and/or a colleague, hand out materials.

- **Step 7:** Give students enough guidance to get them started, and then walk around to observe and help. Watch the time, so you can budget for clean up and questions.
Chapter 4: How to Get Into (and Out Of) the Classroom

- **Step 8:** Answer students’ questions.
- **Step 9:** Leave giveaways with the teacher.
- **Step 10:** Thank the students for the opportunity to share your experiences (this always gets a round of applause).

When you finish planning your presentation, run it by the teacher for his or her input. This gives the teacher the opportunity to set the scene for you by having students draft questions or do some research prior to your visit. It also helps the teacher to fine-tune your presentation to fit the needs of the students. For example, you might find that your vocabulary is too sophisticated or too simple for your audience.

5. **Practice your presentation.**

If you have the time, do a trial run of your presentation in front of the teacher you are visiting, or your colleagues, family or friends. Time what you do and adjust your plan if necessary. It’s easy to underestimate time passing when you are talking to students. This is especially important if you are planning on using audiovisual support or including a hands-on investigation. Although your investigation may seem very simple, it always pays to try it out ahead of time yourself. You may find that the directions, as written, can be confusing or that it takes much longer than you thought to collect and record data.

6. **Think about bringing a colleague to help.**

Although you will have the classroom teacher available to help, when handing out materials and papers, you will be grateful for extra hands. If you can, bring a younger colleague to assist you. It’s important that students meet as many role models as possible, and they will enjoy interacting with scientists in many stages of their careers.

7. **During your visit.**

Although it is the teacher’s responsibility to manage the students, it still helps to know some classroom management techniques yourself.

- **Getting the class’ attention.** Ask the teacher what technique he or she uses to get the whole class’ attention. For example, some teachers in elementary school start counting out loud and the students are expected to be quiet by the count of three. Other teachers start clapping their hands and the students join in and then stop after three claps. Middle school teachers sometimes use what are called “signals” – they hold up a hand sign something like the Boy Scout salute. The students follow suit until everyone is focused on the teacher. High school teachers have been known to flick the light switch for the room. The whole idea is to capture the students’ attention for long enough to bring their eyes back to you.

- **Managing materials and handout distribution.** Enlist the help of the teacher or a colleague to hand out materials to students when you are ready for start using them. It’s hard for students, especially in the earlier grades, to keep from handling materials as soon as they arrive, so plan accordingly. In Chapter 5, there are a number of suggestions for how to organize materials for each investigation, such as using baggies, shoe boxes, etc. Be sure to allot enough time at the end of your visit to re-organize materials and pick them up from the students. Most students from middle elementary on up will clean up for you if you ask them.

- **Managing questions and answers.** Before you arrive, ask the teacher if the students can have name tents (for younger students) or name badges (for older
students). Just knowing a students’ first name makes question and answer sessions a lot more personal to the students and easier for you to manage. When you ask a question during your visit, make it a point to call on a different student each time. This rule also works when students are asking you questions at the end of your visit. Try to be as accepting of students’ ideas as you can. Use phrases like “That’s a very interesting idea. Does anyone have another idea to share?” Saying things like “No, that’s not right.” stops interaction and makes the students nervous about volunteering information.

- **Managing safety.** It is imperative that you clear in advance with the teacher what you are planning to do and bring. For example, if you are planning on bringing a rock hammer to hand around to students, the teacher might see this as inadvisable. There might be no problem, however, with demonstrating how to use the hammer yourself.

- **Behavior problems.** Be sure that you arrange with the teacher that he or she will be responsible for any problems with student behavior. You don’t want to be in a situation where a couple of students start punching one another and the teacher leaves you in charge of the class to take the students to the principal. In cases like this, teachers should call for a member of the administration to come to them, or have a colleague cover their class briefly.

8. **Follow up with the teacher after your visit.**

   Either in person, or via telephone or e-mail, contact the teacher to find out what worked and what didn’t in your visit. Adjust your presentation accordingly for your next visit.

9. **Evaluate your own experience.**

   Reflect on your school and classroom visit. Think about how you felt at different times during your visit such as, interacting with the teacher, facing your audience of students, making a presentation to them, getting them started on your chosen activity, monitoring how they were working, talking to individual students, answering questions and how the event came to a close. If this was your first time, what experience have you now had that has allayed your former apprehensions? What surprised you that you will need to address before your next visit? What did you feel really good about? What did you learn not to do next time? Make a few notes about these things to keep in mind for future visits.

10. **Additional things you could do to help students in the school**

    Your visit to a school is a chance to gauge other ways in which you may be able to help teachers and students and the school. For example, you may notice that they lack resources or equipment that you could help provide. Maybe there are resources from your own workplace that you no longer need, but could still be useful to a school. You may also be able to offer teachers and students the chance to visit your workplace or other venue that links with their studies. You can suggest other professionals who could visit the class. Many schools struggle for resources and opportunities to provide students with real-world experiences. You can certainly offer advice. Be alert for opportunities to help them where you can.

11. **Plan for your next visit soon**

    Don’t let too much time go by until you do it again! The more often you contribute in this way, the better you will become at delivering exciting and important experiences to teachers and students. Think of it this way. There’s a real chance that something you say or do may be the beginning of a whole new world of possibilities for a student. Most of us
were inspired by someone in our past: teacher, family member; friend; social leader; hero; or a chance encounter with a stranger. You'll probably never know, but you could be that person.

The Big Day
With all the preparation and planning outlined above, you should be ready and eager to meet the students face to face. So, like you planned, arrive early, get checked in at the front office, and bring your materials to the right place.

You will be a curious distraction as soon as students notice you. If you have some time to wait, you can prime their curiosity with hints about the activity. If you need help setting up, you might ask for volunteers to hand out materials, re-arrange chairs, etc.

Once things get going, be as confident and comfortable as you can. You can break the ice by having the students talk a bit first. Ask the class some questions about the topics in the activity or related material they have covered in recent class work. You can then guide the discussion toward the issues on which you hope to focus. Don't be afraid to call on the teacher, too.

Always try for a positive, open-minded flavor in the discussions. Promote inquiry and self discovery, of both questions and answers. You may need to bring the focus back to the key issues, but remember those off-topic questions for future visits. And don't be afraid to admit that you don't know all the answers. You can best represent science by showing how un-answered questions can provide the motivation for new research.

At any grade level, you may encounter challenging or even controversial situations. Questions about the age of the Earth, the origin of species, the environmental impacts of resource development, and other touchy topics can put you in the hot seat. You will have to decide for yourself how to answer, but avoid telling students that a particular view or belief is wrong. You can try to narrow the discussion to what physical data and scientific analysis might conclude, and decline to offer philosophical or political opinion. More than one teacher has deflected religious issues by telling students they can be “fired” by breaking school rules.

Afterward and Follow-up
Most of us find the enrichment experience inspirational. As many have said before, you do not truly understand something until you have to explain it (and even more so when the target audience is a class of 4th grade students). You almost certainly will have learned some new ways of viewing the material you covered, and encountered some questions that you could not answer.

Try to solicit feedback from the teacher, and from students in higher grade levels. Don’t be surprised if you get invited back for other topics, or to return next year. Some teachers may nominate you for science club contacts, school or district-wide science committees, or other opportunities. On the other hand, don’t be too surprised if you don’t hear from the teacher, at least right away, since teachers are some of the busiest professionals. You might initiate the follow-up discussion, especially if you promised any more materials or information during your visit.

More than anything else, know that you have made a positive difference. The students and teachers you met gained new knowledge available only from you. They met a role model that might influence future studies and career choices. They saw how science can applied with their own hands and minds. And at least for a brief time, you were part of the inspiration and development of young minds. We hope you enjoyed it!
Chapter 5: Investigations for Different Age Levels

Chapter 5 contains a set of sample Earth science investigations that are suitable for various age levels. Each investigation comes with a materials list, directions, tips on preparation, safety information and handouts for students. There are additional investigations on the AAPG YEA web site at www.aapg.org/k12resources/index.cfm, as well as the AGI Education and Outreach web sites at www.Earthsciweek.org/forteachers/classroomactivities.html (Earth Science Week investigations) and www.k5geosource.org/activities/invest/index.html (K-5 GeoSource investigations). AGI will continue to develop activities for this handbook, which you can download from the AGI professional development web site and add to the book.

<table>
<thead>
<tr>
<th>Investigation</th>
<th>Grade Level</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Identifying Minerals</td>
<td>3-6</td>
<td>25</td>
</tr>
<tr>
<td>Dinosaur Footprints</td>
<td>3-9</td>
<td>32</td>
</tr>
<tr>
<td>Fossils and Ancient Environments</td>
<td>5-8</td>
<td>35</td>
</tr>
<tr>
<td>Earthquake Waves</td>
<td>4-8</td>
<td>39</td>
</tr>
<tr>
<td>Finding the Epicenter of an Earthquake</td>
<td>7-12</td>
<td>42</td>
</tr>
<tr>
<td>Testing Soil Samples</td>
<td>4-8</td>
<td>49</td>
</tr>
<tr>
<td>Cookie Dig</td>
<td>K-5</td>
<td>52</td>
</tr>
<tr>
<td>How Does the Rock Cycle Work?</td>
<td>3-6</td>
<td>58</td>
</tr>
<tr>
<td>Evolution of Dinosaurs</td>
<td>K-3</td>
<td>62</td>
</tr>
<tr>
<td>The Soil Detective Challenge</td>
<td>3-6</td>
<td>66</td>
</tr>
<tr>
<td>Thinking About Systems</td>
<td>3-12</td>
<td>69</td>
</tr>
<tr>
<td>An Introduction to Earth Systems</td>
<td>4-12</td>
<td>71</td>
</tr>
<tr>
<td>Building and Testing Earthquake-Resistant</td>
<td>4-8</td>
<td>75</td>
</tr>
<tr>
<td>Structures</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Modeling Convection</td>
<td>6-12</td>
<td>79</td>
</tr>
</tbody>
</table>
Identifying Minerals

Grades 3 - 6

Lesson time:
45 minutes (including introduction and clean-up)

Objective:
Students will be able to:
• Identify minerals according to physical properties by using color, luster, Moh’s hardness scale, the streak test and an identification sheet.

Materials:
Provide students, in groups of four, with the following:
• 1 Sample Bag of seven numbered minerals: 1. calcite, 2. feldspar, 3. kaolinite, 4. biotite mica, 5. hematite, 6. galena, and 7. graphite
• 1 Tool Bag with 1 unglazed porcelain tile (approx 10 cm X 10 cm); 1 copper penny; 1 glass plate (approx 10 cm X 10 cm); 1 steel nail; 4 hand lenses
• 1 pen or pencil to record observations
• 1 Observation Sheet per student (included below)
• 1 copy of the Mohs’ Mineral Hardness Scale per student (included below)
• 1 copy of the Mineral Identification sheet per student (included below)

Purpose:
It is important that your students begin to understand that rocks are made of minerals. Different rocks have different characteristics because of their minerals, the ways in which the rocks were formed, and the processes that acted on the rocks since they were formed. In this investigation students will understand how geoscientists identify minerals by color, luster, and tests for streak and hardness.

Safety:
This investigation is considered generally safe to do with students. However, please review it for the specific setting, materials, students, and conventional safety precautions.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period, as well as how many copies of handouts and sets of materials you need to bring. Alert the teacher that this investigation is set up for groups of four.
2. Collect all the materials in the list below and organize them into one Tool Bag for each group of four students (zip-closing baggie with 4 hand lenses, 1 porcelain tile, 1 nail, 1 copper penny and 1 glass plate) and one Sample Bag per group (zip-closing baggie with 7 numbered mineral samples in each)
3. Make photocopies of the handouts. Collect any giveaways for the students, such as mineral samples or mineral posters.
4. Run through the investigation yourself and record the data, just to see how long it takes. Adjust the timing to the class period, remembering that you will need time to introduce the investigation, clean up afterwards and re-set up for the next class (if you are working with more than one class). You can reduce the amount of time this investigation takes by cutting the number of mineral samples down and eliminating the hardness test.

Investigation Question:
How do you identify minerals by their physical properties?

What to Do:
1. (5 minutes) Introduce the idea of minerals by asking students what minerals they have on them (or in them!) Take all responses, and ask students why they think that knowing how to identify different minerals could be important. Again, accept all responses. Let students know that they will be using some of the same techniques that geoscientists use to identify different mineral samples.
2. (10 minutes) Work with the teacher to hand out the Sample Bags. Ask students to take the samples out of the bags and take turns examining each one. Give them a few minutes to do this, and then ask them to group the minerals in any way that seems to make sense to them. Take volunteers from each group to explain why they grouped the minerals.
the way they did.

3. **(10 minutes)** With the teacher’s help, hand out the Observation Sheets, the Moh’s Hardness Scale, the Mineral Identification Sheets and the Tool Bags. Explain that the way that geoscientists identify minerals by color, luster, streak and hardness is a bit like detective work. The students will need to find clues, through their observations, of what each of the minerals are. Demonstrate how to streak the minerals and how to do the hardness test. Walk the students through the Moh’s Hardness Scale handout and the Observation Sheet.

4. **(10 minutes)** Direct the students to take turns using the tools and the different mineral samples. As they make their observations and tests, they should record these data on their observation sheets. When they finish, ask them to compare their data to the Mineral Identification Sheet to find out the names of the mineral samples.

5. **(5 minutes)** When everyone is finished, hold up each mineral sample and ask groups to tell what they think it is and why. [Answer key is included with this investigation.] Be sure to accept all student responses. Questions you might ask include:
   - Which clues worked best to identify your minerals? (*Students usually find the streak test and color the easiest to interpret.*)
   - Which clues weren’t very useful? Why is that? (*Many students have trouble interpreting the hardness test and younger students are unfamiliar with the term “luster.”*)

6. **(5 minutes)** Ask students to put the samples and tools into their separate bags. Collect all the materials for the next class. Thank the students for their time and attention. (If you have giveaways, you can leave them for the teacher to distribute to save time.)
Chapter 5: Investigations for Different Age Levels

Mineral Identification:

**Calcite:**
Hardness-3.0
Luster-glassy
Streak-white
Color-colorless, white, pink, yellow, or brown.

**Feldspar:**
Hardness-6.0
Luster-Glassy
Streak- white
Color- green, pink, gray, cream

**Kaolinite:**
Hardness-1.5
Luster-dull
Streak-white
Color-white, grayish white, yellowish white

**Biotite Mica:**
Hardness-2.5
Luster-pearly
Streak-very faint gray
Color-dark brown, black

**Hematite:**
Hardness-6.5
Luster-metallic
Streak-reddish brown
Color-reddish gray, black, blackish red

**Galena:**
Hardness-2.5
Luster-metallic
Streak-grayish black
Color- light to dark gray

**Graphite:**
Hardness-1.5
Luster-semi metallic
Streak-black
Color-black, dark gray,
Moh’s Mineral Hardness Scale

<table>
<thead>
<tr>
<th>Hardness</th>
<th>Mineral</th>
<th>Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Talc</td>
<td>---</td>
</tr>
<tr>
<td>2</td>
<td>Gypsum</td>
<td>Finger nail is 2.5</td>
</tr>
<tr>
<td>3</td>
<td>Calcite</td>
<td>Copper penny is 3.5</td>
</tr>
<tr>
<td>4</td>
<td>Fluorite</td>
<td>---</td>
</tr>
<tr>
<td>5</td>
<td>Apatite</td>
<td>Glass is 5.5</td>
</tr>
<tr>
<td>6</td>
<td>Feldspar</td>
<td>Steel nail is 6.5</td>
</tr>
<tr>
<td>7</td>
<td>Quartz</td>
<td>---</td>
</tr>
<tr>
<td>8</td>
<td>Topaz</td>
<td>---</td>
</tr>
<tr>
<td>9</td>
<td>Corundum</td>
<td>---</td>
</tr>
<tr>
<td>10</td>
<td>Diamond</td>
<td>This is the Hardest Mineral</td>
</tr>
</tbody>
</table>

Mohs’ Mineral Hardness Scale was established in 1812 by the German mineralologist, Friedrich Mohs. The hardness of a mineral is determined by whether its surface is scratched by a substance of known or defined hardness.
Observation Sheet

Mineral Identification

Identify each mineral based on its color, luster, streak, and hardness.

**Mineral Sample 1:**

Color-
Luster-
Streak-
Hardness-

*Mineral Name:*

**Mineral Sample 2:**

Color-
Luster-
Streak-
Hardness-

*Mineral Name:*

**Mineral Sample 3:**

Color-
Luster-
Streak-
Hardness-

*Mineral Name:*
Chapter 5: Investigations for Different Age Levels

**Mineral Sample 4:**
Color-
Luster-
Streak-
Hardness-
*Mineral Name:*

---

**Mineral Sample 5:**
Color-
Luster-
Streak-
Hardness-
*Mineral Name:*

---

**Mineral Sample 6:**
Color-
Luster-
Streak-
Hardness-
*Mineral Name:*

---

**Mineral Sample 7:**
Color-
Luster-
Streak-
Hardness-
*Mineral Name:*
Mineral Sample Answer Key

Answer Key:

Mineral 1: Kaolinite
Mineral 2: Graphite
Mineral 3: Biotite Mica
Mineral 4: Calcite
Mineral 5: Feldspar
Mineral 6: Galena
Mineral 7: Hematite
Dinosaur Footprints

Grades 3 – 9

Lesson time:
45 minutes

Objective:
Students will be able to:
• Investigate how scientific knowledge changes due to differing viewpoints and additional data by making observations and developing scientific explanations on a set of footprints.

Materials
For instructional purposes:
• Overhead transparency of the Footprints Puzzle handout (below)
• Paper and pencils for students to record their thoughts and predictions
• Plaster of Paris or clay footprints in shoeboxes

Purpose:
Trace fossils, which are physical evidence of life activities of now vanished organisms, are more prevalent than body (bones) fossils. One organism can leave behind many traces (e.g. footprints), but only one set of hard parts (e.g. bones) actually becomes a fossil. Trace fossils include tracks, trails, burrows, feeding marks, and resting marks. Trace fossils are valuable to paleontologists, because they can tell us more about the behavior of the ancient organisms.

The purpose of this investigation is to give the students the opportunity to describe what they see, and to use evidence and logical reasoning to support an explanation. They will be able to duplicate the experience of paleontologists, who make observations and use these observations as evidence to develop scientific explanations about what the behavior of ancient organisms. They will learn that, as scientists learn new things and make more observations, their explanations often change.

Safety:
This investigation is considered safe to do with students.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period. Alert the teacher that this investigation is set up for groups of four and whole class discussion. You will also need to arrange for an overhead projector and screen.
2. Make a plaster of Paris or clay imprint of a couple of different-sized footprints in two shoeboxes to bring to the class. You could use a man’s shoe and a woman’s high heel; two different sizes of bare feet; or a flip flop and a tennis shoe. These will be “grabbers” to start your discussion about footprints as evidence.
4. Collect any giveaways for the students, such as fossil posters or geologic time bookmarks.

Investigation Question:
How do additional data and different viewpoints change explanations?

What to Do:
1. (10 minutes) Hold up the first footprint in the shoebox so that everyone can see. Be sure to accept as many explanations as you can. Some questions you might ask include:
   • What can you tell about the person who made this footprint by just looking at it? (Show them the second footprint.)
   • What can you tell me about who made this footprint? How is it different from the first one?.
2. (2 minutes) Tell students that scientists use footprints and other visual
Chapter 5: Investigations for Different Age Levels

data to make inferences about events. This is the job of detectives and forensic specialists as well. Let them know that today, they will be using footprint data as scientists do to try to infer what happened in the past.

3. **(8 minutes)** Put the Dinosaur Footprint transparency on the overhead projector, covering up Positions 2 and 3 with a piece of paper. Ask students: “What do you think is happening here?” Let students talk this over in their small groups for a few minutes, and then ask them to share their thoughts. Be sure to accept as many explanations as you can. Some questions you can ask the students during the discussion are:
   - How many animals do you think this picture shows? What is your evidence for that?
   - In which direction are the animals moving? How do you know?
   - Do you think these animals are the same size? Why or why not?

4. What do you think will happen next, and why? Write down your predictions. **(8 minutes)** Now, show students Positions 1 and 2 on the transparency. Again, ask them to discuss this in their small groups for a few minutes and then ask for their thoughts. Be sure to accept as many explanations as you can. Questions that could help during the discussion include:
   - What do you think happened here? What is your evidence for that?
   - What do you think will happen next, and why? Write down your predictions.

5. **(8 minutes)** Finally, show all three positions on the transparency and ask students to think again about what might have happened. Let them share their thoughts and their reasons for those thoughts. Were their predictions accurate?

6. **(7 minutes)** Ask students why they thought there were so many different explanations for what happened. For older students, ask them what additional evidence they could collect that would help them to be more certain about their explanations [dating procedures, etc.] Let students know that scientific knowledge is constantly changing for many reasons. Sometimes new data are collected that result in changes in explanations or new techniques are developed that allow scientists to learn more about existing data. Other times, different scientists interpret the same data differently.

7. **(2 minutes).** Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Chapter 5: Investigations for Different Age Levels

Footprint Puzzle
Chapter 5: Investigations for Different Age Levels

Fossils and Ancient Environments

Grades 5 – 8

Lesson time:
60 - 90 minutes

Objective:
Students will be able to:
- Relate characteristics of individual fossils and fossil assemblages to probable living environments by investigating fossils and applying their interpretation to models of past Earth conditions that might be very different from present day at any given location.

Materials:
Provide each group of four with the following:
- Fossil kits: these should be sets of 2 or 3 fossil animals or plants that came from the same paleo-environments. Fossil shells and invertebrates in sandstone from beach/shoreface; leaf imprints and wood fragments in coal rich silts from swamps; ammonites and fish in shales from open marine; etc. (or you can order fossil kits here: http://www.educationalfossils.com/fossilkits.htm)
- Hand lenses or magnifiers
- Rulers
- Modern Environment Examples

For individual students
- Observation sheet

For instructional purposes:
- (Optional) Video or image of Geerat Vermeij from: http://www.pbs.org/kcet/shapeoflife/episodes/surv_explo1.html

Purpose:
Fossils give us an amazing picture of past life on Earth, because they are evidence of living things from long ago. Fossils can tell us about the living conditions, or environments, of ancient times. In this investigation, students will explore a set of fossils to determine the living conditions of the ancient life.

Safety:
This investigation is considered safe to do with students. However, consider the contents of your individual sample kits for potential hazards.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period. Alert the teacher that this investigation is set up for groups of four and whole class discussion. You will also need to arrange for an overhead or digital projector and screen.
2. Gather the fossil sets and supplemental data as described in the materials section. Make sure you have enough supplies for each group. Contact the teacher to find out how many student groups are in the class.
3. Duplicate the observation sheet. Contact the teacher to find out how many copies you need to make.
4. Collect any giveaways for the students, such as fossil posters or geologic time bookmarks.
5. Make an overhead copy of the Modern Environment Examples found below.

Investigation Question:
What can fossils tell us about ancient life and ancient environments?

What to Do:
1. (5 minutes) Introduce students to the concept of fossils by either sharing the story of Geerat Vermeij or sharing some of your experiences as a paleontologist. If you decided to share your story about being a paleontologist, keep it short and be sure to point out how you make observations and collect data. The story about Geerat Vermeij is below:
   - Geerat (pronounced Gary) Vermeij (pronounced ver-may) is a scientist who studies Earth’s past life. He is an expert on mollusk fossils, and studies them by collecting evidence through his fingers. Because Geerat has been blind since childhood, he has become more dependent on his other senses, particularly touch. With his sense of touch, Geerat learns about a mollusk’s shell through its curves, chips, spiral growth and ridgelines.
   - Share the little video clip on Geerat Vermeij from PBS. Please note that the video clip is about 3 min long and your computer
Chapter 5: Investigations for Different Age Levels

- Modern Environment Examples (make an overhead of this)
- Flip chart or blackboard and markers

would need Real Player to use it:

2. **(5 minutes)** Discuss the many ways scientists collect and record data to understand past Earth conditions. Be sure to accept as many explanations as you can. Questions you might ask:
   - How does Geerat Vermeij make observations about mollusks? *(Record responses on a flip chart or board.)*
   - What can Geerat Vermeij’s observations about mollusk shells tell us about mollusks? Could you make similar observations about fossils? *(Record responses on a flip chart or board.)*

3. **(20 minutes)** Explain to the students that, in their student groups, they will use the hand lenses or magnifiers and their senses to make observations about the fossils to find clues about what kind of life the fossil represents. Stress that students will need to use their senses, particularly touch and sight, to look for clues. Distribute the fossil kits to each team. Tell students that the fossil kits are all different, so there will be many different interpretations on the fossils. Encourage teams to first collect observations and then make interpretations.

4. **(10 minutes)** Pass out observation sheets to all the students and have students pick one fossil from their fossil kits and draw a picture of it on their observation sheet.

5. **(10-20 minutes)** Show the Model Environment Examples overhead. Inform students that modern living things may help provide insights into paleo-environments. Instruct student groups to pick a fossil and draw a picture of the environment their fossil lived in on their observation sheet. Visit with individual teams and ask them about their interpretations and evidence.

6. **(5-10 minutes)** Have each team prepare to present their fossil and its environment. Tell them they will need to describe their observations and explain what evidence they used to justify their paleo-environment interpretation.

7. **(10-20 minutes)** Provide each team with 2-3 minutes to present their results, with another 1-2 minutes for a question from the rest of the class (remind the class that as scientists, they are peers that help improve the investigation). Be sure to provide each team with positive feedback.

8. **(2 minutes)** Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Investigating Fossils and Ancient Environments
Observation Sheet

Step 1: Pick one fossil and draw a picture of it.

Step 2: Draw a picture of the type of living environment your group’s chosen fossil. What about your fossil made you think it lived in this environment?
Modern Environment Examples

- Muddy, shallow water
- Swamp
- Fish, sandy bottom
- Fish, coral reef
- Rocky beach
- Nautilus, open water
Earthquake Waves

Grades 4–8

Lesson time:
30 - 40 minutes

Objective:
Students will be able to:
• Understand the significance of different seismic waves by recognizing how they move

Materials:
For instructional purposes:
• Stopwatch
• Photos of Earthquakes (these could be made into a PowerPoint or overhead transparency depending on the technology requirements of the classroom)
• Whiteboard or flip chart and markers
• See-through bin filled with water
• Metal weight or coin
• Overhead projector and screen

Purpose:
Earthquakes are exciting and dangerous, and many Earth scientists try to determine the risks they pose to people. In fact, earthquakes are one of the most costly natural hazards faced by the United States, posing a significant risk to 75 million Americans in 39 States. Earthquakes occur every day. It is important to study earthquakes so that you can learn how to minimize risks to the damaging effects caused by an earthquake. In this investigation, students will learn about the significance of the different waves and how seismographers work.

Safety:
This investigation is considered safe to do with students. Be prepared for some horseplay during the human seismic wave simulation.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period. Alert the teacher that this investigation requires a long open area for students to line up and will create a modest amount of noise.
2. Find out the technology requirements for the classroom and create either a PowerPoint or overhead transparency of the Photos of Earthquakes.
3. Collect any giveaways for the students, such as plate tectonics or earthquake posters.

Investigation Question:
How are earthquakes detected?

What to Do:
1. (5 minutes) Prompt a small discussion about earthquakes by starting a demonstration on waves. Put the water-filled bin on the overhead projector and turn the projector on. Ask students to watch what happens when you drop a metal weight into a bin of water. Be sure to accept as many explanations as you can. Questions you might ask the students:
   • What happened to the surface of the water? (Student responses should reflect how the water rippled like waves when the weight was dropped.)
   • What did it sound like? (Student responses will vary.)
   • If you were on the surface of the water when the weight fell in, what would it feel like? (Student responses will vary.)
2. (2-3 minutes) Share the Photos of Earthquakes. Be sure to accept as many explanations as you can and record the responses on a flip chart or board. Some questions you could use are:
   • What would you expect to see, hear, and feel in an earthquake?
   • What caused these earthquakes?
Chapter 5: Investigations for Different Age Levels

3. **(2-3 minutes)** Explain to the students that earthquakes are the result of a sudden release of energy in the Earth’s crust. This energy creates waves similar to the ones created by the metal weight when it hit the water, called **seismic waves**. These waves spread out in all directions from where the **focus**, or place within the Earth’s crust where the sudden release of energy first occurred. There are many different types of seismic waves which students will explore through a simulation.

4. **(10-20 minutes)** Start the simulation.
   - Ask the students to line up shoulder to shoulder in a line. Have them stand close enough to touch shoulders. (Another option is to have students stand in a circle, so that they will be able to see the waves as they move.)
   - Inform students that you will send a different wave through the line to see how quickly each type of wave moves.
   - Explain to students that you are going to send a “surface wave” down the line. *(Write this wave on the board or flip chart.)* This will be done by pushing down on the shoulder of the first student, who will then bend his/her knees and return to standing. The adjacent student can duck down only when s/he feels his/her neighbor move. *(Have the teacher time how long the wave takes to travel down the line. Have the teacher record the time on the board or flip chart.)*
   - Next, explain to students that you will send a shear (S) wave down the line. *(Write this wave on the board or flip chart.)* This will be done by pushing the shoulder of the first student forward or back and have the student return to upright. Again, the next student will lean forward or back only when s/he feels his/her neighbor move. *(Have the teacher time how long the wave takes to travel down the line. Have the teacher record the time on the board or flip chart by the name of the wave.)*
   - Finally, explain to students that you will send the compressional (P) wave down the line. *(Write this wave on the board or flip chart.)* This will be done by pushing the shoulder of the first student in the direction of the line, and having the students repeat the movement to the end. *(Have the teacher time how long the wave takes to travel down the line. Have the teacher record the time on the board or flip chart by the name of the wave.)*
   - Note that it may take a few trials to get a good sample of each wave. The compressional wave will be fastest and the surface wave will be slowest.

5. **(5 minutes)** Discuss the simulation. Be sure to accept as many explanations as you can. Some questions you might use are:
   - Which seismic wave was the fastest? Why?
   - How do you think scientists study seismic waves?
   - What is the difference between a surface wave, S wave and P wave?
   - Which seismic wave would do the most damage to a community? Why?

6. **(2 minutes).** Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Chapter 5: Investigations for Different Age Levels

Photos of Earthquakes

Unidentified earthquake damage image

Collapsed Interstate 880 in California

Damage to a second kitchen in a townhouse near the Northridge Fashion Center

Wooden structure that shifted on its foundation during the 1989 Loma Prieta earthquake.

1988 Armenian earthquake

Collapse of apartment building over garage in Reseda following the 1971 San Fernando earthquake.
Finding the Epicenter of an Earthquake

Grades 7-12

Lesson time:
45 minutes (including introduction and clean-up)

Objective:
Students will be able to:
• Understand how S and P waves are used to find the epicenter of an earthquake by applying their seismic knowledge and mathematical skills to seismographs in order to triangulate an earthquake epicenter.

Materials:
Provide each student with the following:
• Map of southwestern United States
• Seismograms from seismic stations in Fresno, CA; Phoenix, AZ; and Las Vegas, NV
• A modified travel time curve for S-P wave
• A Data Table for the Seismic Stations
• A drawing compass
• Pencil

For instructional purposes:
• Overhead transparency of each of the handouts
• Overhead projector (contact classroom teacher about this) and screen
• Optional: overhead transparency or PowerPoint of Photos of Earthquakes from pg. 41
• Overhead transparency markers

Purpose:
Earthquakes occur every day all over the United States and all over the world. Most of these earthquakes are small tremors that can’t be felt by people, but occasionally an earthquake occurs on a large magnitude that causes millions of dollars in property damage and kills hundreds to thousands of people. Earthquakes can also cause tsunamis, which are very large waves that can damage coastlines and put coastal residents in danger.

Some places are more prone to earthquakes than others. For example, the western United States has earthquakes more frequently and on a larger scale than the eastern part of the country. Earthquakes occur along faults, which are cracks in the Earth’s crust that build tension. When the tension becomes too great, the fault slips, causing an earthquake. The western U.S. has more faults than the eastern U.S., and therefore the western U.S. has more earthquakes. The nation’s most famous fault is the San Andreas Fault, which runs along a north-south trend in southern California, and happens to run directly through Los Angeles.

In this investigation, participants will understand that S and P waves are used to find the epicenter of an earthquake by using seismograph data to triangulate an epicenter.

Safety:
This investigation is considered generally safe to do with students. However, please review it for your specific setting, materials, students, and conventional safety precautions.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period, as well as how many copies of handouts and sets of materials you need to bring.
2. Collect all the materials in the list.
4. Make an overhead copy of each of the handouts. Notify the classroom teacher of technology needs (overhead projector).
5. Collect any giveaways for the students, such as earthquake posters or plate tectonic fliers.
6. Run through the investigation yourself and record the data, just to see how long it takes. Adjust the timing to the class period, remembering that you will need time to introduce the investigation, clean up afterwards, and re-set up for the next class (if you are working with more than one class).

Investigation Question:
How do we determine the epicenter of an earthquake?

What to Do:
1. (5 minutes) Prompt a discussion about earthquakes. Optional: show photos or videos of earthquakes and related damage. (See Photos of
Chapter 5: Investigations for Different Age Levels

*Earthquakes from the Earthquake Wave investigation.* Be sure to accept as many explanations as you can. Some questions you might use for the discussion are:

- What do you know about the causes and impacts of earthquakes? *(Student responses will vary.)*
- What do you know about seismic waves? *(Student responses will vary.)*
- Have any of you ever experienced an earthquake or know anyone who has? What did it feel like? Was there an initial quake followed by smaller quakes? *(Student responses will vary.)*

2. *(5 minutes)* Show the three seismographs and point out the first arrivals of the P- and S-waves. *Ask students to explain what they see.* Talk about how the S-P interval increases with distance between the epicenter and seismograph station. *Ask how this might be used to determine the distance from the earthquake to the station.*

3. *(30 minutes)* Hand out the work sheet (A Modified Travel Time Curve and Table 1). Describe how independent seismograph stations can determine distances that plot as circles on a map. Explain that at least three stations are necessary to find the epicenter of an earthquake. Also explain that although three stations is the minimum, often seismologists use more than three, and the more they use the more accurate the location of the epicenter becomes. Have students work through the exercise, following these steps:

- **Use seismograms from seismic stations in Fresno, CA, Phoenix, AZ, and Las Vegas, NV.** For each seismogram, students will find the first arrival times of the P- and S-waves. The first “jump” is the arrival of the P-wave. In each seismogram, the P-wave arrives at time=0 seconds. Also in each seismogram, the second big “jump” is the arrival of the S-wave. For Fresno, the S-wave time is 36 seconds. For Phoenix, the S-wave time is 61 seconds. For Las Vegas, the S-wave time is 39 seconds. It is okay if students are off by one or two seconds, but the closer they are to the correct number of seconds, the more accurate their epicenter location will be.

- **Find the S-P interval for each seismogram and record answers in the S-P column of Table 1.** Because the P-wave time for each seismogram is set as 0 seconds, the S-P interval will be the time of the S-wave arrival. For example, the S-P interval for Fresno is 36 seconds (i.e.: 36 seconds-0 seconds= 36 seconds). Likewise, S-P for Phoenix is 61 seconds and S-P for Las Vegas is 39 seconds. Have the students record their S-P intervals for each seismograph station in Table 1.

- **Find the distance to the epicenter (in kilometers) from each recording station and record answers in Table 1.** To do this, have the students use *A Modified Travel Time Curve for S-P Wave*, which is the Modified Travel Time Curve. The y-axis shows time in seconds. The x-axis shows distance to the epicenter from the recording station in kilometers. The line is a linear plot of S-P that has been done for students previously and is specific to this example. Explain that S-P is always a linear relationship, but don’t worry about trying to explain why. You may confuse them if you do. To find the distance to the epicenter, use the S-P interval you found for each station in step 2. For example, S-P for Fresno is 36 seconds. On the y-axis of the travel time curve count up to 36 seconds. Then with
Chapter 5: Investigations for Different Age Levels

a pencil, draw a line to the S-P line and put a dot. Finally, draw a line with a pencil down to the y-axis and make another point. That point is the distance (in kilometers) from the Fresno seismograph station to the epicenter of the earthquake. The distance is 355 kilometers. For Phoenix the distance to the epicenter is 600 kilometers, and from Las Vegas the distance to the epicenter is 380 kilometers. Have students record their answers for each station in the Distance from the Epicenter column of Table 1. It may help to do the first one together.

- Find the epicenter of the earthquake on the (Map of Southwestern United States). The students will need the drawing compass to draw circles around each seismograph station. For each station, use the scale on the map to set the drawing compass to the distances found in step 3. For Fresno the distance found was 355 km. Set the compass for 355 km using the scale on the map. Then put the point of the compass on Fresno and draw a complete circle. Do the same for Phoenix using a distance of 600 km (students will have to extend the scale to make it 600 km long). (It may be helpful to do this before starting the lesson). Finally, draw a circle for Las Vegas. Where the three circles meet is the epicenter of the earthquake. If the circles to not meet exactly, then the epicenter is the center of the triangle formed where the circles should meet. In this activity, the epicenter of the earthquake is in the center of Los Angeles, CA. Ask students what fault they think caused this earthquake. The answer is the San Andreas Fault.

4. (5 minutes) Discuss how gathering information on epicenters can be applied. If the curriculum has already covered plate tectonics, you can lead the discussion towards plate boundaries. Ask students what kind of boundary the San Andreas Fault is (a transform boundary).

5. (2 minutes). Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.

References:

- Activity is modified from: http://www.indiana.edu/~pepp/curriculum/2001/elleman/elleman.htm
- Geology Labs Online: http://www.sciencecourseware.com/virtualearthquake/
- Animation using p and s waves, for understanding epicenter location: http://highered.mcgraw-hill.com/sites/dl/free/0073135151/90798/16_08.swf
Map of Southwestern United States
Seismograms From Seismic Stations in Fresno, CA, Phoenix, AZ, and Las Vegas, NV

Fresno, CA

Phoenix, AZ

Las Vegas, NV
A Modified Travel Time Curve for S-P Wave
## A Data Table for the Seismic Stations

<table>
<thead>
<tr>
<th>Station</th>
<th>S-P Interval (time in seconds)</th>
<th>Distance from the epicenter (in kilometers)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresno, CA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Phoenix, AZ</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Las Vegas, NV</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Testing Soil Samples

Purpose:

Soil plays a unique role in our life. Soil helps to maintain air quality, stores water and nutrients for plants, and filters contaminants from surface water. Where there is soil, life flourishes. Determining a soil’s pH is important because many plants will only grow in either alkaline or acidic conditions, additionally, the pH can affect the availability of nutrients in the soil. In this activity students will learn how soil scientists and gardeners determine which soil is best for the growth of certain plants, by sampling different soils and testing their pH levels.

Safety:

Students should wear goggles and be sure to wash their hands after finishing this investigation. Please review the investigation for any additional safety precautions for the specific setting, materials, or students.

Preparation:

Before going to the classroom, you will need to:

1. Contact the teacher to find out the length of the class period, as well as how many copies of handouts and sets of materials you need to bring. Alert the teacher that this investigation is set up for groups of four.
2. Collect all the materials in the list below and organize them into one shoebox for each group of four students.
3. Make photocopies of the handouts. Collect any giveaways for the students, such as soil bookmarks or posters.
4. Run through the investigation yourself and record the data, just to see how long it takes. Adjust the timing to the class period, remembering that you will need time to introduce the investigation, clean up afterwards and re-set up for the next class (if you are working with more than one class). You can reduce the amount of time this investigation takes by cutting the number of soil samples from three to two.
5. Collect any giveaways for the students, such as soil posters or bookmarks.

Investigation Question:

How do you know what soil is best for what plants?

What to Do:

1. (5 minutes) Prompt a small discussion on the importance of soils. Be sure to accept as many explanations as you can. Some questions you might use are:
   - What is soil made of? (Some students might say that it is made up of plants and animals and miss the fact that soil is also made up of rocks and water. Record them on a flip chart or overhead.)
   - What would the world be like if there was no soil? (Student responses should reflect how there would be no life or plants.)
Chapter 5: Investigations for Different Age Levels

- Why is soil important? *(Student responses should reflect how things grow in soil.)*

2. *(7 minutes)* Hand out the shoeboxes containing all the materials to each group of four students. Ask the students to put a small amount of soil from each of the three bags onto the white paper and examine the soil with both the naked eye and the magnifier. Ask what differences they see between the three types of soil.

3. *(3 minutes)* Explain that soil is a mixture of living and non-living material. Ask students to identify some examples of each in their soil samples. Tell students that soil scientists have a number of ways of finding out what’s in soil. One is to observe the soil, just as the students are doing. Another way is to use chemicals to test the soil for different important components.

4. *(5 minutes)* Ask students to look on the backs of their soil test kits. There, they should find information about what types of plants do best in certain types of soil. Ask students why they think it is important to test soil for pH, N, P, and K. Take all responses.

5. *(5 minutes)* Hand out the directions for using the soil test kits and make sure that students put on their safety goggles. Demonstrate how to test the soil by adding water and the test chemicals to the soil samples.

6. *(15 minutes)* Direct the students to test their soil samples and record their results. Walk around as they work to help students who have questions or concerns.

7. *(5 minutes)* When everyone is finished, ask students to report their results for soil samples A, B, and C. You might find it easiest to do this by having a large chart on the board that students can fill in when they finish with their soil testing.

8. *(5 minutes)* Have students compare and discuss the various results for soils A, B, and C. Be sure to accept as many explanations as you can. Questions you might ask the students:

   - How might you be able to explain any wide variations in the data?

9. *(2 minutes)* Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
## Fruit and Vegetable Preferences for pH

<table>
<thead>
<tr>
<th>Fruit/Herb</th>
<th>pH 4.0-6.0</th>
<th>pH 5.0-6.5</th>
<th>pH 6.0-7.5</th>
<th>pH 5.0-7.5</th>
<th>pH 6.0-8.0</th>
</tr>
</thead>
<tbody>
<tr>
<td>Potato</td>
<td>Apple</td>
<td>Apricot</td>
<td>Banana</td>
<td>Avocado</td>
<td></td>
</tr>
<tr>
<td>Blackberry</td>
<td>Cherry</td>
<td>Grapevine</td>
<td>Rhubarb</td>
<td>Asparagus</td>
<td></td>
</tr>
<tr>
<td>Cranberry</td>
<td>Grapefruit</td>
<td>Grapefruit</td>
<td>Strawberry</td>
<td>Ginger</td>
<td></td>
</tr>
<tr>
<td>Gooseberry</td>
<td>Mango</td>
<td>Hazelnut</td>
<td>Raspberry</td>
<td>Leek</td>
<td></td>
</tr>
<tr>
<td>Melon</td>
<td>Hop</td>
<td>Lemmon</td>
<td>Carrot</td>
<td>Mint</td>
<td></td>
</tr>
<tr>
<td>Pineapple</td>
<td>Pomegranate</td>
<td>Lychee</td>
<td>Cauliflower</td>
<td>Paprika</td>
<td></td>
</tr>
<tr>
<td>Watermelon</td>
<td>Basil</td>
<td>Nectarine</td>
<td>Sweet corn</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Basil</td>
<td>Chicory</td>
<td>Peach</td>
<td>Cucumber</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Chicory</td>
<td>Fennel</td>
<td>Plum</td>
<td>Garlic</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fennel</td>
<td>Olive</td>
<td>Quince</td>
<td>Lentil</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Olive</td>
<td>Peanut</td>
<td>Artichoke</td>
<td>Parsley</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Peanut</td>
<td>Sweet potato</td>
<td>Bean</td>
<td>Pepper</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sweet potato</td>
<td>Rice</td>
<td>Beetroot</td>
<td>Pumpkin</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rice</td>
<td>Rosemary</td>
<td>Broccoli</td>
<td>Shallot</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Rosemary</td>
<td>Sage</td>
<td>Brussels sprouts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sage</td>
<td>Soybean</td>
<td>Cabbage</td>
<td>Spearmint</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Soybean</td>
<td></td>
<td>Calabrese</td>
<td>Thyme</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Celery</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chinese</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Cabbage</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Chives</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Lettuce</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Millet</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mushroom</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Mustard</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Onion</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Pea</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Peppermint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Radish</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Spinach</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5: Investigations for Different Age Levels

Cookie Dig

Grades K-5

Lesson time:
35-45 minutes (including introduction and clean-up)

Objective:
Students will be able to:
• Explain one method that paleontologists use in finding and sorting potential fossils.

Materials:
For instructional purposes:
• Large pan of no bake cookie bars (see preparations for more details)
• Posterboard-size copy of Paleo Cookie Dig Grid. The template can be found below. You might want to draw this on a blackboard or chalkboard before you start your presentation. Make sure you have chalk or dry erase markers.
• Images of Paleontology in Action (see samples below)

Provide each group of four with the following:
• 4 toothpicks
• 1 piece of the cookie bar
• 1 paper plate
• Pencil or pen
• Paper towels
• Pad of sticky notes
• 1 Data Sheet (see below)

Purpose:
Fossils are records of past life. Many young students are fascinated by dinosaur fossils or images of dinosaurs from movies, but they don’t understand how scientists find fossils. In this investigation, students will be introduced to the concept of digging for fossils through a simulated paleontology dig using a grid and a chunky cookie bar.

Safety:
There are no particular safety concerns for this activity.

Preparation:
1. Before beginning this lesson use the basic recipe below to prepare a 13 X 9 X 2" pan of rice cereal bars (Paleo Bars). To the basic mixture, add ½ cup each of four non-melting ingredients such as raisins, macaroni, peanuts, or sunflower seeds still in the shell. The idea is to have a chunky cookie bar with obvious parts.
2. Collect images of paleontologists and their work. Samples from the Earth Science World Image Bank (www.earthscienceworld.org) are below. Images could be printed or in a PowerPoint presentation. If images are in a PowerPoint, remember to ask the teacher if you can use a computer and projector.
3. Collect materials for the investigation and duplicate Data Sheets.
4. Collect any giveaways for students, such as fossil posters or geologic time scale bookmarks.

Investigation Question:
How do paleontologists find fossils?

What to Do:
1. (4 minutes) Introduce the concept of paleontology as a career by showing students images of paleontologists at work. (See images below.) Ask students:
   • What are the scientists doing? (Allow all students who want to answer to answer. Students should raise their hand before you accept their answer).
   • Do you think scientists are using a process to remove and look at fossils? Explain that scientists are indeed using a process to remove and study the fossils and that students will be using this method to simulate a dig.
2. (3 minutes) Show the class the entire pan of Paleo Bars. Explain that when paleontologists remove fossils from the ground, they divide the area into squares called "quadrants." (Cut the bars into quadrants. Make sure that you will have enough quadrants for each group of four students). Then explain that each group will receive one of the cookie quadrants, toothpicks, magnifiers, paper plate, Data Sheet, and paper towels. Their job will be to use the toothpicks to study the quadrant. Ask students to group parts of the cookie by type on the paper plate and record on their worksheet how many materials were in their
quadrants (e.g. all raisins should be grouped together, as should rice cereal bits).

3. **(20 minutes)** Students study the Paleo Bar and take it apart. Students should also be grouping like materials and recording how many of each material they found on their Data Sheet. (*Walk around the classroom and help groups that are having trouble with this task. When all groups are done, have students stop what they are doing and refocus their attention back to you.*)

4. **(5 minutes)** Explain to students that they will use the information from the Data Sheets to create a class bar graph that illustrates what was found in each quadrant. Pass out sticky notes and have students record how many rice cereal bits were in their quadrant. Have each group place the relevant sticky note on the appropriate square on the posterboard-size grid. Pass out more sticky notes and repeat the procedure for each non-melting ingredient in the Paleo Bars.

5. **(5 minutes)** As a class, analyze the graph. Be sure to accept as many explanations as you can. Questions you might ask students:
   - Were all quadrants the same or different?
   - Did your group have the same amount of ingredients in your quadrant as a different group?
   - Why do you think this happened?

6. **(3 minutes)** End the discussion by stating that scientists who study fossils use a similar method when they are systematically studying an area of land or a bone-bed where fossils can be found. Thank students for their time. You can leave giveaways behind for the classroom teacher to distribute.
Recipe for Paleo Bars

**Prep Time**
20 minutes

**Total Time**
30 minutes

**Servings**
12

**Ingredients**
- 3 tablespoons margarine or butter
- ½ cup peanuts
- ½ cup macaroni pasta
- ½ cup sunflower seeds in the shell
- 1 package (10 oz./ about 40) regular marshmallows
  - or -
- 4 cups miniature marshmallows
- 3 cups rice cereal

**Directions**
1. Melt margarine in large saucepan over low heat. Add marshmallows and stir until completely melted. Remove from heat.
2. Add cereal. Stir until well coated.
3. Using buttered spatula or waxed paper, press mixture evenly into 13 x 9 x 2-inch pan coated with cooking spray. Cut into 2-inch squares when cool. Best if served the same day.
Chapter 5: Investigations for Different Age Levels

Paleontology Images

A paleontologist is removing bone fossils from a cliff.

A paleontologist is excavating fossils in Colorado's Dry Mesa Quarry.

This paleontologist at Utah's Dinosaur National Monument is relieving the shoulder bones of a large Stegosaurus.

This skull is being prepared for study by National Park Service and visiting paleontologists at Utah's Dinosaur National Monument.

This paleontologist is excavating fossils in Colorado's Dry Mesa Quarry.

A paleontologist is studying the jaw of an Antrodemus fossil.

American Association of Petroleum Geologists and The American Geological Institute
The Geoscience Professional’s Science Enrichment Handbook 55
Data Sheet

<table>
<thead>
<tr>
<th>Material Name</th>
<th>Number</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rice Cereal bits</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
</tr>
</tbody>
</table>
### Template for the Posterboard-Size Grid

<table>
<thead>
<tr>
<th></th>
<th>Rice Cereal Bits</th>
<th>Ingredient A</th>
<th>Ingredient B</th>
<th>Ingredient C</th>
<th>Ingredient D</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groups</td>
<td>Non-melting ingredients</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>10</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>6</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
How Does the Rock Cycle Work?

How Does the Rock Cycle Work?

Grades 3-6

Lesson time:
45 minutes

Objective:
Students will be able to:
- Explain how heat and pressure affect rocks by making observations to crayon shavings that are placed under heat and pressure.

Materials:
For each student:
- Two pieces of 11" X 11" wax paper
- One bag of crayon shavings
- A handout showing the steps of the rock cycle
- A heavy book or large, clean, wooden cutting board to demonstrate compaction

For instructional purposes:
- A clothing iron to "metamorphose" the sediments

Purpose:
The rock cycle is the combination of all the processes that act to break down rocks, move sedimentary materials from place to place, and produce new rocks. In this investigation, students will discover what happens to rocks under lots of pressure and heat through a simulation that uses crayon shavings.

Safety:
This investigation is considered safe to do with students. An adult will help with the compaction. Make sure that only an adult does the ironing of the crayons to metamorphose them. Be prepared to keep the activity moving and allow for extra clean-up because the crayon shavings can get on the floor.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period and the number of students in the class. Discuss any previous discussions about the rock cycle of understanding of the three main rock types.
2. Alert the teacher that this investigation requires an electrical outlet to plug in the iron (see description of materials for clarification) and you will need extra safety support with the iron.
3. Prepare the crayon shavings from 3 to 4 different color crayons by using a hand held pencil sharpener or a pair of scissors to scrape the outside of the crayon like a carrot and a carrot peeler.
4. Divide about a spoonful of shavings into a sandwich bag, one for each student. The shavings will represent sediments in this investigation.
5. Duplicate the work sheet, with potential modification for grade level. If you are working with Kindergarteners it is important to remember that they will not all be reading. Describe the pictures rather than using just words so the students know where you are on the diagram.
6. Collect any giveaways for the students, such as fossil posters or geologic time scale bookmarks.

Investigation Questions:
How does the rock cycle work?

What to Do:
1. (5 minutes) Spend the first five minutes getting to know the general geologic knowledge of the class. Try to keep the whole discussion as dynamic as possible. Most students should have some interest or have made observations about Earth processes. The key is to get them to discuss these ideas, so that they will be more involved in the activity as a whole. Be sure to accept as many explanations as you can.
Questions you might ask are:
- Have you have ever collected a rock?
- Do you have a rock collection?
- Do you know the three major types of rocks?
Chapter 5: Investigations for Different Age Levels

2. **(5 minutes)** The next step is to introduce the three types of rocks (igneous, sedimentary, and metamorphic). Introduce the term sediment. Be sure to accept as many explanations as you can. Some questions you might ask are:
   - What are sediments?
   - Where are sediments found (on a beach, in a river, etc.)?
   - Can you find sediments inside a volcano? If not, why not?

3. **(5 minutes)** Explain that liquid rock or lava is found inside a volcano and whether that liquid rock is cooled below ground or above ground controls the size of the crystals. Now getting back to sediments, the igneous rocks get broken into smaller and smaller pieces; this is how the sediments form. Once you have introduced the concept of sediment, hand out the diagram of the rock cycle.

4. **(5 minutes)** Have the students take turns identifying the directions that sediments change between the arrows on the diagram. Ask them why at some places on the circle are there two paths that the sediments/magma can take. Now ask them if they would like to have their own sediments to follow the cycle with.

5. **(7 minutes)** Hand out the wax paper and the crayon shavings. Explain that the different colors of crayons represent the sedimentary rock forming minerals (quartz, feldspar, micas, and limestone). Have students make a pile of the crayons on their wax paper similar to the way sand might pile up due to wave action on a beach. Ask the students to consider what might happen to those sand grains next on the rock cycle. Might they be compacted and buried?

6. **(10 minutes)** This is the most fun part of this activity, the compaction and metamorphism phase. Have the students place the second piece of wax paper on top of their sediments. If the teacher is in the room, he or she can help take the heavy book or cutting board around to students, place it on top of their wax paper and help them pound on their sediments to compact them. Have them make observations about how their pile of sediments changed after adding pressure. Once they are satisfied with the compaction, an adult should use the iron to melt the crayon shavings to metamorphose them. Depending on the classroom set up and the age of the students, either have the metamorphic processes occur on their desk or have the students carry the pieces of wax paper carefully to an area where they can be ironed one at a time. Make sure to point out how the colors have blended together to form a new color-this is a similar process to mineral re-crystallization that occurs in metamorphism.

7. **(5 minutes)** At the end of the activity, start a discussion into what happened with the crayon shavings. Be sure to accept as many explanations as you can. Some questions you might want to ask include:
   - What happened to the crayon shavings when you put pressure on them with the book?
   - Do you think that the same thing happens to rocks when they are placed under lots of pressure? Why/Why not?
   - What happened to the crayon shavings when you added heat?
   - Do you think that the same thing happens to rocks when they are placed under lots of heat? Why/Why not?

8. **(2 minutes)** Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Below is a handout to use to illustrate the rock cycle from a NASA website on the Six Fundamental Concepts in Geology (http://rst.gsfc.nasa.gov/Sect2/Sect2_1a.html ).
Chapter 5: Investigations for Different Age Levels

The Rock Cycle
Chapter 5: Investigations for Different Age Levels

Evolution of Dinosaurs

Grades K-3

Lesson time:
35-45 minutes (including introduction and clean-up)

Objective:
Students will be able to:
• Demonstrate an understanding about different kinds of dinosaurs by identifying key features of each dinosaur and being able to explain how that attribute is an adaptation to their environment.

Materials:
For instructional purposes:
• A shallow bin with about 2” of sand to bury the rubber dinosaurs
• Rubber dinosaurs or a color copy of Images of Dinosaurs. The rubber dinosaurs can be found in most teacher supply stores in the math aisle for about $9.00 for 100. They usually are primary-colored. Make sure you have the following dinosaurs if you decide to use the rubber dinosaurs: Tyrannosaurus Rex, Apatosaurus, Triceratops, Stegosaurus, and Velociraptor
• The book Ten Little Dinosaurs by Pattie Schnetzler and Jim Harris (googly eye book) or another children’s story about dinosaurs

Purpose:
The study of dinosaurs stretches children’s imaginations, provides new perspectives on time and space, and invites students to discover worlds very different from our modern Earth. The study of dinosaurs is important in understanding the causes of past major extinctions of land animals. In this investigation, students will make basic observations about specific traits of dinosaurs and discuss how those traits suited dinosaurs to their environments.

Safety:
This investigation is considered safe to do with students. Make sure students do not hurt each other when they are doing movements.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period and the number of students in the class. Ask the teacher for about 5 minutes to set up prior to beginning.
2. Prepare handouts and/or bring a small rubber dinosaur for each student. Students will want to keep the dinosaurs, so you will need to decide whether these are giveaways. You could bring along a few sheets of dinosaur stickers to give away.
3. Keep in mind that this activity is for young students with a lot of energy. Ask the teacher to work with you to re-gain students’ attention after each part of the activity.
4. Collect any giveaways for students, such as fossil posters or geologic time scale bookmarks.

Investigation Question:
How do paleontologists know how dinosaurs lived?

What to Do:
1. (3-5 minutes) Introduce the concepts of extinction and making observations. Be sure to accept as many explanations as you can. Some questions that you can use are:
   • Could you go see a dinosaur in a zoo? Could you have a dinosaur as a pet? Why not? (Answer: Because dinosaurs are extinct; they are no longer living anywhere on Earth.)
   • How do we know that dinosaurs used to exist? (Answer: They left fossils of their bones.)
   • If we only have bones and footprints, how do we find out more about dinosaurs? (Be sure to accept as many explanations as you can.)
   • How can we know what dinosaurs ate? (Answer: By what kind of teeth they had.)
   • How can we know how they walked? (Answer: By the way their leg bones are shaped.)
   • By raising you hand in agreement, who would like to be a
Chapter 5: Investigations for Different Age Levels

paleontologist (scientist who studies dinosaurs)?

2. **(5 minutes)** Explain that a paleontologist digs up dinosaur fossils and studies them to understand how dinosaurs used to look and live. Ask students to dig in the sand and pull out one rubber dinosaur. *(Each student in the class should have an opportunity to dig in the sand and find a dinosaur.)* Once each student has a dinosaur, have them compare their dinosaurs to their peers’ dinosaurs. Ask the students:
   - Do all the students have the same dinosaur?

3. **(15-20 minutes)** Go through each dinosaur with the students to make observations about their finds. Be sure to accept as many explanations for the questions below as you can.
   - **Tyrannosaurus Rex:** This dinosaur has long back legs and large teeth.
     - What do you think it ate? *(Answer: Meat. A dinosaur that eats meat is a carnivore. It also had arms that were so short it could not touch its pinky fingers together. Have the students stand up, put their arms at their sides and then bend their elbows so that they cannot touch their pinky fingers together.)*
     - If this is how short your arms were, how would you eat? *(Answer: You would rip food with your teeth and stomp on it.)*
     - Have the students stomp around a bit to feel like a big fierce T-rex.
   - **Apatosaurus:** This dinosaur has a small head and a very long neck.
     - Why would it need such a long neck? *(Answer: It eats leaves from tree tops. It also walks on four legs.)*
     - Does it look like it could run quickly? *(Answer: It is a very big dinosaur that moves slowly.)*
     - What do we call a dinosaur that eats plants? *(Answer: A herbivore.)*
   - **Triceratops:** This dinosaur has horns and a frill around its head. It also has a beak-like mouth to eat grass.
     - What might it use its horns for? *(Answer: Protection.)*
     - Have the students put two fingers from one hand up on their foreheads and a pointer finger from the other hand pointing off their nose. Let them pretend to be a triceratops trying to protect itself from being eaten.
   - **Stegosaurus:** This dinosaur has plates running down its back and a spiky tail.
     - Is this to help it hunt?
     - If it was a hunter, do you think it would have such stumpy legs and not be able to run very quickly? *(Answer: The plates and spiky tail are for protection. This dinosaur has one of the smallest brains of any dinosaur.)*
   - **Velociraptor:** This is one of the fiercest, smartest dinosaurs.
     - Have them look at its legs. Do they think it could run quickly? *(Answer: Yes.)*
     - Why might this dinosaur need to run quickly? *(Answer: To hunt.)*
     - Explain that this dinosaur would usually hunt in packs. Paleontologists know this from the footprints that they find. This dinosaur is also a carnivore.
     - Are you (the student) a carnivore or herbivore? *(Answer: Since humans eat meat and plants, we are omnivores.)*
4. **(5-7 minutes)** Once you have gone through the dinosaurs, wrap up the activity by reading a story about dinosaurs. This allows students to see pictures of different dinosaurs again. It also gives them a slightly different context in which to hear dinosaur names, and it reinforces some of the attributes that they observed from their rubber animals. Ask students if they have any questions or would like to share any stories about their favorite dinosaurs. End the activity by complimenting them on what good paleontologists they were. You can leave giveaways behind for the classroom teacher to distribute.
Chapter 5: Investigations for Different Age Levels

Images of Dinosaurs

Artist's rendering of a Tyrannosaurus Rex

An artist's rendering of an Apatosaurus

An artist's rendering of a Triceratops

An artist's rendering of a Stegosaurus

An artist's rendering of a Velociraptor
Chapter 5: Investigations for Different Age Levels

The Soil Detective Challenge

Grades 3-6

Lesson time:

60-90 minutes (including introduction and clean-up)

Objective:

Students will be able to:
• Investigate soil by making and recording observations on different soil samples.

Materials:

Provide each groups of four with the following:
• 1 soil sample: should be a handful or two of soil in a quart size zip-closing plastic bag .
• White paper to cover desktops
• Magnifiers or hand lenses
• Ruler
• Observation sheet
• Colored pencils

These items will be placed on a table for the second part of the investigation:
• Signs that identify each area that the soil came from (E. G. Area A, Area B, Area C)
• Rock samples: collect the appropriate bed rock sample for each soil, both fresh and weathered if possible.
• Vegetation samples: collect representative leaves, grass, etc.
• Supplemental data such as photos of each sample site

Instructional purposes:
• White board or flip chart
• Markers

Purpose:

Soils come from rocks and other things that reflect local conditions. Soil is essential for life. In this investigation, students will be able to identify soil properties that can be related to original bedrock, climate and vegetation. At the same time, they will learn about practical issues related to soils.

Safety:

This investigation is considered safe to do with students. Monitor student movement when they start looking at the samples on the table. Consider the contents of your individual sample kits for potential hazards.

Preparation:

Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period. Alert the teacher that this investigation is set up for groups of four and whole class discussion. You will also need to arrange for an overhead or digital projector and screen.
2. Gather the soil, rock, and vegetation samples and supplemental data as described in the Materials list. Gather enough equipment sets for all teams. Make sure you record where each soil, rock and vegetation sample came from. Collect enough different types of soils from as many environments as possible (e.g. sand or clay rich, arid or humid environments, etc)
3. Take pictures of the place where you took each sample and make a color copy of the image.
4. Duplicate the observation sheet.
5. When you get to the classroom you will need to arrange the rock samples, vegetation and photographs on a table. Make sure the teacher knows that you will need a table for this purpose. Arrange the rock samples, vegetation and photographs on the table by areas. (E.G. Area A will have a picture of a desert, sandstone samples, and maybe cactus; Area B will have a picture of a forest, samples of dead leaves, and pebbles)
6. Make signs that identify each area where the soil sample came from. (e.g. Area A, Area B, Area C, Area D)
7. Collect any giveaways for the students, such as soil posters or bookmarks.

Investigation Question:

What can you investigate about soil?

What to Do:

1. (5 minutes) Prompt a discussion about soils. Be sure to accept as many explanations as you can. Questions you might ask students:
   • What is soil?
   • How is soil useful?
   • How is soil formed?
Chapter 5: Investigations for Different Age Levels

- What is soil made from?
- How is soil different from other soil? Why?

2. (10-15 minutes) Distribute the soil samples to each student team. Explain to students that the soil samples are all different, so there will be different interpretations/answers. Instruct students to:
   1. Cover their workspace with the white paper.
   2. Place soil sample on the paper.
   3. Use their senses (sight, touch and smell), hand lenses and ruler to examine the soil sample.
   4. Record observations on their observation sheet (As students are making observations on their observation sheet, walk around to each group and help those groups that are having problems. When 1 or 2 groups have finished making observations, move to the next part of the investigation.)

3. (10-20 minutes) Introduce students to the next part of the investigation. You will have to stop the investigation process and get students’ attention. Ask the classroom teacher to help you with this because they have special tricks that they use. Explain to the students that they will have time to finish making observations to their soil after you are done talking to them. Point out the table with the bedrock, vegetation and photographs. Explain to the students that they will use their observations about the soil to make an educated guess about where their soil came from. The samples of bedrock, vegetation and the photographs are all of areas where each soil sample came from. This is the last question on their observation sheet. Tell students that they need to be done making their observations about the soil before they are allowed to become a detective and go to the table. (Monitor students as they come up to the table. There should be no pushing or shoving and they are only allowed to come up to the table if they have finished their observations.)

4. (5 minutes) Discuss student observations. Draw a table on the board with column headings of Sight, Smell, Touch to record student’s observations. Be sure to accept as many explanations as you can. Questions you might ask students:
   - What did your soil look like?
   - How did your soil smell?
   - How did your soil feel?
   - Did all groups have the same observations? Why? Why not?
   - Where did your soil sample come from? Why did you think this?

5. (2 minutes) Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Chapter 5: Investigations for Different Age Levels

Your name: ________________________________

Observation Sheet: The Soil Detective Challenge

Draw a picture of your soil sample.

How does your soil smell? (Stale, metallic)

What does your soil feel like? (Wet, sandy, gritty, smooth, sticky, dry, slick, silty, clay-like)

What does your soil look like? (Color, sediments, materials in the soil)

Identify where you think your soil sample came from. What evidence from your observations support your answer?
Thinking About Systems

Grades 3 - 12

Lesson time:
45-50 minutes (including introduction and clean-up)

Objective:
Students will be able to:
• Understand how systems work by examining objects that work as a system.

Materials:
Provide students, in groups of four, with the following:
• Poster paper
• Colored markers

For Instructional purposes:
• Overhead projector, transparencies and marker or chalkboard
• Objects with parts that work as a system (stapler, can opener, umbrella, nail clippers, tongs, ballpoint pens, etc.)
• Flip chart or board and markers

Purpose:
A system is a group of related features or objects that are organized in some way. Different parts of a system interact with each other. This causes a system to function in some way as a whole. Every system has a driving force that makes it work. In any system, there can be a large number of parts and processes. Both are very important features of systems, and without either of them, nothing would happen. A system relies on all of its parts to function and will not function properly if some parts are removed. The way that Earth works is very complicated, but thinking of it as a system enables us to break it down into smaller pieces that are easier to explore and understand.

This investigation is designed to introduce the concept of a system and how that system’s parts work together as a whole. This is an introduction to thinking of the Earth as a system.

Safety:
This investigation is considered generally safe to do with students. However, please review it for the specific setting, materials, students, and conventional safety precautions.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period, as well as how many sets of materials you need to bring. Alert the teacher that this investigation is set up for groups of four.
2. Collect all the materials listed in the materials section and organize them into one Tool Bag for each group of four students
3. Collect any giveaways for the students, such as Earth system posters or bookmarks.
4. Run through the investigation yourself, just to see how long it takes. Adjust the timing to the class period, remembering that you will need time to introduce the investigation, clean up afterwards and re-set up for the next class (if you are working with more than one class).

Investigation Question:
What is a system?

What to Do:
1. (2-5 minutes) Ask your participants to name something that is a system. Record their ideas on the overhead or board. Ask them to explain why they think their suggestions are systems.
2. (2-5 minutes) Divide the participants into groups of 3 or 4. Give each group an object, poster paper and markers.
3. (12-20 minutes) Ask and allow each group to examine its object as a system. Here are some questions that they should answer (you might want to write them on the overhead or board):
   • What are its parts?
   • What is the energy that makes the system work?
   • What is the output of the system?
4. **(5-10 minutes)** Ask groups to draw a diagram of their object on the poster paper and label its parts and what they do. They should explain what kind of energy makes the object work as a system and describe the output of the system.

5. **(5-10 minutes)** When all the groups finish, ask them to hang their posters up in a gallery format. Each group can then present its poster or the participants can “tour” the gallery.

6. **(2 minutes)** Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Chapter 5: Investigations for Different Age Levels

An Introduction to Earth Systems

Grades 4-12

Lesson time:
50-60 minutes

Objective:

Students will be able to:
• Make connections between the different spheres of the Earth system by observing their outdoors and categorizing their observations.

Materials:

Provide students, in groups of four, with the following:
• Large sheets of poster paper
• Markers
• Earth Systems diagram

All students:
• Notepads to record observations
• Pen or pencil

For instructional purposes:
• Access to the outdoors
• Sample of Earth Systems Concept Map Poster (you could put this on an overhead or PowerPoint)

Background:

The geosphere includes the crust and the interior of the planet. It contains all of the rocky parts of the planet, the processes that cause them to form, and the processes that have caused them to change during Earth’s history. There are thousands of parts and processes in the geosphere. It has parts that can be as small as a mineral grain or as large as the ocean floor. Some processes act slowly, like the gradual wearing away of cliffs by the sea. Others are more dramatic, like the violent release of gases and magma during a volcanic eruption.

The fluid spheres are the liquid and gas parts of the Earth system. The atmosphere includes the mixture of gases that surrounds the Earth. The hydrosphere includes the planet’s water system. Its parts include oceans, lakes, rivers, and frozen water in glaciers. A special property of the fluid spheres is that their materials flow. Processes in the fluid spheres include the water cycle, the circulation of the atmosphere and oceans, and weather.

The biosphere contains the living and once-living parts of the Earth system. It is organized into complex webs of microorganisms, animals, and plants. It also includes dead and decomposing living things and special molecules from once-living material. Processes vary from simple predator — prey relationships to changes over millions of years in the kinds of living things that make up communities. This part of the Earth system is distributed widely across the Earth, from the cold dark depths of the oceans, to the thick rainforest near the Equator.

Purpose:

This investigation is designed to help participants make connections between the different components of the Earth System (biosphere, hydrosphere, atmosphere and geosphere) through observing their local outdoor area, categorizing the observations into one or more “spheres”, and drawing links between the spheres.

Safety:

This investigation is considered generally safe to do with students. You will want to have the classroom teacher help you monitor students when you move outside to make observations. However, please review it for the specific setting, materials, students, and conventional safety precautions.

Preparation:

Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period, as well as how many copies of handouts and sets of materials you need to bring.
2. Alert the teacher that this investigation is set up for groups of four and that you will need his/her help when you take the students outside to make observations.
3. Find out what technology is available and make either a PowerPoint or overhead copy of the Earth Systems Concept Map Poster.
4. Collect all the materials in the list below and organize them into one
Chapter 5: Investigations for Different Age Levels

Tool Bag for each group of four students

5. Make photocopies of the handouts. Collect any giveaways for the students, such as posters or Geologic time bookmarks.

6. Run through the investigation yourself and record the data, just to see how long it takes. Adjust the timing to the class period, remembering that you will need time to introduce the investigation, clean up afterwards and re-set up for the next class (if you are working with more than one class).

Investigation Question:

What are the spheres of the Earth System and what parts and processes occur in these spheres?

What to Do:

1. **(5 minutes)** Share your experience as a scientist with the students. Be sure to keep it simple and emphasize how you make observations.

2. **(5 minutes)** Hand out copies of the Earth Systems diagram to each group of three or four participants. Read the diagram over with the participants to make sure that they understand what each system comprises.

3. **(10-15 minutes)** Provide participants with paper. They will be going outside with you to write down as many observations about the outside world as they can. Encourage them to use not just their sight, but also their hearing, and senses of touch and smell as they make their observations. For example, they might not see any birds or insects, but they might hear bird song and insects buzzing. They also might hear the wind through the trees or smell flowers. They can feel the dampness from dew on the grass or hear water flowing. (Ask the classroom teacher to help you with managing the class outside and making sure that students stay on task.)

4. **(5-10 minutes)** When they come back inside, ask them to work in small groups to categorize all their observations into the sphere where they best fit. Caution them that there will be overlap, but not to be concerned about that.

5. **(10-15 minutes)** Next, ask participants to work in their groups to make a poster showing the interaction of the parts and processes of the Earth’s systems, using their observations as specific examples. They could use a concept map format for this, but they should feel free to use their creativity. They might want to use arrows between the different systems, for example, possibly using different colored arrows for positive and negative effects. They could also use Post-it notes to show processes or examples. [Note: An example of one possible poster is attached. You could share this example with the class to give them one idea of how they might want to organize their observations.]

6. **(10-15 minutes)** When each group finishes its poster, they should have the opportunity to present what they have discovered about the parts and processes of the Earth systems and the links between them.

7. **(2 minutes)** Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Earth Systems Diagram
Chapter 5: Investigations for Different Age Levels

Earth Systems Concept Map Poster Example

HYDROSHERE
- Clouds
- Rain
- Fire hydrants

ATMOSPHERE
- Wind
- Air in lungs
- Floating balloon

Evaporates and condenses into clouds

Precipitates as rain

Soil contains water.

Erodes soil

Soil eats away:
- Wood
- Rocks
- Mills

Many plants grow in soil.

Habitat for organisms.

Rotting organisms enrich soil.

Key: Blue = Examples; Red = Parts of systems; Black = Processes
Building and Testing Earthquake-Resistant Structures

Grades 4 - 8

Lesson time:
50-60 minutes (including introduction and clean-up)

Objective:
Students will be able to:
• Discuss how different magnitudes of earthquakes affect structures differently by simulating how buildings become damaged in an earthquake

Materials:
Provide students, in groups of two, with the following:
• 16 4” x 6” (10 x 15 cm) index cards
• Roll of clear plastic tape
• 12” square (30.5 cm) piece of cardboard for a base
• Box of metal paper clips
• Paper and pen to record observations
• Watch with a second hand or stopwatch
• Observation Sheet

Purpose:
Earthquakes are a sudden motion that results from a release of built up energy within the Earth. Seismologists can record the energy (seismic waves) from earthquakes by using an instrument called a seismometer. The greater the amount of energy, the more the needle on the seismometer jumps to make “pulse-like” patterns. When we think of earthquakes, we often think of the damage that occurs as a result of the quake. With many earthquakes, damage to buildings and structures can be devastating.

In this investigation, students will learn how different magnitudes of earthquakes affect structures differently. Depending upon how a structure is built, the damage done to the structure can vary.

Safety:
Participants should put on safety goggles before starting this investigation. Please review it for the specific setting, materials, students, and conventional safety precautions.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period, as well as how many copies of handouts and sets of materials you need to bring.
2. Alert the teacher that this investigation is set up for groups of two.
3. Collect all the materials in the materials list and organize them into one Tool Bag for each group of four students (zip-closing baggie with index cards, roll of plastic tape, cardboard base, paper clips, and stopwatch)
5. Collect any giveaways for the students, such as plate tectonic posters.
6. Run through the investigation yourself and record the data, just to see how long it takes. Adjust the timing to the class period, remembering that you will need time to introduce the investigation, clean up afterwards and re-set up for the next class.

Investigation Question:
How do earthquakes destroy buildings?

What to Do:
1. (5 minutes) Introduce participants to the destruction earthquakes cause by sharing Photos of Earthquakes (from page 41) and discussing how the damage to the building happened. Be sure to accept as many explanations as you can. Some questions you might want to ask are:
   • What happened in this picture? How do you know?
   • What caused the damage to the buildings?
2. (5-10 minutes). Have the classroom teacher help break students up into pairs. Instruct each pair of students to build structures. Participants will:
   • Roll 12 index cards into equal-size tubes and secure them with tape.
   • On the cardboard base, build a model of a four-story building by
using the tubes as pillars and using the remaining index cards as floors and the roof. Do not tape the tubes or cards together, but you should tape the floor of your structure to the cardboard base!

3. **(5-10 minutes)** After all the participants have finished building their structures, instruct participants to shake the base gently for five seconds. Participants should record their observations. Then shake for 10 seconds, 15 seconds, and 20 seconds. Record what you observe after each interval of shaking. This shaking demonstrates a small-scale earthquake and its effect on structures that are not properly reinforced.

4. **(5-10 minutes)** Instruct participants to rebuild the structure as before. Now, repeat your test and shake the base faster and harder than before. Participants should record their observations on their observation sheet. This demonstrates a much larger earthquake and the extensive damage to structures that are not properly reinforced. Discuss results. Be sure to accept as many explanations as you can. Some questions you might want to ask are:
   - Was your building more or less resistant than it was for the first shaking tests? Why was that?
   - How do you think you could make your structure stronger and more stable?

5. **(10-20 minutes)** Rebuild the structure you tested, but this time, use the tape and paper clips to reinforce the structure so that it will not collapse easily. Once you have built your reinforced structure, repeat the tests as before, by first shaking the base gently and then harder and faster. If necessary, add more reinforcing material to make your structure as stable as you can and repeat the shaking tests. Participants should record their observations on the observation sheet. Discuss the results of the simulation. Be sure to accept as many explanations as you can. Some questions you might want to ask are:
   - What did you have to do to your structure to keep it from falling down? What was the most important reinforcement you made and why?
   - What differences did you see in testing the reinforced structure compared to the non-reinforced structure?
   - How can your models resemble and demonstrate what happens to real buildings during an earthquake?
   - If you had to design a building to withstand an earthquake, what would you do to make sure it was strong enough, and why?

6. **(2 minutes)** Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
## Observation Sheet

**Small scale earthquake and structures that are not properly reinforced**

<table>
<thead>
<tr>
<th>Time</th>
<th>Draw or describe what happened to your structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 seconds</td>
<td></td>
</tr>
<tr>
<td>10 seconds</td>
<td></td>
</tr>
<tr>
<td>15 seconds</td>
<td></td>
</tr>
<tr>
<td>20 seconds</td>
<td></td>
</tr>
</tbody>
</table>

**Larger earthquake and structures that are not properly reinforced**

<table>
<thead>
<tr>
<th>Time</th>
<th>Draw or describe what happened to your structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 seconds</td>
<td></td>
</tr>
<tr>
<td>10 seconds</td>
<td></td>
</tr>
<tr>
<td>15 seconds</td>
<td></td>
</tr>
<tr>
<td>20 seconds</td>
<td></td>
</tr>
</tbody>
</table>
## Small scale earthquake and structures that are properly reinforced

<table>
<thead>
<tr>
<th>Time</th>
<th>Draw or describe what happened to your structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 seconds</td>
<td></td>
</tr>
<tr>
<td>10 seconds</td>
<td></td>
</tr>
<tr>
<td>15 seconds</td>
<td></td>
</tr>
<tr>
<td>20 seconds</td>
<td></td>
</tr>
</tbody>
</table>

## Larger earthquake and structures that are properly reinforced

<table>
<thead>
<tr>
<th>Time</th>
<th>Draw or describe what happened to your structure</th>
</tr>
</thead>
<tbody>
<tr>
<td>5 seconds</td>
<td></td>
</tr>
<tr>
<td>10 seconds</td>
<td></td>
</tr>
<tr>
<td>15 seconds</td>
<td></td>
</tr>
<tr>
<td>20 seconds</td>
<td></td>
</tr>
</tbody>
</table>
Chapter 5: Investigations for Different Age Levels

Modeling Convection

Grades 6–12

Lesson time:
30 - 45 minutes

Objective:
Students will be able to:
• Understand how convection moves many Earth processes by simulating the convection process with beets and water

Materials:
For preparation right before starting the activity:
• Knife to pare and cut beets into cubes
• Fresh beets (not canned)

For each student group of two:
• 1 cube of fresh beet
• Metric ruler
• Clear 10 oz plastic cup
• Supply of hot water in foam cup
• Foam cup full of ice cubes
• Paper towels and soap
• Piece of blank white paper
• Pen or pencil

For instructional purposes:
• (optional) Overhead of directions for the convection model.

Background:
Convection is the density-driven movement of a fluid material. Often, convection is driven by either heating from below or cooling from above the fluid. When a liquid is heated, it expands slightly, which makes it less dense. The fluid with lower density rises up, in the same way that a party balloon filled with helium rises up. When the heated liquid reaches cool surroundings, it shrinks, making it density greater. It then sinks down toward where it was first heated.

Many Earth processes are driven by convection. Convection moves ocean currents, weather currents, and tectonic plates.

Purpose:
In this investigation, participants will model convection on a small scale using beets and water.

Safety:
Make sure you cube the beet, so participants will not use the knife. Remind students to wash their hands after they handle the beet.

Preparation:
Before going to the classroom, you will need to:
1. Contact the teacher to find out the length of the class period, as well as how many sets of materials you need to bring.
2. Alert the teacher that this investigation is set up for groups of two.
3. Alert the teacher that you will need an overhead projector (if you decide to use it).
4. Collect all the materials in the materials list and organize them into one Tool Bag for each group of two students
5. Collect any giveaways for the students, such as plate tectonic posters or weather posters.
6. Run through the investigation yourself and record the data, just to see how long it takes. Adjust the timing to the class period, remembering that you will need time to introduce the investigation, clean up afterwards and re-set up for the next class.

Investigation Question:
How does the weather move?

What to Do:
1. (5 minutes) Introduce the concept of convection by starting a short discussion. Be sure to accept as many explanations as you can. Questions you might want to use are:
   • How does the weather move?
   • Why do you think the weather can/cannot move?
   • What evidence do you have that supports your answer?
Chapter 5: Investigations for Different Age Levels

2. **(2 minutes)** Explain to the participants that they will be modeling convection with beets and water.

3. **(2-5 minutes)** Demonstrate what each group will do *(You could put these instructions on an overhead or flipchart so that participants can refer to them as they do their own convection model.)*:
   - Fill the cup 2/3 full of hot water and quickly put a layer of ice cubes on the top. The beet cube needs to go into the cup immediately after the ice goes on.
   - Observe what happens to the color coming from the beet cube.

4. **(2-5 minutes)** Pass out materials to each student pair. Each pair of participants should have a clear plastic cup, paper towels, a 1 cm cube of fresh beet, a supply of ice and a supply of hot water, pen or pencil, and blank piece of paper.

5. **(10-20 minutes)** Instruct participants to start the investigation when they have their materials. Have participants observe what happens to the color coming from the beet cube. Instruct students to draw a picture of what they observe.

6. **(5 minutes)** Discuss the results with the class. Be sure to accept as many explanations as you can. Questions you might want to use are:
   - In which direction does the color move first?
   - What happens when the color hits the layer of floating ice?
   - How well does this model what happens in deep ocean convection?

7. **(2 minutes)** Remind participants to wash their hands when they finish, as the color from beets can stain their skin temporarily. Thank students for their time and attention. You can leave giveaways behind for the classroom teacher to distribute.
Chapter 6: Resources

Web Sites

- AGI’s Education web site (www.agiweb.org/geoeducation.html)
- AAPG’s YEA resources (www.aapg.org/k12resources/index.cfm)
- American Petroleum Institute’s educational materials (www.api.org/classroom/)
- Earth Science Week (www.earthsciweek.org)
- Image Bank (http://www.earthscienceworld.org/images/)
- K-5 GeoSource (www.k5geosource.org)
- Offshore Energy Center (www.oceanstaroec.com/education/education.htm)
- NASA’s Earth Observatory (http://earthobservatory.nasa.gov/)
- National Science Education Standards. (http://books.nap.edu/readingroom/books/nses/)
- Benchmarks for Science Literacy (www.literacynet.org/science/benchmarks.html)
- USGS Educational Resources (http://education.usgs.gov/)

Books


Hassard, J., 1988, Adventures in Geology, Alexandria, Virginia, American Geological Institute


Reports


Chapter 6: Resources

Materials

- Association of American State Geologists (AASG) (www.stategeologists.org/) Good resource for rocks and minerals
- Earth Science World Image Bank (www.earthscienceworld.org/images/) Good resource for Earth science images.
- Water Cycle Poster USGS (ga.water.usgs.gov/edu/watercycle.html)
- NASA teaching materials (search.nasa.gov/search/edFilterSearch.jsp?empty=true)
- USGS teaching materials (education.usgs.gov/)
- EPA teaching materials (www.epa.gov/teachers/order-publications.htm)
- Paleontology Portal (www.paleoportal.org/)