Annenberg/CPB
Professional Development Course Guide

Essential Science for Teachers

Earth and Space Science

An eight-part professional development course for K–6 science teachers

Produced by the Harvard-Smithsonian Center for Astrophysics

Essential Science for Teachers: Earth and Space Science

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About the Course

Course Overview

The story of Earth is a fascinating one, and most of what is known about the Earth has been gathered through observation and interpretation. Children are careful observers of their surroundings and try to make sense of their world from a very early age. As teachers, it is important to encourage students' curiosity, to help them sharpen their observation and interpretation skills, and to share with them the excitement of exploring the Earth and solar system. The challenge is to ensure that their understandings are scientifically accurate. To do this, teachers need to be comfortable with the science content they teach and have their own sound understandings of core science concepts. ***Essential Science for Teachers: Earth and Space Science*** is a content course designed to help K–6 teachers enhance their understandings of "big ideas" in Earth and space science.

This course is composed of eight sessions, each with a one-hour video program addressing an Earth and space science topic that relates to the science curricula taught in elementary school. Posing the question, "What is Earth's structure and its place in the universe?," the course begins by looking at soil, the top layer of the solid Earth. It then explores the nature of the Earth's crust and interior and the changes on Earth's surface that result from tectonic plate movement. Moving on from the solid Earth, the course continues with the study of water and atmosphere, and concludes with an exploration into Earth's cosmic neighborhood, the solar system. Video examples, colorful graphics, lively animations, working models, and other visual strategies are used to bring meaning to the content being addressed.

Earth and Space Science also highlights the ideas that children bring to the classroom. The programs present interviews of children that uncover their ideas about science concepts related to the content of each program, which provides participants the additional opportunity to confront their own science ideas. The programs also feature first- through sixth-grade classrooms in which teachers and students explore Earth and space topics. Connections to current science knowledge are made through interviews with scientists about the ideas they apply in their work on a daily basis.

By exploring topics that range from soil to the solar system, *Earth and Space Science* strives to provide participants the opportunity to increase their science content knowledge, to learn more about students' Earth and space science conceptions, and to develop new understandings of how this content connects to K–6 classrooms.

About the Course, cont'd.

Session Descriptions

Session 1. Earth's Solid Membrane: Soil

How does soil appear on a newly born, barren volcanic island? In this session, participants explore how soil is formed, its role in many Earth processes, its composition and structure, and its place in the structure of the Earth.

Session 2. Every Rock Tells a Story

How can we use rocks to understand events in the Earth's past? In this session, participants explore the processes that form sedimentary rocks, learn how fossils are preserved, and are introduced to the theory of plate tectonics.

Session 3. Journey to the Earth's Interior

How do we know what the interior of the Earth is like if we've never been there? In this session, participants examine the internal structure of the Earth and learn how it is possible for entire continents to move across its surface.

Session 4. The Engine That Drives the Earth

What drives the movement of tectonic plates? In this session, participants learn how plates interact at plate margins, how volcanoes work, and the story of Hawaii's formation.

Session 5. When Continents Collide

How is it possible that marine fossils are found on Mount Everest, the world's highest continental mountain? In this session, participants learn what happens when continents collide and how this process shapes the surface of the Earth.

Session 6. Restless Landscapes

If almost all mountains are formed the same way, why do they look so different? In this session, participants learn about the forces continually at work on the surface of the Earth that sculpt the ever-changing landscape.

Session 7. Our Nearest Neighbor: The Moon

Why is the Moon, our nearest neighbor in the solar system, so different from the Earth? In this session, participants explore the complex connections between the Earth and Moon, the origin of the Moon, and the roles played by gravity and collisions in the Earth–Moon system.

Session 8. Order out of Chaos: Our Solar System

Why do all the planets orbit the Sun in the same direction and why are the planets closest to the Sun so different from the gas giants farther out? In this session, participants gain a better understanding of the nature of the solar system by examining its formation.

About the Course, cont'd.

Featured Classrooms

Session 1. James Buchanan Elementary School, Lancaster, Pennsylvania

Tim Mackey's fifth graders generate ideas about the depths of soil layers and what lies beneath them. They investigate soil samples to learn about the elements of soil, and look for clues in the soil to determine the type of environment the soil was collected from.

Session 2. Silver Lake Elementary School, Middletown, Delaware

Laurie Wicks' third graders conduct a fossil investigation. They gather information on fossil specimens and speculate on how fossils form.

Session 3. The Epiphany School, Dorchester, Massachusetts

Keedar Whittle leads sixth graders on an exploration into seismic waves and the structure of the Earth. Using Slinkys and Silly Putty, students learn about the kinds of seismic waves that originate during earthquakes and what they can tell us about the Earth. They also discover the properties of solids that flow, to better understand how it is possible for tectonic plates to move.

Session 4. The Epiphany School, Dorchester, Massachusetts

We again join Keedar Whittle to observe his sixth graders as they conduct an investigation into plate boundaries and plate movement. The students examine models of how plates behave at their margins, and learn about one mechanism of plate movement.

Session 5. Goddard School of Science and Technology, Worcester, Massachusetts

Duke Dawson guides fifth graders as they think about the shapes on the Earth's surface, called landforms, and the forces that sculpt them. The students grapple with the question of how mountains form and explore a model for mountain building.

Session 6. Quashnett Elementary School, Mashpee, Massachusetts

Fifth graders work with science consultant Barbara Waters to confront their ideas about underground water supplies. The students draw their initial ideas of what it looks like underground and where water goes after it rains. After manipulating two models for landscape and groundwater, students revisit their initial pictures to see how their thinking has changed.

Session 7. Naaba Ani Elementary School, Bloomfield, New Mexico

Kathy Price's fifth graders learn about angular size and think about the scale of the Earth-Moon system. Her students model the sizes of the Earth and the Moon and the distance between them.

Session 8. Charlotte A. Dunning Elementary, Framingham, Massachusetts

Carol Berlin's third graders take a tour of the planets as they learn about the scale of sizes and distances within our solar system. Students use scale models of the planets and create a schoolyard model of the solar system.

Course Components

On-Site Activities

Essential Science for Teachers: Earth and Space Science consists of eight sessions (see Note below), each of which includes group activities and discussions as well as an hour-long video program.

Weekly sessions, which should be scheduled for approximately three hours, may be scheduled around live broadcasts, in which case you will want to begin at least 60 minutes before the scheduled broadcast. You may prefer to pre-record the programs on videocassette and schedule the sessions at a time that is more convenient for all participants and that would allow you to stop and restart the video as you discuss it.

This guide provides activities and discussion topics for pre- and post-viewing investigations that complement each of the eight one-hour video programs.

Getting Ready (Site Investigation)

In preparation for watching the program, you will engage in 60 minutes of investigation through discussion and activity.

Viewing the Program

Then you will watch the 60-minute video, which includes classroom footage, commentary, science demonstrations, and more.

Going Further (Site Investigation)

Wrap up the session with an additional 60 minutes of investigation through discussion and activity.

Note: See the Graduate Course Requirements section for suggestions for scheduling the eight programs into an intensive 15-week course.

Between Sessions

Homework Assignments

Each session will contain the following homework activities. All participants should complete the assignments marked with *—the Reading Assignment, the Problem Set, the Ongoing Concept Mapping, and Preparing for the Next Session. Participants taking the course for graduate credit must complete all of the listed assignments, including those described in the Graduate Course Requirements section.

Note: Required Hours for Graduate Credit

If you are taking this course for graduate credit, the complete set of homework activities has been designed to fulfill the additional three hours required per session. The time taken to complete each assignment will vary among individuals, so no time estimates have been given. Each assignment will result in some form of evidence of learning. This evidence may be useful in building a portfolio for course assessment purposes.

*Reading Assignment

Reading assignments will expose you to research on children's ideas about Earth and space science and reinforce your understanding of the science content included in each of the sessions. Readings will be discussed at the session that follows their assignment. The readings can be found in the Appendix.

Course Components, cont'd.

*Earth and Space Science Problem Set
Each session will be accompanied by a problem set that will reinforce content learning by asking questions that apply or extend Earth and space science concepts addressed in the video. Possible answers for the problem set will be provided at the end of the session materials. It should be emphasized that many questions have a variety of answers—answers that vary depending on the understandings of the person answering the question. The intent is not to give you "right answers," but to allow you to compare yours with more advanced learners in physical science.

*Ongoing Concept Mapping
Within each session, several fundamental concepts are explored. Creating a set of concept maps will provide you with an opportunity to reflect on your understandings of these concepts and their connections to one another as well as to see how the content in each session relates to that of other sessions. A more detailed explanation of concept mapping is included in Session 1.

Guided Journal Entry
As you proceed through this course, one way of building and connecting understandings is to reflect upon your learning as you go. In each session, one or more questions will be suggested to guide a journal entry. At the end of the course, these entries should help you see how your ideas have progressed.

Guided Channel-Talk Posting
Although this is a course designed to help enhance your understandings of life science concepts, the intention is for you to use this knowledge to inform your teaching. Often, a community of learners who are also teachers can collaborate to support one another in transforming content knowledge into successful classroom action. In each session, one or more questions will be suggested to guide a discussion on Channel-Talk to facilitate this type of collaboration among participants.

Suggestions for Textbook Reading
We strongly recommend that you acquire introductory college-level texts in both geology and astronomy to refer to in this course. Reading topics will be listed in each session, and can be located in most textbooks in the Table of Contents or Index.

*Preparing for the Next Session
This section will get you thinking about upcoming topics and remind you to bring materials needed for the next session's activities.

Ongoing Activities
The following are activities that you should work on between sessions for the duration of the course:

Course Web Site: www.learner.org/channel/courses/essential/earthspace
Go online for additional activities and resources.

Channel-Talk
You can communicate with other course participants throughout the country via the course's email discussion list. To subscribe to Channel-TalkEarthSpace, visit www.learner.org/mailman/listinfo/channel-talkearthspace.

Graduate Course Requirements

Graduate Course Assignments

The *Essential Science for Teachers: Earth and Space Science* professional development course is designed to be a three-credit graduate-level course for teachers. For more information about how to obtain graduate credit, visit the Annenberg/CPB homepage at www.learner.org.

To be eligible for graduate credit, participants must complete the following projects in addition to all of the regular course activities and assignments. Homework assignments should take approximately three hours per week to complete.

Annotated Bibliography

Prepare an annotated bibliography of a minimum of 25 resources, which can include articles given as reading assignments. Readings can relate to Earth or space science content, conceptual change, constructivism, or inquiry teaching and learning. Each entry in the bibliography should include the bibliographical information on the resource, a summary of the content in the reading, and notes on ideas you find helpful or interesting.

Action Research Project

Action research is an effective method of professional development that seeks to improve teaching practices, expand a teacher's knowledge base, and improve the quality of student learning. Your action research project should address new understandings that developed through this course, and how they relate to your classroom practice. As part of your project, maintain a research diary that documents your experiences as you implement new practices in your classroom. Your diary might contain research data, explanatory comments, information on students gathered from classroom interactions or interviews, written reflections, ideas and insights, and/or recommendations for improving practice.

The second component of the project is a final paper, minimally 10 pages in length, double spaced, using 10- or 12-point fonts, that summarizes your findings, reflects on the research process, outlines your professional development during your research, and makes recommendations for improving future practice. Additional readings to support your action research are recommended.

Refer to the Appendix for the Action Research Guide, which provides week-by-week directions for conducting your project as well as a list of recommended readings on the action research process.

Portfolio

Create a portfolio evidencing your work for the course. The portfolio might be divided into the following sections: action research diary and final paper; journal, which includes guided entries and reflective entries; annotated bibliography; and homework assignments. Additional sections may be added at your discretion.

Geology and Astronomy Texts

It is *strongly* recommended that participants acquire introductory college-level geology and astronomy texts. Suggested readings will be listed for the science topics being addressed in each session.

Graduate Course Requirements, cont'd.

Graduate Course Assessment

The successful participant will:

- Attend and actively participate in all class sessions
- Come prepared to class sessions, having completed all reading and homework assignments
- Assemble a course portfolio with all required components present
- Create journal entries that demonstrate an in-depth understanding of relevant concepts and processes, reflect on new learning, and communicate ideas clearly
- Prepare an action research diary that exhibits well-organized thoughts and insightful interpretations and extensions
- Write an action research final paper that meets length and organization requirements and evidences growth in developing research skills
- Compile an annotated bibliography that contains a minimum of 25 resources with the required bibliographical information, summaries, and comments

Scheduling Course Sessions

Below are recommended options for scheduling credit and non-credit class meetings, based on how participants are viewing the video programs. Because of the amount and kinds of work associated with a graduate-level course, it is recommended that participation in the course for credit be over a 15-week period. "Work weeks" are scheduled to allow participants time to work on their assignments required for graduate credit.

Option One: **Viewing the Programs Recorded on Tape or on Learner.org's Video on Demand (VoD) (for Graduate Credit)**	
Week 1	View Program 1 and complete assignments
Week 2	View Program 2 and complete assignments
Week 3	Work Week
Week 4	View Program 3 and complete assignments
Week 5	View Program 4 and complete assignments
Week 6	Work Week
Week 7	View Program 5 and complete assignments
Week 8	View Program 6 and complete assignments
Week 9	Work Week
Week 10	View Program 7 and complete assignments
Week 11	View Program 8 and complete assignments
Weeks 12–15	Complete long-term coursework: assemble portfolio components, action research project and paper, and annotated bibliography
Option Two: **Viewing the Programs Live in Real Time on the Annenberg/CPB Channel (for Graduate Credit)**	
Week 1	View Program 1 and complete assignments
Week 2	View Program 2 and complete assignments
Week 3	View Program 3 and complete assignments
Week 4	View Program 4 and complete assignments
Week 5	View Program 5 and complete assignments
Week 6	View Program 6 and complete assignments
Week 7	View Program 7 and complete assignments
Week 8	View Program 8 and complete assignments
Weeks 9–15	Complete long-term coursework: assemble portfolio components, action research project and paper, and annotated bibliography

Scheduling Course Sessions, cont'd.

Option Three: **Viewing the Programs Recorded on Tape or Live in Real Time (Not for Graduate Credit)**	
Week 1	View Program 1 and complete assignments
Week 2	View Program 2 and complete assignments
Week 3	View Program 3 and complete assignments
Week 4	View Program 4 and complete assignments
Week 5	View Program 5 and complete assignments
Week 6	View Program 6 and complete assignments
Week 7	View Program 7 and complete assignments
Week 8	View Program 8 and complete assignments

About the Site Investigations

Helpful Hints

Included in the materials for each session you will find detailed instructions for the content of your Getting Ready and Going Further activities (Site Investigations). The following hints are intended to help you and your colleagues get the most out of these pre- and post-video discussions.

Designate a Facilitator

Each week, one person should be responsible for facilitating the Site Investigations (or you might select two people—one to facilitate Getting Ready, the other to facilitate Going Further). We recommend that participants rotate the role of facilitator on a weekly basis.

Review the Site Investigations and Bring the Necessary Materials

Be sure to read over the Getting Ready and Going Further sections of your materials before arriving at each session. The Site Investigations will be the most productive if you and your colleagues come to the sessions prepared for the discussions. A few of the Site Investigations require special materials (see the following page). The facilitator should be responsible for bringing these when necessary.

Note to Facilitators: Remind participants that there is an assignment to be completed prior to Session 1. Details are listed in the Session 1 materials, in a section titled Before Session 1.

Keep an Eye on the Time

Sixty minutes go by very quickly, and it is easy to lose track of the time. You should keep an eye on the clock so that you are able to get through everything before the course video begins. (Sites that are watching the course on videotape will have more flexibility if their Site Investigation runs longer than expected.)

About the Site Investigations, cont'd.

Record Your Discussions

We recommend that someone take notes during each site discussion, or, even better, that you make an audiotape recording of the discussions each week. These notes and/or audiotape can serve as make-up materials in case anyone misses a session.

Share Your Discussions on the Internet

The Site Investigations are merely a starting point. We encourage you to continue your discussions with participants from other sites on Channel-TalkEarthSpace, the course email discussion list.

Materials

Facilitators should bring the listed materials to the course sessions.

General Materials

During each session, different activities may require various supplies for writing, displaying, and conducting activities. These may be provided at your location, or you may wish to bring a set of supplies for the course.

- Writing/drawing paper (8.5-in. x 11-in.)
- Chalk or dry-erase markers
- Tape
- Scissors
- Paper towels
- Sticky notes of various colors
- Markers and crayons

Specialized Materials

Essential Science for Teachers: Earth and Space Science is designed to require few specialized materials. The following is a list of items that are not required but may enhance session activities:

- Rock collection specimens
- Fossil specimens

Individual Session Materials

Session 1. Earth's Solid Membrane: Soil

- Samples of two different soils (see Note, next page) (1.5 cups in volume per pair)
- Magnifying glass (1 per pair)
- Tall cylindrical glass jars with lids (2 per pair)
- Wooden coffee stirrers (2 per pair)
- Egg carton tops (1-dozen size), plastic or foam (2 per pair)
- Wide, flat bowls (2 per pair)

About the Site Investigations, cont'd.

Note: Find two different locations from which to take the soil. The following are possible locations from which to take your samples:

- Wooded areas
- Gardens or farms
- Parks, athletic fields, or playgrounds
- Construction sites
- Deserts or beaches for a sandy soil
- Water environments, such as on the shores of lakes, ponds, or rivers

Session 2. Every Rock Tells a Story

- Magnifying glass (1 per pair)
- Small container for water (1 per pair)

Session 3. Journey to the Earth's Interior

- Slinkys® (1 per pair)
- Silly Putty® (1 container per pair)

Session 4. The Engine That Drives the Earth

- No materials need to be brought by the facilitator.

Session 5. When Continents Collide

- Playdough in three different colors (see Note below) (1/2 cup in volume of each color per pair)
- Waxed paper (80 cm per pair)

Note: Playdough recipes are listed in many books and can also be easily found on the Internet.

Session 6. Restless Landscapes

- Magnifying glass (1 per pair)
- Plastic container with lid (1 per pair)
- Waxed paper (80 cm per pair)
- Broadsheet newsprint paper (18-in. x 24-in.) (1 sheet per pair)
- Sand (1/4 cup per pair)
- Ice cubes (2 per pair)

Session 7. Our Nearest Neighbor: The Moon

- Large balloons (2 per pair)

Session 8. Order out of Chaos: Our Solar System

- Rulers (1 per pair)
- Broadsheet newsprint paper (18-in. x 24-in.) (2 per pair)

About the Contributors

Course Developer

Chris Irwin, Ed.D. c.

After graduating from the State University of New York system with a B.S. in elementary education, Chris worked in private and public education in Vermont for 13 years. After obtaining an M.S. in K-8 math and science education from the Massachusetts College of Liberal Arts in North Adams, Massachusetts, she stayed on as a faculty member in the education department, teaching early childhood and elementary curriculum courses and mathematics and science methods courses to preservice and inservice teachers. During this time, Chris held visiting instructor status at the University of Massachusetts, Amherst, and served as an educational researcher on several science education projects. After teaching college for nine years, Chris joined the education staff at the Science Discovery Museum in Acton, Massachusetts, and maintains an affiliation with the museum. Chris is currently an Ed.D. candidate at the University of Massachusetts, Amherst, studying inquiry-based teaching and learning and children's science conceptions.

Onscreen Guides

Brittina A. Argow, M.S.

Britt Argow received her B.A. in British literature with a minor in geology from the College of William and Mary. She worked as a nursery school teacher before pursuing an M.S. in geology at Stanford University, focusing on coastal sedimentology and micropaleontology. While there, she was involved with the Center for Teaching and Learning, where she developed workshops to better prepare teaching assistants in science and engineering. After graduate school, Britt accepted an assistant professorship at Westchester Community College in New York, where she taught earth science, oceanography, and physical geography. She received recognition for her innovative approach to science education, employing and developing new curricula, teaching, and testing methods. Britt has also worked for the National Park Service, where she specialized in public education and developing new science education curricula, for the United States Geological Survey, and as a consulting geologist. She has recently returned to graduate school at Boston University and is pursuing a Ph.D. in coastal geology as a National Science Foundation Graduate Research Fellow.

F. Joseph Reilly

After earning a B.S. in elementary education from Boston University, Joe Reilly has spent his entire professional career as an educator of children and adults. Joe is a master teacher with more than 25 years of experience teaching kindergarten, first, and second graders in the Greater Boston area. He was a Fulbright Teaching Fellow, spending a year abroad in Oxfordshire, England, and received a grant to travel to Cuba to study literacy achievement. Along with teaching elementary students, Joe currently teaches preservice and inservice teachers in the School of Education at Boston College, and supervises student teachers as well. Joe has been an on-camera teacher for the McGraw Hill *Educational Psychology Series* as well as for the *Teaching Math Library* for Annenberg/CPB. Joe is also a consultant and pilot teacher for TERC, a non-profit education research and development organization dedicated to improving mathematics, science, and technology teaching and learning.

Julie Libarkin, Ph.D.

Dr. Julie Libarkin is currently a member of the faculty of the geology department at Ohio University in Athens, where she teaches undergraduate geology courses. She has done extensive science study, starting at the Thomas Jefferson High School of Science and Technology in Alexandria, Virginia. Julie next completed a B.S. at the College of William and Mary with a dual focus on geology and physics, and went on to earn a Ph.D. in geosciences at the University of Arizona at Tucson. Moving to a research position at the science education department of the Harvard Smithsonian Center for Astrophysics in Cambridge, Massachusetts, she was granted several National Science Foundation postdoctoral fellowships in science, mathematics, engineering, and technology education. Julie conducts research on mountain building processes, cosmogenic isotopes, student conceptions, cognition, and assessment, and publishes numerous articles on these subjects.

About the Contributors, cont'd.

Scientists

Oliver Chadwick, Ph.D.

Dr. Chadwick is one of the world's leading scientists in relating soils to ecology and Earth system science. He is a joint professor in the geography department and environmental studies program at the University of California, Santa Barbara. His work for the department of geography is in the areas of soil sciences: soil formation and advanced classification and evolution of soil landscapes. Dr. Chadwick's research interests include soil classification, the evolution of soil landscapes, soil geochemistry, quaternary geology (the study of the Earth over the last 1.6 million years), and interactions between soil, atmosphere, water, and vegetation. His current work includes the Hawaii Ecosystems Project, utilizing Hawaii as a model ecosystem to understand changes in soil and the sources of nutrients to rainforests.

Carol de Wet, Ph.D.

Dr. Carol de Wet is an associate professor in the geosciences department at Franklin and Marshall College in Lancaster, Pennsylvania. There she teaches courses in geology, specifically sedimentology (sedimentary rocks and their formation), coral reef geology, and environmental geology. Dr. de Wet also works one-on-one with students, mentoring them in their individual research and publication efforts. Her personal research interests are in sedimentology and geochemistry. Dr. de Wet has done extensive research on carbonate deposits, submarine processes of rock cementation, sedimentary rocks in lacustrine (lake) environments, paleoclimates (ancient climatic conditions), and plate tectonics. Dr. de Wet was a recipient of the Geological Society of America Donald L. & Carolyn N. Biggs Earth Science Teaching Award in 2000.

R. Hank Donnelly, Ph.D.

Dr. R. Hank Donnelly is a research astrophysicist at the Harvard-Smithsonian Center for Astrophysics. He studies the formation of clusters of galaxies to learn more about the formation and evolution of structure in the universe. Dr. Donnelly is also a specialist in astronomical instruments and he is the calibration scientist for the High Resolution Camera at the CHANDRA X-ray Center. He is active in improving science education and literacy and brings astronomy to elementary and middle school classrooms through Project Astro, as well as teaching undergraduate astronomy at Harvard University. He received his Ph.D. from the University of California, Santa Cruz, in 1993. He is an outdoor enthusiast and he enjoys playing lacrosse and scuba diving.

Scott J. Kenyon, Ph.D.

Dr. Scott J. Kenyon is a senior astrophysicist at the Harvard-Smithsonian Center for Astrophysics. Dr. Kenyon's research focuses on the formation and evolution of stars and planets. His Ph.D. dissertation on symbiotic stars was expanded into a monograph and still remains the primary reference in the field. Dr. Kenyon's research lies at the boundary between observations and theory: He uses observations to test theories and theories to make predictions, which in turn can be tested with observations. His recent work includes the formation of Kuiper Belt Objects like Pluto. He is the author or co-author of more than 100 peer-reviewed scientific papers. And he is a member of several academic societies including the American Association for the Advancement of Science, the American Astronomical Society, and the International Astronomical Union. He received the Copernicus Medal from the Nicolaus Copernicus University in 1987, and in 1995 shared the Hoopes Prize of Harvard University with Jane Luu and Sarah T. Stewart. He is a fellow of the American Association for the Advancement of Science.

Keith Klepeis, Ph.D.

Dr. Keith Klepeis is a structural geologist in the department of geology at the University of Vermont. Prior to that, he was a lecturer in structural geology (the study of the geological processes that deform the Earth's crust and create mountains), field geology (the methodology of field investigations), and plate tectonics at the University of Sydney in Australia. Dr. Klepeis was a National Science Foundation Postdoctoral Fellow at Bryn Mawr College and Princeton University, working on tectonic problems in Alaska and coastal British Columbia. Keith's current research centers on examining interactions between rock deformation, metamorphism, magmatism, tectonic plate motions, processes at plate boundary zones, and orogenic (mountain building) systems. His interests are diverse, but focus on the structure and evolution of convergent, divergent, and transform plate boundaries, orogenic belts, and fault systems.

About the Contributors, cont'd.

Andy Kurtz, Ph.D.

Dr. Kurtz is an assistant professor at Boston University in the department of Earth sciences. His research involves studying the geochemistry of Earth's surface; Earth history; global cycles of carbon, sulfur, and silicon; and the evolution of Earth's surface environments throughout geologic time. Particular areas of interest include understanding the connections between terrestrial and marine processes, and the relationship between silicate weathering and climate. Ongoing collaborative research projects use the Hawaiian islands as a "natural laboratory" to study geochemical, soil, and ecological processes. For several years he has been involved in a multidisciplinary project with Oliver Chadwick (see above) developed by leaders in the fields of soil science, ecology, and geochemistry. The Hawaii Ecosystems Project uses the Hawaiian islands to examine the evolving relationship between ecosystem function, soil development, and weathering based on a series of sites ranging in age from a few hundred to several million years old.

Myron Lecar, Ph.D.

Dr. Myron Lecar has been a lecturer in astronomy at the Harvard-Smithsonian Center for Astrophysics since 1965. He attended the Massachusetts Institute of Technology as an undergraduate and received his Ph.D. from Yale University in 1963. He was one of the founding members of the NASA Institute for Space Physics at Columbia University, while he was a graduate student at Yale. In 1972, he was involved in building the first astronomical observatory in Israel. Dr. Lecar's research interests include gravitational dynamics, planet formation, and the dynamics of our solar system. He has authored or co-authored more than 90 scientific articles. A paper he wrote with Dr. Paul Gorenstein and Dr. Daniel Farbricant, his colleagues at the Harvard-Smithsonian Center for Astrophysics, was included as one of 50 path-breaking papers of the twentieth century in the centennial edition of the American Astronomical Society. He currently works with Dr. Dimitar Sasselov and Dr. Matt Holman on planets orbiting other stars.

Elissa Levine, Ph.D.

Dr. Levine has been studying soil properties since the 1970s. She is a soil scientist at the NASA Goddard Space Flight Center in Greenbelt, Maryland. There, using satellite imagery, computer technology, and fieldwork data, she studies ecosystems, focusing on the role soils play in ecosystems in order to better understand how soils affect and are affected by climate, acid rain, land use, and other processes. Dr. Levine is also the principal soil scientist for GLOBE (Global Learning and Observations to Benefit the Environment). GLOBE, an international program for students from kindergarten through 12th grade, promotes partnerships between students and scientists. Dr. Levine is the recipient of the 2003 Association of Women Soil Scientist Mentoring Award for her work with the Soil Characterization Investigation at the GLOBE Program and her ongoing efforts to educate youth about soil science.

Michael Manga, Ph.D.

Dr. Michael Manga is an associate professor of Earth and planetary science at the University of California at Berkeley. He received his B.S. in geophysics from McGill University in Montreal, and his Ph.D. in Earth and planetary science from Harvard University in 1994. Dr. Manga studies a wide range of geologic phenomena including fluid mechanics, hydrology, and physical volcanology, all in order to better understand planetary evolution. He and his collaborators study geological processes by devising models that compress geological time scales from billions of years to hours. He has authored or co-authored more than 75 peer-reviewed scientific papers. He is a fellow of the Geological Society of America, and the recipient of numerous medals and awards for achievements in research and teaching.

About the Contributors, cont'd.

Ursula B. Marvin, Ph.D.

Dr. Ursula B. Marvin is a senior geologist emerita of geology and historian of science at the Harvard-Smithsonian Center for Astrophysics. She studied history as an undergraduate at Tufts University and earned masters and doctorate degrees in geology from Harvard University. From 1952 to 1958, Dr. Marvin and her husband, a mining geologist, spent six years in Brazil and Angola examining mineral deposits. Between 1978 and 1985, she spent three field seasons in Antarctica, two of them collecting meteorites and one sampling the Cretaceous-Tertiary boundary for evidence of the impact that is thought to have triggered the extinction of the dinosaurs 65 million years ago. Dr. Marvin is the author of more than 120 scientific articles and a book titled *Continental Drift, the Evolution of a Concept*. *Asteroid Marvin* was named for her in 1991 by the Minor Planet Bureau of the International Astronomical Union, and *Marvin Nunatak*, a mountain peak in Antarctica, was named in her honor in 1992. Dr. Marvin officially retired in 1998, but continues her research. She is also active in resolving problems in undergraduate education, especially the personal and professional problems women face pursuing careers in science.

Harrison H. Schmitt, Ph.D.

Dr. Harrison H. Schmitt received his doctorate in geology from Harvard University in 1964 and went to work with astrogeologist Eugene Shoemaker at the United States Geological Survey developing lunar field geological methods and mapping the surface of the Moon. In 1965, he was selected into NASA's scientist-astronaut training program and in 1972, he became the first scientist-astronaut to walk on the Moon. Dr. Schmitt was the lunar module pilot on Apollo 17. He and Gene Eugene Cernan, the Commander, spent 22 hours and 4 minutes on the lunar surface. In 1975, Dr. Schmitt resigned from NASA to serve as one of New Mexico's senators for one term. He is currently an adjunct professor of engineering physics at the University of Wisconsin in Madison.

David Sherrod, Ph.D.

Dr. David Sherrod is a volcanologist with the United States Geological Survey (USGS). He received his Ph.D. from the University of California at Santa Barbara. He was stationed at the USGS Cascade Volcano Observatory in Vancouver, Washington until 1996, when he transferred to the USGS's Hawaii Volcano Observatory on the big island of Hawaii. In 2004, he returned to the Cascade Volcano Observatory. Dr. Sherrod's recent research focuses on the evolution of the Hawaiian volcanoes after they traveled over hot spots.

Sarah T. Stewart, Ph.D.

Dr. Sarah T. Stewart is an assistant professor of planetary science in the department of Earth and planetary sciences at Harvard University. She received her A.B. in astronomy and astrophysics and physics from Harvard University in 1995. In 2002, she earned her Ph.D. in planetary science from the California Institute of Technology. Dr. Stewart's research interests include collisional processes, planet formation, and the evolution of planetary surfaces. She is the director of the Shock Compression Laboratory at Harvard University, where she conducts impact experiments on planetary materials to simulate large impact events and collisions in the solar system.

John A. Wood, Ph.D.

Dr. John A. Wood is a senior scientist of planetary and lunar science at the Harvard-Smithsonian Center for Astrophysics. He received his Ph.D. in geology from the Massachusetts Institute of Technology in 1958. Dr. Wood's research interests include the study of primitive planetary material, and meteorites in particular. He also works on the origin of planets and our solar system. He was part of a team of scientists who first theorized that rocky planetary bodies start out molten and cool over time. This idea is known as the magma ocean hypothesis and grew out of Dr. Wood's research on the lunar samples returned by the Apollo missions. Over the course of his career, Dr. Wood has served as an advisor to many NASA missions and programs and authored or co-authored over 150 scientific papers on planetary science topics.

Instructional Materials Appearing in the Course

FOSS: Full Option Science System

Lawrence Hall of Science

The K–6 Full Option Science System (FOSS) is a researched-based, classroom-tested science program consisting of 27 units across Earth, physical, and life science, as well as scientific reasoning and technology topics. The FOSS science program originally began at the Lawrence Hall of Science as a science enrichment program. Over the past 20 years, with the support of the National Science Foundation and the University of California at Berkeley, the program has evolved into a total curriculum for students grades K–6.

The FOSS science program was designed to engage students in learning important science concepts and developing the ability to construct ideas through their own inquiries, investigations, and analyses as they explore the natural world. FOSS investigations are crafted to guarantee that the cognitive demands placed on students are appropriate for their cognitive abilities. Developmental appropriateness and in-depth exposure to subject matter with multiple experiences provides challenges for all students and results in a much deeper understanding of the subject.

The scientific thinking processes guide the selection of content for FOSS. The thoughtful introduction of science concepts and the careful sequencing of ideas result in a curriculum that leads to the learning of science with understanding by all students.

For more information, contact Delta Education, Inc.; 1-800-258-1302; http://www.deltaeducation.com/-teachers/science/foss.html

ARIES: Astronomy Based Physical Science

Harvard-Smithsonian Center for Astrophysics

ARIES is an astronomy based curriculum consisting of eight learning modules addressing important concepts of basic astronomy such as time, light, color, motion, waves, energy and their interrelations, for students in grades 3-8. ARIES was developed at the Harvard-Smithsonian Center for Astrophysics, funded by the National Science Foundation, and created with support from Harvard University and The Smithsonian Institution.

The primary educational objective of ARIES is to help children learn how nature behaves, and to use models to predict nature's behavior. During hands-on explorations, students uncover their prior knowledge, pose questions and make predictions, and construct models of nature based on their observations. The ARIES curriculum helps learners develop deep conceptual understanding of important scientific principles.

The ARIES curriculum builds on the curiosity and interest stimulated by students' personal experiences with astronomical phenomena using innovative, simple, and affordable materials. Through discovery-based explorations, students gather evidence from experiences with equipment they construct. With ARIES, students use the processes of observing, describing, recording, modeling, and predicting to rethink their personal theories about the natural world.

For more information contact Charlesbridge Publishers; 1-800-225-3214; http://www.charlesbridge.com/-school/aries.htm.

Instructional Materials Appearing in the Course, cont'd.

WISE: The Web-based Inquiry Science Environment

University of California at Berkeley

The Web-based Inquiry Science Environment (WISE) is a free online science learning environment for students in grades 4 through 12, supported by the National Science Foundation. The WISE learning environment is built on the foundation of the Computer as Learning Partner (CLP) and Knowledge Integration Environment (KIE) Projects. WISE curriculum projects are written by partnerships of researchers, teachers, and natural scientists.

Projects consist of a sequence of activities during which students critique Web evidence, compare arguments about a current scientific controversy, or design a solution to an environmental problem. WISE projects are designed to support students as they explore current science controversies and design solutions to scientific problems. WISE projects are built to facilitate deep interactions among students and between students and teacher, about students' science ideas.

In the WISE learning environment, students collaboratively perform knowledge integration activities that help them add new ideas to their repertoire and reorganize their ideas to create a coherent understanding. Questions and evidence in the project are designed to challenge students' prior ideas. Students work in pairs, and activities often call upon students to explain evidence to one another. Internet materials and learning environment technology help students reflect on relevant topics to build their own understanding.

For more information go to http://wise.berkeley.edu.

Scholastic Science Place: Hands-On Science Series

Scholastic, Inc.

Scholastic Science Place is a Kindergarten through sixth grade hands-on science curriculum. This science curriculum consists of 42 units that encompass Earth, physical and life science topics. Each K–6 unit is co-developed by Scholastic with a nationally recognized museum or science center.

Three major themes organize the units of study: scale and structure, systems and interactions, and patterns of change. Each of the units contains learning experiences in which teachers guide student investigation. Lessons provide opportunities for students to use critical thinking and model making as they explore core science concepts. Lesson activities are designed to help students appreciate diverse perspectives and develop science literacy.

The Scholastic Science Place series manuals supply teachers with information about the typical ideas children bring to the classroom regarding unit content, as well as providing opportunities for students to examine their own ideas about the world. Students learn science content and process knowledge through active, investigative experiences developed to be in alignment with the National Science Education Standards and the Benchmarks for Science Literacy.

For more information, contact Scholastic, Inc.; 212-343-6100 or 1-800-Scholastic.

Instructional Materials Appearing in the Course, cont'd.

Watershed to Bay: A Raindrop Journey

University of Massachusetts Cooperative Extension System

"Watershed to Bay: A Raindrop Journey" curriculum unit is designed for students in grades 4 through 8. The focus of the science content in this unit centers on groundwater, watershed systems, and related geology content. It was developed with funds from the University of Massachusetts, the United States Department of Agriculture, and the Massachusetts Bays Program.

Critical and creative thinking strategies are the framework for building understanding of the science content embedded in the Raindrop Journey unit. The activities integrate interdisciplinary themes, hands-on experiences, and the use of models to link familiar ideas to new learning. During the unit, students visualize a raindrop moving through a watershed, using a series of hands-on models to discover and understand what happens to rain or snowmelt when it seeps underground in a watershed. Students also learn how the geology of an area affects the path a raindrop would take to get to the ocean.

The approach to learning utilized in this unit uses creative and critical thinking tasks developed specifically to assist students in examining the ideas they hold regarding concepts addressed in this unit. Students use models made from common materials to expose their pre-instructional ideas. Children spend time drawing and discussing their ideas before and after instruction, and think and talk about how their ideas have changed.

For more information contact The University of Massachusetts Cooperative Extension System, Stockbridge Hall, University of Massachusetts, Amherst, Amherst, MA 01003-0099.

Project Earth Science: Geology

National Science Teachers Association

Project Earth Science: Geology is part of a four volume series designed for students in grades 5 through 10, funded by the National Science Foundation. Project Earth Science was originally conceived as a program in leadership development to prepare middle school science teachers to lead workshops on Earth science topics.

Project Earth Science: Geology is designed based on the theory of plate tectonics; a theory that unifies our understanding of geologic features and processes such as volcanoes, earthquakes, the structure of the Earth, the rock cycle, apparent continental drift, and the movement, creation and destruction of lithospheric plates. The Project Earth Science activities were field tested over a two-year period in professional development workshops and classrooms across the country.

The activities are designed to address fundamental geology concepts. Students participating in these activities will conduct investigations, create models, learn how scientific knowledge is created and how it evolves.

For more information contact NSTA Press, 1840 Wilson Boulevard, Arlington, VA 22201-3000; 1-800-277-5300; http://www.nsta.org.

Standards

National Science Education Standards

National Research Council (NRC)

Earth and Space Science Content Standards: K-4

http://bob.nap.edu/readingroom/books/nses/html/6c.html#es

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, 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 and 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 temperatures 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.
- Objects in the sky have patterns of movement. The Sun, for example, appears to move across the sky in the same way everyday, 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.

Earth and Space Science Content Standards: 5-8

http://bob.nap.edu/readingroom/books/nses/html/6c.html#es

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 movements.
- Landforms 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.

Standards, cont'd.

- 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 re-crystallized 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 rocks underground.
- Water is a solvent. As it passes through the water cycle is 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, 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 the 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.

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.
- 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.

Standards, cont'd.

Earth and Space Science Content Standards: 9-12

http://bob.nap.edu/readingroom/books/nses/html/6c.html#es

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 the mantle that propels the plates comprising the Earth's surface across the face of the globe.
- Heating of the 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 such as cloud cover and the earth's rotation, and static conditions such as the position of the 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 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.
- 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.

Benchmarks

American Association for the Advancement of Science (AAAS)

Project 2061 Benchmarks

The Physical Setting

http://www.project2061.org/tools/benchol/ch4/ch4.htm

The Physical Setting: Standards K–2

The Universe

- There are more stars in the sky than anyone can easily count, but they are not scattered evenly, and they are not all the same brightness or color.
- The Sun can be seen only in the daytime, but the Moon can be seen sometimes at night and sometimes during the day. The Sun, Moon and stars all appear to move slowly across the sky.
- The Moon looks a little different every day, but looks the same again about every four weeks.

The Earth

- Some events in nature have a repeating pattern. The weather changes some from day to day, but things such as temperature and rain (or snow) tend to be high, low, or medium in the same months every year.
- Water can be a liquid or a solid and can go back and forth from one form to the other. If water is turned into ice and then the ice is allowed to melt, the amount of water is the same as it was before freezing.
- Water left in an open container disappears, but water in a closed container does not disappear.

Processes That Shape the Earth

- Chunks of rocks come in many sizes and shapes, from boulders to grains of sand and even smaller.
- Change is something that happens to many things.
- Animals and plants sometimes cause changes in their surroundings.

The Physical Setting: Standards 3–5

The Universe

- The patterns of stars in the sky stay the same, although they appear to move across the sky nightly, and different stars can be seen in different seasons.
- Telescopes magnify the appearance of some distant objects in the sky, including the Moon and planets. The number of stars that can be seen through telescopes is dramatically greater than can be seen by the unaided eye.
- Planets change their positions against the background of stars.
- The Earth is one of several planets that orbit the Sun, and the Moon orbits around the Earth.
- Stars are like the Sun, some being smaller and some larger, but so far away that they look like points of light.

Benchmarks, cont'd.

The Earth

- Things on or near the Earth are pulled toward it by the Earth's gravity.
- Like all planets and stars, the Earth is approximately spherical in shape. The rotation of the Earth on its axis every 24 hours produces the night-and-day cycle. To people on Earth, this turning of the planet makes it seem as though the Sun, Moon, planets, and stars are orbiting the earth once a day.
- When liquid water disappears, it turns into a gas (vapor) in the air and can reappear as a liquid when cooled, or as a solid if cooled below the freezing point of water. Clouds and fog are made of tiny droplets of water.
- Air is a substance that surrounds us, takes up space, and whose movement we feel as wind.

Processes That Shape the Earth

- Waves, wind, water, and ice shape and reshape the earth's land surface by eroding rock and soil in some areas and depositing them in other areas, sometimes in seasonal layers.
- Rock is composed of different combinations of minerals. Smaller rocks come from the breakage and weathering of bedrock and larger rocks. Soil is made partly from weathered rock, partly from plant remains—and also contains many living organisms.

The Physical Setting: Standards 5–8

The Universe

- The Sun is a medium-sized star located near the edge of a disk-shaped galaxy of stars, part of which can be seen as a glowing band of light that spans the sky on a very clear night. The universe contains many billions of galaxies, and each galaxy contains many billions of stars. To the naked eye, even the closest of these galaxies is no more than a dim, fuzzy spot.
- The Sun is many thousands of times closer to the Earth than any other star. Light from the Sun takes a few minutes to reach the Earth, but light from the next nearest star takes a few years to arrive. The trip to that star would take the fastest rocket thousands of years. Some distant galaxies are so far away that their light takes several billion years to reach the Earth. People on Earth, therefore, see them as they were that long ago in the past.
- Nine planets of very different size, composition, and surface features move around the Sun in nearly circular orbits. Some planets have a great variety of moons and even flat rings of rock and ice particles orbiting around them. Some of these planets and moons show evidence of geologic activity. The Earth is orbited by one moon, many artificial satellites, and debris.
- Large numbers of chunks of rock orbit the Sun. Some of those that the Earth meets in its yearly orbit around the sun glow and disintegrate from friction as they plunge through the atmosphere—and sometimes impact the ground. Other chunks of rocks mixed with ice have long, off-center orbits that carry them close to the Sun, where the sun's radiation (of light and particles) boils off frozen material from their surfaces and pushes it into a long, illuminated tail.

Benchmarks, cont'd.

The Earth

- We live on a relatively small planet, the third from the Sun in the only system of planets definitely known to exist (although other, similar systems may be discovered in the universe).
- The Earth is mostly rock. Three-fourths of its surface is covered by a relatively thin layer of water (some of it frozen), and the entire planet is surrounded by a relatively thin blanket of air. It is the only body in the solar system that appears able to support life. The other planets have compositions and conditions very different from the Earth's.
- Everything on or anywhere near the Earth is pulled toward the Earth's center by gravitational force.
- Because the Earth turns daily on an axis that is tilted relative to the plane of the Earth's yearly orbit around the Sun, sunlight falls more intensely on different parts of the Earth during the year. The difference in heating of the earth's surface produces the planet's seasons and weather patterns.
- The Moon's orbit around the Earth once in about 28 days changes what part of the moon is lighted by the Sun and how much of that part can be seen from the Earth—the phases of the Moon.
- Climates have sometimes changed abruptly in the past as a result of changes in the earth's crust, such as volcanic eruptions or impacts of huge rocks from space. Even relatively small changes in atmospheric or ocean content can have widespread effects on climate if the change lasts long enough.
- The cycling of water in and out of the atmosphere plays an important role in determining climatic patterns. Water evaporates from the surface of the Earth, rises and cools, condenses into rain or snow, and falls again to the surface. The water falling on land collects in rivers and lakes, soil, and porous layers of rock, and much of it flows back into the ocean.
- Fresh water, limited in supply, is essential for life and also for most industrial processes. Rivers, lakes, and groundwater can be depleted or polluted, becoming unavailable or unsuitable for life.
- Heat energy carried by ocean currents has a strong influence on climate around the world.
- Some minerals are very rare and some exist in great quantities, but—for practical purposes—the ability to recover them is just as important as their abundance. As minerals are depleted, obtaining them becomes more difficult. Recycling and the development of substitutes can reduce the rate of depletion but may also be costly.
- The benefits of the Earth's resources—such as fresh water, air, soil, and trees—can be reduced by using them wastefully or by deliberately or inadvertently destroying them. The atmosphere and the oceans have a limited capacity to absorb wastes and recycle materials naturally. Cleaning up polluted air, water, or soil or restoring depleted soil, forests, or fishing grounds can be very difficult and costly.

Processes That Shape the Earth

- The interior of the Earth is hot. Heat flow and movement of material within the earth cause earthquakes and volcanic eruptions and create mountains and ocean basins. Gas and dust from large volcanoes can change the atmosphere.
- Some changes in the Earth's surface are abrupt (such as earthquakes and volcanic eruptions) while other changes happen very slowly (such as uplift and wearing down of mountains). The Earth's surface is shaped in part by the motion of water and wind over very long times, which act to level mountain ranges.
- Sediments of sand and smaller particles (sometimes containing the remains of organisms) are gradually buried and are cemented together by dissolved minerals to form solid rock again.

Benchmarks, cont'd.

- Sedimentary rock buried deep enough may be reformed by pressure and heat, perhaps melting and recrystallizing into different kinds of rock. These re-formed rock layers may be forced up again to become land surface and even mountains. Subsequently, this new rock too will erode. Rock bears evidence of the minerals, temperatures, and forces that created it.
- Thousands of layers of sedimentary rock confirm the long history of the changing surface of the earth and the changing life forms whose remains are found in successive layers. The youngest layers are not always found on top, because of folding, breaking, and uplift of layers.
- Although weathered rock is the basic component of soil, the composition and texture of soil and its fertility and resistance to erosion are greatly influenced by plant roots and debris, bacteria, fungi, worms, insects, rodents, and other organisms.
- Human activities, such as reducing the amount of forest cover, increasing the amount and variety of chemicals released into the atmosphere, and intensive farming, have changed the earth's land, oceans, and atmosphere. Some of these changes have decreased the capacity of the environment to support some life forms.

The Physical Setting: Standards 9–12

The Universe

- The stars differ from each other in size, temperature, and age, but they appear to be made up of the same elements that are found on the Earth and to behave according to the same physical principles. Unlike the Sun, most stars are in systems of two or more stars orbiting around one another.
- On the basis of scientific evidence, the universe is estimated to be over ten billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. Stars condensed by gravity out of clouds of molecules of the lightest elements until nuclear fusion of the light elements into heavier ones began to occur. Fusion released great amounts of energy over millions of years. Eventually, some stars exploded, producing clouds of heavy elements from which other stars and planets could later condense. The process of star formation and destruction continues.
- Increasingly sophisticated technology is used to learn about the universe. Visual, radio, and x-ray telescopes collect information from across the entire spectrum of electromagnetic waves; computers handle an avalanche of data and increasingly complicated computations to interpret them; space probes send back data and materials from the remote parts of the solar system; and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed.
- Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe.

The Earth

- Life is adapted to conditions on the Earth, including the force of gravity that enables the planet to retain an adequate atmosphere, and an intensity of radiation from the sun that allows water to cycle between liquid and vapor.
- Weather (in the short run) and climate (in the long run) involve the transfer of energy in and out of the atmosphere. Solar radiation heats the landmasses, oceans, and air. Transfer of heat energy at the boundaries between the atmosphere, the landmasses, and the oceans results in layers of different temperatures and densities in both the ocean and atmosphere. The action of gravitational force on regions of different densities causes them to rise or fall—and such circulation, influenced by the rotation of the Earth, produces winds and ocean currents.

Benchmarks, cont'd.

Processes That Shape the Earth

- Plants alter the Earth's atmosphere by removing carbon dioxide from it, using the carbon to make sugars and releasing oxygen. This process is responsible for the oxygen content of the air.
- The formation, weathering, sedimentation, and reformation of rock constitute a continuing "rock cycle" in which the total amount of material stays the same as its forms change.
- The slow movement of material within the Earth results from heat flowing out from the deep interior and the action of gravitational forces on regions of different density.
- The solid crust of the Earth—including both the continents and the ocean basins—consists of separate plates that ride on a denser, hot, gradually deformable layer of the Earth. The crust sections move very slowly, pressing against one another in some places, pulling apart in other places. Ocean-floor plates may slide under continental plates, sinking deep into the earth. The surface layers of these plates may fold, forming mountain ranges.
- Earthquakes often occur along the boundaries between colliding plates, and molten rock from below creates pressure that is released by volcanic eruptions, helping to build up mountains. Under the ocean basins, molten rock may well up between separating plates to create new ocean floor. Volcanic activity along the ocean floor may form undersea mountains, which can thrust above the ocean's surface to become islands.