Earth Systems Science Committee

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**Course Focus:** An Earth System Science Course is focused on the application of fundamental concepts and principles as powerful tools in understanding the interconnectedness of the Earth’s Systems, including the exosphere, geosphere, atmosphere, hydrosphere, and biosphere. Students engage in empirical investigations that require the application of their understandings of the interconnectedness of Earth Systems in decision making and problem solving.

**Mission of Science Education:** *Scientifically literate students possess the knowledge and understanding of scientific concepts and processes required for personal decision-making, participation in civic and cultural affairs, and economic productivity.*

**Vision of Science Education:** A quality science education fosters a population that:

- Experiences the richness and excitement of knowing about the natural world and understanding how it functions.
- Uses appropriate scientific processes and principles in making personal decisions.
- Engages intelligently in public discourse and debate about matters of scientific and technological concern.
- Applies scientific knowledge and skills to increase economic productivity.

**What is a Laboratory/Inquiry-Based Science Course?**

We begin to answer this question by stating that Laboratory science is a practice not a place. Laboratory/inquiry-based science courses (lab course) emphasize student sense making opportunities rather than focusing on course title or seat time.

Next, we look at the question from a structure and function perspective. The function of our K-12 science instruction should be students becoming scientifically proficient. The definition of proficiency has evolved over the past several years. Knowing science requires individuals to integrate a complex structure of many types of knowledge. These knowledge types include the ideas of science, the relationships between the ideas, the reasons for these relationships, and the ways to use these ideas to complete the following tasks: explain and predict other phenomena, interpret situations, solve problems and participate productively in science practice and discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). Therefore rigorous instruction must evolve from a focus on learning all of the facts and specific examples about a concept to an understanding and application of core principles of the discipline and an integration of that knowledge with the processes that are necessary for practicing science discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). The requirement that all high school science courses to be laboratory/inquiry-based reflects the importance of the necessity for each of us to examine how well our instructional practices are likely to result in our students becoming scientifically literate.

From an academic perspective, contemporary views of learning prize understanding and application or knowledge in use. Learners who understand can use and apply novel ideas in diverse contexts, drawing connections among multiple representations of a given concept. They appreciate the foundations of knowledge and consider the evidence for claims. Accomplished learners know when to ask a question, how to challenge claims, where to go to learn more, and they are aware of their own ideas and how these change over time. (2007, NRC)

The classic scientific method as taught for many years provides only a very general approximation of the actual working of scientists. The process of theory development and testing is iterative, uses both deductive and inductive logic, and incorporates many tools besides direct experiment. Modeling (both mechanical models and computer simulations) and scenario building (including thought experiments) play an important role in the development of scientific knowledge. The ability to examine one’s own knowledge and conceptual frameworks, to evaluate them in
relation to new information or competing alternative frameworks, and to alter them by a deliberate and conscious effort are key scientific practices. (2007, NRC)

The process by which scientific understandings are developed and the form that those understandings take differ from one domain of science to another, but all sciences share certain common features at the core of their problem-solving and inquiry approaches. Chief among these is that data and evidence hold a primary position in deciding any issue. Thus, when well-established data, from experiment or observation, conflict with a theory or hypothesis, then that idea must be modified or abandoned and other explanations must be sought that can incorporate or take account of the new evidence. This also means that models, theories, and hypotheses are valued to the extent that they make testable (or in principle testable) precise predictions for as yet unmeasured or unobserved effects; provide a coherent conceptual framework that is consistent with a body of facts that are currently known; and offer suggestions of new paths for further study. (2007, NRC)

A process of argumentation and analysis that relates data and theory is another essential feature of science. This includes evaluation of data quality, modeling, and development of new testable questions from the theory, as well as modifying theories as data dictates the need. Finally, scientists need to be able to examine, review, and evaluate their own knowledge. Holding some parts of a conceptual framework as more or less established and being aware of the ways in which that knowledge may be incomplete are critical scientific practices. (2007, NRC)

Lab science courses emphasize the importance of students independently creating scientific arguments and explanations for observations made during investigations. Science courses thereby become a sense-making enterprise for students in which they are systematically provided with ongoing opportunities to:

- Interact directly with the natural and designed world using tools, data-collection techniques, models, and theories of science.
- Actively participate in scientific investigations and use cognitive and manipulative skills associated with the formulation of scientific explanations.
- Use evidence, apply logic, and construct arguments for their proposed explanations.

The lab science requirement implicitly and explicitly point to a more student-centered approach to instructional design that engages learners in inquiry. Inquiry, as defined in the revised standards, envisions learners who:

- Are engaged by scientifically-oriented questions.
- Prioritize evidence that addresses scientifically-oriented questions.
- Formulate explanations from that evidence to address those scientifically-oriented questions.
- Evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding.
- Communicate and justify their proposed explanations.

Fundamental principles of lab science course design assist students in achieving science proficiency through sense making experiences that:

- Are designed with clear learning outcomes in mind.
- Are sequenced thoughtfully into the flow of classroom science instruction.
- Integrate learning of science content with learning about science practices.
• Incorporate ongoing student reflection and discussion (National Research Council, 2007).

If lab science is a practice not a place, then what kinds of things should my students be doing in a lab science course? Students’ K-12 lab science experiences should include the following:

• **Physical manipulation of authentic substances or systems:** This may include such activities as chemistry experiments, plant and animal observations, and investigations of force and motion.

• **Interaction with simulations:** In 21st century laboratory science courses, students can work with computerized models, or simulations, that represent aspects of natural phenomena that cannot be observed directly because they are very large, very small, very slow, very fast, or very complex. Students may also model the interaction of molecules in chemistry or manipulate models of cells, animal or plant systems, wave motion, weather patterns, or geological formations using simulations.

• **Interaction with authentic data:** Students may interact with authentic data that are obtained and represented in a variety of forms. For example, they may study photographs to examine characteristics of the moon or other heavenly bodies or analyze emission and absorption spectra in the light from stars. Data may be incorporated in films, DVDs, computer programs, or other formats.

• **Access to large databases:** In many fields of science, researchers have arranged for empirical data to be normalized and aggregated—for example, genome databases, astronomy image collections, databases of climatic events over long time periods, biological field observations. Some students may be able to access authentic and timely scientific data using the Internet and can also manipulate and analyze authentic data in new forms of laboratory experiences (Bell, 2005).

• **Remote access to scientific instruments and observations:** When available, laboratory experiences enabled by the Internet can link students to remote instruments, such as the environmental scanning electron microscope (Thakkar et al., 2000), or allow them to control automated telescopes (Gould, 2004).

Sometimes, administrative code language (structure) issued from the NJDOE results in a compliance approach to meeting the requirements rather than an approach based on the spirit and intent of the language. It is often preferable to provide teachers with the expectations for outcomes (function). In the process of transforming your course, remain focused on the desired result of student proficiency. Knowing science requires individuals to integrate a complex structure of many types of knowledge. These knowledge types include the ideas of science, the relationships between the ideas, the reasons for these relationships, and the ways to use these ideas to complete the following tasks: explain and predict other phenomena, interpret situations, solve problems and participate productively in science practice and discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). Therefore rigorous instruction must evolve from a focus on learning all of the facts and specific examples about a concept to an understanding and application of core principles of the discipline and an integration of that knowledge with the processes that are necessary for practicing science discourse (ACT, 2007; College Board, 2009; NJCCCS, 2009). The requirement that all high school science courses to be laboratory/inquiry- based reflects the importance of the necessity for each of us to examine how well our instructional practices are likely to result in our students becoming scientifically literate.
Earth System Science Core Content Outline:

The Core Content for High School Lab Science: Earth Systems Science has been derived through the use of *Benchmarks for Science Literacy, Atlas of Science Literacy Volumes One and Two*, and the *Frameworks for Atmospheric Science, Earth Science, Climate*, and *Ocean Literacy*.

A. **Objects in the Universe:** Our universe has been expanding and evolving for 13.7 billion years under the influence of gravitational and nuclear forces. As gravity governs its expansion, organizational patterns, and the movement of celestial bodies, nuclear forces within stars govern its evolution through the processes of stellar birth and death. These same processes governed the formation of our solar system 4.6 billion years ago.

1. **Origin of Modern Astronomy,** including the work of 17th-century astronomers, and the prior scientists who believed the Earth was the center of the universe (geocentric model).

2. **Formation of the Solar System,** including the properties and characteristics of solar system objects, combined with radioactive dating of meteorites and lunar samples provide evidence that Earth and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago.

3. **Stellar Evolution,** including how stars experience significant changes during their life cycles, which is illustrated with a Hertzsprung-Russell (H-R) Diagram.

4. **Organization of the Universe,** including how the Sun as one of an estimated two hundred billion stars in our Milky Way galaxy, which together with over one hundred billion other galaxies make up the universe.

5. **The Big Bang Theory,** including the origin of the universe at approximately 13.7 billion years ago. Shortly after the Big Bang, matter (primarily hydrogen and helium) began to coalesce to form galaxies and stars.

6. **Expanding Universe,** including the Big Bang theory, the universe has been expanding since its beginning, explaining the apparent movement of galaxies away from one another.

B. **History of Earth:** From the time that Earth formed from a nebula 4.6 billion years ago, it has been evolving as a result of geologic, biological, physical, and chemical processes.

1. **Evolving Earth,** including how the evolution of life caused dramatic changes in the composition of Earth’s atmosphere, which did not originally contain oxygen gas.

2. **Relative Age Dating,** including the use of index fossils and stratigraphic sequences to determine the sequence of geologic events.

3. **Absolute Age Dating,** including the use of radioactive isotopes in rocks, making it possible to determine how many years ago a given rock sample formed.

C. **Properties of Earth Materials:** Earth’s composition is unique, is related to the origin of our solar system, and provides us with the raw resources needed to sustain life.

1. **Soil Science,** including the role of soils as the interface of the Earth systems, linking together the biosphere, geosphere, atmosphere, and hydrosphere.

D. **Tectonics:** The theory of plate tectonics provides a framework for understanding the dynamic processes within and on Earth.

1. **Mechanisms for Plate Movement,** including the model of convection currents in the upper mantle driving plate motion.

2. **Paleomagnetism,** including the evidence from lava flows and ocean-floor rocks shows that Earth’s magnetic field reverses (North – South) over geologic time.
E. **Energy in the Earth System**: including the internal and external sources of energy drive Earth systems.
   1. **Global Energy Budget**, including how the Sun is the major external source of energy for Earth’s global energy budget.
   2. **Energy Transfer in the Earth System**, including how the Earth systems have internal and external sources of energy, both of which create heat.

F. **Climate and Weather**: including Earth’s weather and climate systems are the result of complex interactions between land, ocean, ice, and atmosphere.
   1. **Seasonality**, including the global climate differences result from the uneven heating of Earth’s surface by the Sun. Seasonal climate variations are due to the tilt of Earth’s axis with respect to the plane of Earth’s nearly circular orbit around the Sun.
   2. **Energy Transfer in the Climate System**, including how climate is determined by energy transfer from the Sun at and near Earth’s surface. This energy transfer is influenced by dynamic processes, such as cloud cover and Earth’s rotation, as well as static conditions, such as proximity to mountain ranges and the ocean. Human activities, such as the burning of fossil fuels, also affect the global climate.
   3. **Coupled Energy Budget & Hydrologic Cycle**, including how the Earth’s radiation budget varies globally, but is balanced, and how the Earth’s hydrologic cycle is complex and varies globally, regionally, and locally.

G. **Biogeochemical Cycles**: The biogeochemical cycles in the Earth systems include the flow of microscopic and macroscopic resources from one reservoir in the hydrosphere, geosphere, atmosphere, or biosphere to another, are driven by Earth's internal and external sources of energy, and are impacted by human activity.
   2. **Laws of Thermodynamics in the Earth System**, including how the movement of matter through Earth’s system is driven by Earth’s internal and external sources of energy and results in changes in the physical and chemical properties of the matter.
   3. **System Dynamics in the Earth System**, including how natural and human activities impact (positive and negative feedbacks) the cycling of matter and the flow (sources and sinks) of energy through ecosystems.
   4. **Conservation of Matter in the Earth System**, including how the Earth is a system in which chemical elements exist in fixed amounts and move through the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles.
Science Practices:

A. **Understand Scientific Explanations**: Students understand core concepts and principles of science and use measurement and observation tools to assist in categorizing, representing, and interpreting the natural and designed world.

1. Mathematical, physical, and computational tools are used to search for and explain core scientific concepts and principles.

2. Interpretation and manipulation of evidence-based models are used to build and critique arguments/explanations.

3. Revisions of predictions and explanations are based on systematic observations, accurate measurements, and structured data/evidence.

B. **Generate Scientific Evidence Through Active Investigations**: Students master the conceptual, mathematical, physical, and computational tools that need to be applied when constructing and evaluating claims.

1. Logically designed investigations are needed in order to generate the evidence required to build and refine models and explanations.

2. Mathematical tools and technology are used to gather, analyze, and communicate results.

3. Empirical evidence is used to construct and defend arguments.

4. Scientific reasoning is used to evaluate and interpret data patterns and scientific conclusions.

C. **Reflect on Scientific Knowledge**: Scientific knowledge builds on itself over time.

1. Refinement of understandings, explanations, and models occurs as new evidence is incorporated.

2. Data and refined models are used to revise predictions and explanations.

3. Science is a practice in which an established body of knowledge is continually revised, refined, and extended as new evidence emerges.

D. **Participate Productively in Science**: The growth of scientific knowledge involves critique and communication, which are social practices that are governed by a core set of values and norms.

1. Science involves practicing productive social interactions with peers, such as partner talk, whole-group discussions, and small-group work.

2. Science involves using language, both oral and written, as a tool for making thinking public.

3. Ensure that instruments and specimens are properly cared for and that animals, when used, are treated humanely, responsibly, and ethically.
Understanding the Structure and Function of this Document

**Standard:** The Standard outlines the core understanding for each content domain. Each standard statement explains why the strands and cumulative progress indicators are important.

**Strand:** The strand defines a core concept or principle in earth systems science. Each strand runs throughout students’ K-12 academic experience. Each of the earth systems science strands supports the core understanding of the Standard.

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Enduring Understandings</th>
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<tbody>
<tr>
<td>These questions have no ‘right’ or ‘easy’ answer, and are meant to inspire investigation and raise more questions.</td>
<td>These understandings are insights that a student gains through learning experiences, and are transferable to new situations.</td>
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<th>Content Statements</th>
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<tr>
<td>These statements describe the earth systems science concept/content that a student needs to understand.</td>
<td>These statements describe how students can demonstrate their understanding of the concept/content.</td>
</tr>
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**Instructional Focus:**
- The bulleted items are intended to provide a finer grain level of clarification about what students should understand. Reading the Content Statement and the Instructional Focus will help teachers pinpoint what students need to understand.

- The unpacking language comes from *Benchmarks for Science Literacy, National Science Education Standards*, and *Science for All Americans*. The italicized alphanumerical coding after the statement indicates where the language was originally found.

- It is important to note that the Science Practices are not integrated in this section. They must, however, be integrated into the assessments and in the instructional experiences provided to students.

**Common Student Misconceptions:**
Current research in science education emphasizes the importance of knowing students' previous ideas, conceptions, and representations of scientific content. This research also identifies a considerable number and variety of student misconceptions regarding natural processes and systems, while also reporting the complexity of transforming such mistaken ideas or conceptions. Uncovering students' misconceptions are an important issue for the development of teaching strategies and for identifying students' conceptual progress. In an attempt to bridge these gaps, **Common Student Misconceptions** was included in this document to help you address these obstacles to student understanding of earth systems science content.

**Sample Integration of Science Practices and Core Content:**
The 2009 Science Standards implicitly and explicitly point to a more student-centered approach to instructional design that engages learners in inquiry. Inquiry, as defined in the revised standards, envisions learners who are engaged by scientifically-oriented questions; prioritize evidence that addresses scientifically-oriented questions; formulate explanations from that evidence to address those scientifically-oriented questions; evaluate their explanations in light of alternative explanations, particularly those reflecting scientific understanding; and communicate and justify their proposed explanations. The **Sample Integration of Science Practices and Core Content** is a brief sample description of a learning experience that integrates the earth systems science content with the science practices. These experiences can be modified to meet the needs of your students.
**Sample Earth Systems Assessment Item:**

These items have been provided to give you a sample of the types of items that students should encounter in an Earth Systems Science Assessment. These items can be used on classroom assessments or as samples for the creation of school or district items during an exercise in professional development.

**Resources:**

The National Science Digital Library (NSDL) was created by the National Science Foundation to provide organized access to high quality resources and tools that support innovations in teaching and learning at all levels of science, technology, engineering, and mathematics (STEM) education. NSDL provides an organized point of access to high-quality STEM content from a variety of other digital libraries, NSF-funded projects, and NSDL-reviewed web sites. Curriculum Topic Study is a compendium of resources addressing specific topics found in most science curriculums, providing the user with additional support in making curricular decisions.

**Other Web Based Resources:**

Identifies additional high quality digitally based instructional resources, professional development resources that are available digitally, or links to professional development opportunities offered by organizations such as NASA, NOAA, USGS and other federal or state agencies.
**A. Objects in the Universe:** Our universe has been expanding and evolving for 13.7 billion years under the influence of gravitational and nuclear forces. As gravity governs its expansion, organizational patterns, and the movement of celestial bodies, nuclear forces within stars govern its evolution through the processes of stellar birth and death. These same processes governed the formation of our solar system 4.6 billion years ago.

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<td>How does scientific understanding build over time?</td>
<td>Science builds upon itself over time. As new evidence arises and we acquire new understandings, old theories are revised or replaced by new ones.</td>
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<td>Prior to the work of 17th-century astronomers, scientists believed the Earth was the center of the universe (geocentric model).</td>
<td>Explain how new evidence obtained using telescopes (e.g., the phases of Venus or the moons of Jupiter) allowed 17th-century astronomers to displace the geocentric model of the universe. (5.4.12.A.1)</td>
</tr>
</tbody>
</table>

**Instructional Focus:**

- The work of Copernicus, Galileo, Brahe, and Kepler eventually changed people's perception of their place in the universe. 10A/H8 (BSL) In the 16th Century, Copernicus suggested that … the Earth was turning around in one day and orbiting around the Sun once a year. This explanation was rejected by nearly everyone because it violated common sense… and flew in the face of the belief that the earth was at the center of the Universe. Using the newly invented telescope to study the sky, Galileo made many discoveries that supported the ideas of Copernicus. 10A (BSL)

- Openness to new and unusual ideas about how the world works can now be developed in the study of historical cases…. The Copernican Revolution, for example, illustrates the eventual success of ideas that were initially considered outrageous by nearly everyone. This and other cases illustrate that ideas in science are not easily or quickly accepted. 12A (BSL)

- The usefulness of a model can be tested by comparing its predictions to actual observations in the real world. 11B (BSL)

**Teacher Note:** The challenge of helping students to make sense of this standard (5.4.A) will be to present understandable evidence from sources that range over immense timescales— and from studies of the earth’s interior to observations from outer space. Many students are capable of doing this kind of thinking, but as many as half will need concrete examples and considerable help in following the multistep logic necessary to develop the understandings described in this standard. Because direct experimentation is usually not possible for many concepts with earth and space science, it is important to maintain the spirit of inquiry by focusing on the teaching of questions that can be answered using observational data, the knowledge base of science, and processes of reasoning. (p. 188-189, NSES)

**Common Student Misconceptions:**

- In studying planetary models, it is easy to get bogged down in the distinction between rotating and revolving, and getting it straight may not be worth the effort it requires (p. 240, BSL).

- Avoid selling Copernicus’ model on the basis of simplicity, for in fact it was not mathematically simpler than Ptolemy’s. They were comparably complex…and both predicted comparably well where the planets could be observed at any specified time. (p. 240, BSL)

- High school students may have difficulties understanding the views of historical figures. For example, students
may think of historical figures as inferior because they did not understand what we do today. This “Whiggish perspective” seems to hold for some students with regard to scientists whose theories have been displaced. (NSES, p. 200)

**Sample Integration of Science Practices and Core Content:**


- Engage in exploring how accidental discoveries have caused scientific explanations to change. Accidental Discoveries will help the students understand that science theories change in the face of new evidence, but those changes can be slow in coming. )Teachers' Domain, Accidental Discoveries, published November 30, 2007, retrieved on July 29, 2010, http://www.teachersdomain.org/resource/psu06-swift.sci.discoveries/

**Sample EOC Assessment Items:**

1. What role do mistakes and wrong answers play in science?
2. What is the role of models and evidence in science?
3. Explain how Galileo’s observations of Venus and Jupiter helped to displace the geocentric model.

**Resources:**

- National Science Digital Library, Science Digital Literacy Maps
  - Historical Perspectives: The Copernican Revolution: [http://strandmaps.nsdl.org/?id=SMS-MAP-2312](http://strandmaps.nsdl.org/?id=SMS-MAP-2312)
  - *Science Curriculum Topic Study*: Historical Episodes in Astronomy, p. 196

**Other Web Based Resources:**


- Gettysburg College Project CLEA, Revolution of the Moons of Jupiter Lab(2007), retrieved on September 9,2010
  *Students use Galilean moon data to plot orbits and calculate Jupiter’s mass*
  [http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html](http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html)

- Gettysburg College Project CLEA, The Period of Rotation of the Sun (2005), retrieved September 10, 2010
  *Students use sunspot data to calculate the sun’s period of rotation.*
  [http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html](http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html)


- Physics Department of Montana State University: YPOP, Solar Rotation Study (2001), retrieved on September 30, 2010
  [http://solar.physics.montana.edu/YPOP/Classroom/Lessons/Rotation/](http://solar.physics.montana.edu/YPOP/Classroom/Lessons/Rotation/)
Content Statements

The properties and characteristics of solar system objects, combined with radioactive dating of meteorites and lunar samples, provide evidence that Earth and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago.

Cumulative Progress Indicators

Collect, analyze, and critique evidence that supports the theory that Earth and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. (5.4.12.A.2)

Instructional Focus:

- 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. 4A/H2cd (BSL)
- Eventually, some stars exploded, producing clouds containing heavy elements from which other stars and planets orbiting them could later condense. The process of star formation and destruction continues. 4A/H2e (BSL)
- Our solar system coalesced out of a giant cloud of gas and debris left in the wake of exploding stars about five billion years ago. Everything in and on the earth, including living organisms, is made of this material. (p. 41, SFAA)
- As the earth and other planets formed, the heavier elements fell into their centers. On planets close to the sun (Mercury, Venus, Earth, and Mars) the lightest elements were mostly blown or boiled away by radiation from the newly formed sun; on the outer planets (Jupiter, Saturn, Uranus, and Neptune,) the lighter elements still surround them as deep atmospheres of gas or as frozen solid layers. (p. 41, SFAA)
- Our solar system coalesced out of a giant cloud of gas and debris left in the wake of exploding stars about five billion years ago. Everything in and on the earth, including living organisms, is made of this material. (p. 41, SFAA)

Common Student Misconceptions:

Students should now learn how well the principle of universal gravitation explains the architecture of the universe and much that happens on earth. The principle will become familiar from many examples (star formation, tides, comet orbits, etc.)….. The “Inversely proportional to the square” aspect is not a high priority for literacy. Much more important is escaping the common adult misconceptions that the earth’s gravity does not extend beyond its atmosphere or that it is caused by the atmosphere. (p. 96, BSL)

Sample Integration of Science Practices and Core Content


Sample Assessment Items:

1. All planets in our solar system revolve around the Sun in the same, counterclockwise, direction. Explain how this piece of evidence supports the Nebular Theory.

2. Which of the following is true for chemical compounds that have been detected elsewhere in the universe?
   A. They have a greater average density than the same compounds found on Earth.
   B. They are composed of the same elements that are found on Earth.
   C. They are less reactive chemically than the same compounds found on Earth.
   D. Those with the greatest molar masses are found furthest away from our solar system. (NAEP)
Resources:

- National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: Stars: [http://strandmaps.nsdl.org/?id=SMS-MAP-1292](http://strandmaps.nsdl.org/?id=SMS-MAP-1292)
  The Physical Setting: Galaxies and the Universe: [http://strandmaps.nsdl.org/?id=SMS-MAP-1300](http://strandmaps.nsdl.org/?id=SMS-MAP-1300)

- **Science Curriculum Topic Study**: Origin and Evolution of the Universe: p. 198
- **Science Curriculum Topic Study**: Scale, Size and Distance in the Universe p. 199
- **Science Curriculum Topic Study**: Space Technology and Explorations p. 201

Other Web Based Resources:

- Gettysburg College Project CLEA, Dying Stars and the Birth of the Elements (2006), retrieved October 9, 2010
  Students analyze X-ray spectra of supernova remnants to find abundance of elements and compare to earth composition. [http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html](http://www3.gettysburg.edu/~marschal/clea/CLEAhome.html)
- Origins of Astronomy Scavenger Hunt. From State of N. Carolina science curriculum. This activity provides students with an opportunity to learn the basic facts of the history of astronomy by using the internet. [http://www.learnnc.org/lp/pages/3122](http://www.learnnc.org/lp/pages/3122)

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<td>Stars experience significant changes during their life cycles, which can be illustrated with a Hertzsprung-Russell (H-R) Diagram.</td>
<td>Analyze an H-R diagram and explain the life cycle of stars of different masses using simple stellar models. (5.4.12.A.3)</td>
</tr>
</tbody>
</table>

Instructional Focus:

- 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. 4A/H2cd (BSL)
- 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. (p. 190, NSES)
- 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. 4A/H1a (BSL)
- Eventually, some stars exploded, producing clouds containing heavy elements from which other stars and planets orbiting them could later condense. The process of star formation and destruction continues. 4A/H2e (BSL)
- 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. 4A/H3 (BSL)

**Common Student Misconceptions:**
The HR diagram helps students understand how a star changes throughout its life. The star *does not* physically zip around the universe as it ages. The star physically stays in the same location, but the movement is to show how luminosity (brightness) and surface temperature change with star age. Remember, it’s a diagram, not a star map.

**Sample Integration of Science Practices and Core Content**
- While you are absent from school for two weeks with the flu, you are missing the chapter on stellar evolution in Earth Science class. Before you will be able to return to school, the class will have finished their oral presentations on the evolution of mid-sized and massive stars, and turned in an organized portfolio of supporting materials for their presentations. Since you have a computer at home, your teacher has developed a web quest version on stellar evolution that you can substitute for your oral presentation, so that you will not fall behind the rest of the class.

You will access a website that has 24 numbered and un-sequenced images of various stages of stellar evolution. There are enough stages represented to arrange the images in a sequence from formation to final end product(s) for mid-sized and massive stars - including a Type Ia supernova event. Some of the images may be used for more than one type of sequence. Except for the Image #1 of the Earth, there is a link below each of the images. Since you have missed all the classroom lectures and discussion about stellar evolution, you may have a difficult time understand what evolutionary stage each of the images represents. To help you determine what the images are, click on the link below each image. The links will take you to objects that are in similar stages of evolution. Write a brief description of what stage each object represents for each of the numbered images.


- In Earth Science class, you studied how stars form in stellar nurseries and evolve into white dwarfs, neutron stars, pulsars, black holes and supernovae remnants. The classroom assignment for stellar evolution was a project that consisted of an oral presentation, and a portfolio of supporting materials on the evolutionary tracks of mid-sized stars, including Type Ia supernova events, and massive stars. For the project, you had searched the internet and downloaded several images representing the different stages of evolution for mid-sized and massive stars, and written a brief description for each stage. Your younger sister was fascinated by the beautiful images, and asked her teacher if you could present your project in her 8th grade class. The teacher agreed, and set a date for you to talk about the lives of stars for your sister's 8th grade class.

On the day of your presentation, you grab your portfolio and go to the 8th grade classroom during lunch break so you will have time to review the images and descriptions. It has been two weeks since you presented your project in class. When you open your portfolio, you discover to your horror that the images are all out of sequence, and the descriptions of the images are missing! Your sister must have been looking through the images and gotten them out of sequence - and forgot to put the descriptions back in the portfolio.

Your Task: You still have two hours before the presentation. Put the images in order to show the evolutionary stages for mid-sized and massive stars, and write a brief description for each image

(Stellar Cycles Post Assessment Activity, Harvard-Smithsonian Center for Astrophysics, viewed on October 22, 2010, [http://chandra.harvard.edu/edu/formal/stellar_ev/](http://chandra.harvard.edu/edu/formal/stellar_ev/))

- Explore a web based simulation that models how a star's brightness and surface temperature are measured throughout its life cycle. ASPIRE, Star Life Cycle, published 2003, University of Utah, viewed September 14, 2010, [http://sunshine.chpc.utah.edu/labs/star_life/starlife_main.html](http://sunshine.chpc.utah.edu/labs/star_life/starlife_main.html)
• Use SEEDS star simulator to build your own star! You determine the fate of your star by setting initial characteristics. Then watch as its life story unfolds before your eyes. Build Your Own Star, published 2010, Schlumberger Excellence in Educational Development, Inc., viewed September 14, 2010, http://www.seed.slb.com/labcontent.aspx?id=10142. All rights reserved. Permission is granted to make copies of this document for educational purposes only.

Sample Assessment Items:
1. Explain how measuring the brightness (luminosity) and temperature of large numbers of stars helps scientists understand stellar evolution?
2. It is sometimes said that we are all made of star dust. Using your understanding of stellar evolution, explain this statement.

Resources:
- Science Curriculum Topic Study: Scale, Size and Distance in the Universe p. 199
- Science Curriculum Topic Study: Space Technology and Explorations p. 201
- Science Curriculum Topic Study: Stars and Galaxies p. 202

Other Web Based Resources:

<table>
<thead>
<tr>
<th>Content Statements</th>
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</tr>
</thead>
<tbody>
<tr>
<td>The Sun is one of an estimated two hundred billion stars in our Milky Way galaxy, which together with over one hundred billion other galaxies make up the universe.</td>
<td>Analyze simulated and/or real data to estimate the number of stars in our galaxy and the number of galaxies in our universe. (5.4.12.A.4)</td>
</tr>
</tbody>
</table>

Instructional Focus:
• 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. (p. 190, NSES)
• Natural phenomena often involve sizes, durations, and speeds that are extremely small or extremely large. These phenomena may be difficult to appreciate because they involve magnitudes far outside human experience. 11D/M3 (BSL)
• Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe. 4A/H4 (BSL)
• Technology is essential to science for such purposes as access to outer space and other remote locations, sample collection and treatment, measurement, data collection and storage, computation, and communication of information. 3A/M2 (BSL)
### Common Student Misconceptions:
Using light years to express astronomical distances is not as straightforward as it seems. (Many adults think of light years as a measure of time.) Beginning with analogs such as "automobile hours" may help. (2009, BSL)

### Sample Integration of Science Practices and Core Content:

### Sample Assessment Item:
1. How do scientists estimate the number of stars in our galaxy?
2. How do scientists estimate the number of galaxies in the Universe?

### Resources:
- National Science Digital Library, Science Digital Literacy Map: The Physical Setting
  http://strandmaps.nsdl.org/?id=SMS-MAP-1300
- Science Curriculum Topic Study: Scale, Size and Distance in the Universe p. 199
- Science Curriculum Topic Study: Stars and Galaxies p. 202

<table>
<thead>
<tr>
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</thead>
<tbody>
<tr>
<td>The Big Bang theory places the origin of the universe at approximately 13.7 billion years ago. Shortly after the Big Bang, matter (primarily hydrogen and helium) began to coalesce to form galaxies and stars.</td>
<td>Critique evidence for the theory that the universe evolved as it expanded from a single point 13.7 billion years ago. (5.4.12.A.5)</td>
</tr>
</tbody>
</table>

### Instructional Focus:
- On the basis of scientific evidence, the universe is estimated to be approximately 13.7 billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. 4A (BSL)
- 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. (p. 190, NSES)
- 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 calculations to interpret them; …and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A (BSL)
- 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. 4A/M2de (BSL)
- Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe. 4A/H4 (BSL)

### Common Student Misconceptions:
- Students and adults often think that The Big Bang also created the Solar System. Current evidence places the Big Bang at 13.7 BYA, and the formation of the Solar System at 5BYA. These events are not simultaneous.
• Students and adults often think that The Big Bang is simply an idea, of equal merit to other ideas of how the universe began. It is important that students understand that the current evidence points to an expanding universe; scientists did not choose to create this theory—rather the theory fits the evidence.

Sample Integration of Science Practices and Core Content:

Sample Assessment Item:
1. Describe one piece of evidence that supports the Big Bang Theory and explain why it supports it.
2. Explain how scientists can find evidence for something that happened more than 10 billion years ago.

Resources:
✓ National Science Digital Library, Science Digital Literacy Maps: Galaxies and the Universe: http://strandmaps.nsdl.org/?id=SMS-MAP-1300
✓ Science Curriculum Topic Study: Origin and Evolution of the Universe p. 198

Other Web Based Resources:
✓ Hubble: Galaxies Across Space and Time (http://hubblesource.stsci.edu/exhibits/largefilm/)

Content Statements

According to the Big Bang theory, the universe has been expanding since its beginning, explaining the apparent movement of galaxies away from one another.

Cumulative Progress Indicators

Argue, citing evidence (e.g., Hubble Diagram), the theory of an expanding universe. (5.4.12.A.6)

Instructional Focus:
• On the basis of scientific evidence, the universe is estimated to be approximately 13.7 billion years old. The current theory is that its entire contents expanded explosively from a hot, dense, chaotic mass. 4A/H2ab (BSL)

• 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 calculations to interpret them; …and accelerators give subatomic particles energies that simulate conditions in the stars and in the early history of the universe before stars formed. 4A (BSL)

• A great variety of radiations are electromagnetic waves...Their wavelengths vary from radio waves, the longest, to gamma rays, the shortest. In empty space, all electromagnetic waves move at the same speed—the "speed of light." 4F/H3bcd (BSL)

• The observed wavelength of a wave depends upon the relative motion of the source and the observer. If either is
moving toward the other, the observed wavelength is shorter; if either is moving away, the wavelength is longer. 4F/H5ab (BSL)

- Mathematical models and computer simulations are used in studying evidence from many sources in order to form a scientific account of the universe. 4A/H4 (BSL)

Common Student Misconceptions:

- Students and adults often think that The Big Bang also created the Solar System. Current evidence places the Big Bang at 13.7 BYA, and the formation of the Solar System at 5BYA. These events are not simultaneous.
- Students and adults often think that The Big Bang is simply an idea, of equal merit to other ideas of how the universe began. It is important that students understand that the current evidence points to an expanding universe; scientists did not choose to create this theory—rather the theory fits the evidence.

Sample Integration of Science Practices and Core Content:

Use NOVA resources to learn how Wilson and Penzias's inadvertent discovery changed the future of cosmology when they stumbled upon radiation believed to be left over from the birth of the universe. (Teachers' Domain, Evidence for the Big Bang Theory, published December 17, 2005, retrieved on September 14, 2010, http://www.teachersdomain.org/resource/ess05.sci.ess.eiu.microwave/)

Sample Assessment Item:

1. Describe how Hubble’s Law supports the idea that the universe is expanding.

2. In the Doppler effect, light reaching the Earth from a distant galaxy in an expanding universe is shifted to
   
   A. longer wavelengths
   B. higher frequencies
   C. greater velocities
   D. greater amplitudes

   (NAEP)

Resources:

- National Science Digital Library, Science Digital Literacy Maps: Galaxies and the Universe: http://strandmaps.nsdl.org/?id=SMS-MAP-1300
- Science Curriculum Topic Study: Origin and Evolution of the Universe p. 198

Other Web Based Resources:

- Hubble: Galaxies Across Space and Time (http://hubblesource.stsci.edu/exhibits/largefilm/)
### B. History of Earth:

From the time that Earth formed from a nebula 4.6 billion years ago, it has been evolving as a result of geologic, biological, physical, and chemical processes.

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Enduring Understandings</th>
</tr>
</thead>
<tbody>
<tr>
<td>How and why has the Earth changed over time? How do we know?</td>
<td>Earth is a complex system of interacting rock, water, air, and life that has evolved over time.</td>
</tr>
</tbody>
</table>

<table>
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</tr>
</thead>
<tbody>
<tr>
<td>The evolution of life caused dramatic changes in the composition of Earth’s atmosphere, which did not originally contain oxygen gas.</td>
<td>Trace the evolution of our atmosphere and relate the changes in rock types and life forms to the evolving atmosphere.  (5.4.12.B.1)</td>
</tr>
</tbody>
</table>

### Instructional Focus:

- Modern ideas about evolution and heredity provide a scientific explanation for the history of life on Earth as depicted in the fossil record and in the similarities evident within the diversity of existing organisms. 5F/H7 (BSL)
- Life changes the physical and chemical properties of Earth’s geosphere, hydrosphere, and atmosphere. Living organisms produced most of the oxygen in the atmosphere through photosynthesis and provided the substance of fossil fuels and many sedimentary rocks. The fossil record provides a means for understanding the history of these changes. (6.8, NSF, 2009)
- Earth's atmosphere sustains and protects living things. Its composition has changed over time, as it has been influenced by life and by geological and geochemical processes. Through photosynthesis, plants produce the oxygen in the atmosphere that makes life possible. (FC 1.4, NOAA, 2008)
- Most of the oxygen in the atmosphere originally came from the activities of photosynthetic organisms in the ocean. (4.a, NGS and NOAA, 2005)
- The first life is thought to have started in the ocean. The earliest evidence of life is found in the ocean. (4.b, NGS and NOAA, 2005)

### Common Student Misconceptions:

Some research suggests that students' understanding of evolution is related to their understanding of the nature of science and their general reasoning abilities (Lawson, A., Thomson, L., 1988). Findings indicate that poor reasoners tend to retain nonscientific beliefs because they fail to examine alternative hypotheses and their predicted consequences, and they fail to comprehend conflicting evidence. Thus, they are left with no alternative but to believe their initial intuitions or the misstatements they hear (Lawson, A., Worsnop, W., 1992).

### Sample Assessment Items:

1. Infer the composition of Earth’s atmosphere had never been life on Earth?  
   (Glencoe, 2008)

2. Create a concept map showing the cause and effects of oxygen in Earth’s atmosphere. Include the following in the concept map: oxygen, cellular respiration, ozone, photosynthesis, and cyanobacteria.  
   (Glencoe, 2008)

### Resources:

- National Science Digital Library, Science Digital Literacy Maps
- Historical Perspectives: Climate and Weather: [http://strandmaps.nsdl.org/?id=SMS-MAP-1698](http://strandmaps.nsdl.org/?id=SMS-MAP-1698)
**Content Statements**

Relative dating uses index fossils and stratigraphic sequences to determine the sequence of geologic events.

**Cumulative Progress Indicators**

Correlate stratigraphic columns from various locations by using index fossils and other dating techniques. (*5.4.12.B.2*)

**Instructional Focus:**

- 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. *4C/M5 (BSL)*

- Earth’s rocks and other materials provide a record of its history. Earth scientists use the structure, sequence, and properties of rocks, sediments, and fossils to reconstruct events in Earth’s history. Decay rates of radioactive elements are the primary means of obtaining numerical ages of rocks and organic remains. Understanding geologic processes active in the modern world is crucial to interpreting Earth’s past. (*2.1, NSF, 2009)*

- Over Earth’s vast history, both gradual and catastrophic processes have produced enormous changes. Supercontinents formed and broke apart, the compositions of the atmosphere and ocean changed, sea level rose and fell, living species evolved and went extinct, ice sheets advanced and melted away, meteorites slammed into Earth, and mountains formed and eroded away. (*2.7, NSF, 2009)*

**Common Student Misconceptions:**

Students of all ages may hold the view that the world was always as it is now, or that any changes that have occurred must have been sudden and comprehensive (Freyberg, P., 1985).
Sample Assessment Item:

1. An unusual type of fossil clam is found in rock layers high in the Swiss Alps. The same type of fossil clam is also found in the Rocky Mountains of North America. From this, scientists conclude that

   A. glaciers carried the fossils up the mountains
   B. the Rocky Mountains and the Swiss Alps are both volcanic in origin
   C. clams once lived in mountains, but have since evolved into sea-dwelling creatures
   D. the layers of rocks in which the fossils were found are from the same geologic age

(NAEP)

Resources:

✓ National Science Digital Library, Science Digital Literacy Maps
   The Physical Setting: Changes in Earth's Surface: http://strandmaps.nsdl.org/?id=SMS-MAP-0048
   Common Themes: Patterns of Change: http://strandmaps.nsdl.org/?id=SMS-MAP-2436

✓ Science Curriculum Topic Study: Earth History, p. 176
✓ Science Curriculum Topic Study: Constancy, Equilibrium, and Change, p.268

Other Web Based Resources


Content Statements

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Absolute dating, using radioactive isotopes in rocks, makes it possible to determine how many years ago a given rock sample formed.</td>
<td>Account for the evolution of species by citing specific absolute-dating evidence of fossil samples. (5.4.12.B.3)</td>
</tr>
</tbody>
</table>

Instructional Focus:

• Absolute dating, using radioactive isotopes in rocks, makes it possible to determine how many years ago a given rock sample formed

• Scientific evidence implies that some rock near the earth's surface is several billion years old. But until the 19th century, most people believed that the earth was created just a few thousand years ago. 10D/H1a (BSL)

• Earth’s rocks and other materials provide a record of its history. Earth scientists use the structure, sequence, and properties of rocks, sediments, and fossils to reconstruct events in Earth’s history. Decay rates of radioactive elements are the primary means of obtaining numerical ages of rocks and organic remains. Understanding geologic processes active in the modern world is crucial to interpreting Earth’s past. (2.1, NSF, 2009)

• Fossils are the preserved evidence of ancient life. Fossils document the presence of life early in Earth’s history and the subsequent evolution of life over billions of years. (6.1, NSF, 2009)
Sample Assessment Items:

1. A newspaper article reported that a fossil was found that was 200,000 years old according to generally accepted radioactive dating procedures. A letter to the editor of the newspaper disputed the accuracy of the age determination because the fossil was found closer to the Earth's surface than were previously discovered fossils of the same age.

2. Which of the following would be an appropriate argument against the letter writer's claim?
   - A. Older rock layers commonly lie deeper underground than younger ones.
   - B. Older rock layers may be pushed closer to the surface by geologic processes.
   - C. The age of a rock layer can often help in determining the age of the fossils it contains.
   - D. Fossils form only under certain conditions.

Resources:

- National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: Changes in Earth's Surface: http://strandmaps.nsdl.org/?id=SMS-MAP-0048

- Science Curriculum Topic Study: Earth History, p. 176

Other Web Based Resources


- University of California Museum of Paleontology, Learning from the Fossil Record, retrieved October 2010 http://www.ucmp.berkeley.edu/fosrec/index.html


### C. Properties of Earth Materials:
Earth’s composition is unique, is related to the origin of our solar system, and provides us with the raw resources needed to sustain life.

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Enduring Understandings</th>
</tr>
</thead>
<tbody>
<tr>
<td>How do changes in one part of an Earth system affect other parts of the system?</td>
<td>Composition of the soils and the atmosphere provide the interfaces for changes in the composition of the Earth’s systems.</td>
</tr>
</tbody>
</table>

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<tbody>
<tr>
<td>Soils are at the interface of the Earth systems, linking together the biosphere, geosphere, atmosphere, and hydrosphere.</td>
<td>Model the interrelationships among the spheres in the Earth systems by creating a flow chart. (5.4.12.C.1)</td>
</tr>
</tbody>
</table>

**Instructional Focus:**

- The transfer of matter and energy between the biosphere, geosphere, atmosphere, and hydrosphere often takes place in soils.
  - The unconsolidated mineral or organic material on the immediate surface of the Earth that serves as a natural medium for the growth of land plants.
  - The unconsolidated mineral or organic matter on the surface of the Earth that has been subjected to and shows effects of genetic and environmental factors of: climate (including water and temperature effects), and macro- and microorganisms, conditioned by relief, acting on parent material over a period of time. A product-soil differs from the material from which it is derived in many physical, chemical, biological, and morphological properties and characteristics. (US Department of Agriculture, Viewed August 24, 2010, http://soils.usda.gov/education/facts/soil.html)
- Earth’s atmosphere exchanges energy and matter within the Earth System through processes such as photosynthesis, the water cycle, biogeochemical cycles, the rock cycle and ocean currents. 5.1 (NOAA, 2008).
- The four major systems of Earth are the geosphere, hydrosphere, atmosphere, and biosphere. The geosphere includes a metallic core, solid and molten rock, soil, and sediments. The atmosphere is the envelope of gas surrounding Earth. The hydrosphere includes the ice, water vapor, and liquid water in the atmosphere, the ocean, lakes, streams, soils, and groundwater. The biosphere includes Earth’s life, which can be found in many parts of the geosphere, hydrosphere, and atmosphere. Humans are part of the biosphere, and human activities have important impacts on all four spheres. 3.1 (NSF, 2009).

**Common Student Misconceptions:**

- It is common for students to believe that soil is ‘just dirt’ or any ‘stuff on the ground.’ Students appear to be largely unaware that there are living organisms in the soil and unaware of the role of the living organisms in the soil. The formation of soil is strongly associated with deposition by rivers results from volcanic activity, or that soil is the precursor to rock (Happs).
- Some think dead organisms simply rot away. They do not realize that the matter from the dead organism is converted into other materials in the environment. Some students see decay as a gradual, inevitable consequence of time without need of decomposing agents (Smith, E., Anderson, C., 1986). Some high-school students believe that matter is conserved during decay, but do not know where it goes (Leach, J., Driver, R., Scott, P., Wood-Robinson, C., 1992).
- Students seem to know that some kind of cyclical process takes place in ecosystems (Smith, E., Anderson, C., 1986). Some students see only chains of events and pay little attention to the matter involved in processes such as plant growth or animals eating plants. They think the processes involve creating and destroying matter rather than transforming it from one substance to another. Other students recognize one form of recycling through soil minerals but fail to incorporate water, oxygen, and carbon dioxide into matter cycles. Even after specially
designed instruction, students cling to their misinterpretations. Instruction that traces matter through the ecosystem as a basic pattern of thinking may help correct these difficulties (Smith, E., Anderson, C., 1986).

**Sample Integration of Science Practices and Core Content:**

Urban soils are found in watersheds that provide drinking water, food, waste utilization, and natural resources to communities. Urban soils also are located within cities in park areas, recreation areas, community gardens, green belts, lawns, septic absorption fields, sediment basins and other uses. Development of housing is one of the factors that impact the quality of urban soils.

You are a (pick one: scientists, civil engineers, government officials, relief workers, insurance industry representatives, news media, or homeowners). Based on real scientific data and geography model a city’s decision to either rebuild or relocate homes that have been destroyed in a natural disaster. The class develops criteria for scientific use of data, analysis processes, and accountability of the impact for different roles on project outcomes.

**Resources:**

- National Science Digital Library, Science Digital Literacy Maps
  - The Physical Setting: Weather and Climate: [http://strandmaps.nsdl.org/?id=SMS-MAP-1698](http://strandmaps.nsdl.org/?id=SMS-MAP-1698)
  - The Physical Setting: Changes in the Earth's Surface [http://strandmaps.nsdl.org/?id=SMS-MAP-0048](http://strandmaps.nsdl.org/?id=SMS-MAP-0048)

- Science Curriculum Topic Study: Soil, p. 186
- Science Curriculum Topic Study: Weathering and Erosion, p. 192

**Other Web Based Resources**


**D. Tectonics:** The theory of plate tectonics provides a framework for understanding the dynamic processes within and on Earth

<table>
<thead>
<tr>
<th>Essential Questions</th>
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</tr>
</thead>
<tbody>
<tr>
<td>How and why have the Earth’s tectonic plates changed over time? How do we know?</td>
<td>Theories governing the movement of lithospheric plates were developed over time through the analysis of Earth materials.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Statements</th>
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</tr>
</thead>
<tbody>
<tr>
<td>Convection currents in the upper mantle drive plate motion. Plates are pushed apart at spreading zones and pulled down into the crust at subduction zones.</td>
<td>Explain the mechanisms for plate motions using earthquake data, mathematics, and conceptual models. <em>(5.4.12.D.1)</em></td>
</tr>
</tbody>
</table>

**Instructional Focus:**

- Earth, like other planets, is still cooling, though radioactive decay continuously generates internal heat. This heat flows through and out of Earth’s interior largely through convection, but also through conduction and radiation. The flow of Earth’s heat is like its lifeblood, driving its internal motions. *(4.2 NSF, 2009)*

- 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. *(4C/H5 BSL)*

- Earth’s tectonic plates consist of the rocky crust and uppermost mantle, and move slowly with respect to one another. New oceanic plate continuously forms at mid-ocean ridges and other spreading centers, sinking back into the mantle at ocean trenches. Tectonic plates move steadily at rates of up to 10 centimeters per year. *(4.4 NSF, 2009)*

- 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. *(4C/H4ab BSL)*

- Earth’s interior is in constant motion through the process of convection, with important consequences for the surface. Convection in the iron-rich liquid outer core, along with Earth’s rotation around its axis, generates Earth’s magnetic field. By deflecting solar wind around the planet, the magnetic field prevents the solar wind from stripping away Earth’s atmosphere. Convection in the solid mantle drives the many processes of plate tectonics, including the formation and movements of the continents and oceanic crust. *(4.3 NSF, 2009)*

**Common Student Misconceptions:**

Students of all ages may hold the view that the world was always as it is now, or that any changes that have occurred must have been sudden and comprehensive *(Freyberg, P., 1985)*. The students in these studies did not, however, have any formal instruction on the topics investigated. Moreover, middle-school students taught by traditional means are not able to construct coherent explanations about the causes of volcanoes and earthquakes *(Duschl, R., Smith, M., Kesidou, S., Gitomer, D., Schauble, L., 1992)*

**Sample Integration of Science Practices and Core Content:**

Using the This Dynamic Planet interactive web-based GIS, students investigate plate tectonics, earthquakes, volcanoes, and impact craters. This lesson provides an introduction to thinking spatially and makes an excellent bridge to further investigations using desktop GIS software. Need a Web browser to use.

[http://gis.esri.com/industries/education/arclessons/search_results.cfm?id=301](http://gis.esri.com/industries/education/arclessons/search_results.cfm?id=301)
Sample Assessment Item:

1. The diagram above shows a cross section of the edge of a continent. In this region a section of oceanic crust is gradually moving down under a section of continental crust. Explain how the mountain range near the seacoast on this continent was probably formed. (NAEP)

Resources:

✓ National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: Plate Tectonics: http://strandmaps.nsdl.org/?id=SMS-MAP-0049
  Common Themes: Models: http://strandmaps.nsdl.org/?id=SMS-MAP-2408

✓ Science Curriculum Topic Study: Plate Tectonics, p. 182
✓ Science Curriculum Topic Study: Models, p. 269

Other Web Based Resources:


<table>
<thead>
<tr>
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<th>Cumulative Progress Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evidence from lava flows and ocean-floor rocks shows</td>
<td>Calculate the average rate of seafloor spreading using archived geomagnetic-reversals data. (5.4.12.D.2)</td>
</tr>
<tr>
<td>that Earth’s magnetic field reverses (North – South)</td>
<td></td>
</tr>
<tr>
<td>over geologic time.</td>
<td></td>
</tr>
</tbody>
</table>

Instructional Focus:

• In the 1960s, scientists noted that earthquakes occur much more frequently in certain areas, that the rock around mid-ocean ridges is progressively older the farther it is from the ridge, and that this gradient is symmetrical on either side of the ridge. This evidence, coupled with a scientifically sound physical explanation for how continents could move, transformed the idea of moving continents into the theory of plate tectonics. 10E/H3 (BSL)

• Earth’s crust has two distinct types: continental and oceanic. Continental crust persists at Earth’s surface and can be billions of years old. Oceanic crust continuously forms and recycles back into the mantle; in the ocean, it is nowhere older than about 200 million years. 2.4 (NSF, 2009)

• Earth’s tectonic plates consist of the rocky crust and uppermost mantle, and move slowly with respect to one
Common Student Misconceptions:

Students of all ages may hold the view that the world was always as it is now, or that any changes that have occurred must have been sudden and comprehensive (Freyberg, P., 1985). The students in these studies did not, however, have any formal instruction on the topics investigated. Moreover, middle-school students taught by traditional means are not able to construct coherent explanations about the causes of volcanoes and earthquakes (Duschl, R., Smith, M., Kesidou, S., Gitomer, D., Schauble, L., 1992)

Sample Assessment Item:

1. Why are the magnetic bands in the eastern Pacific Ocean so far apart compared to the magnetic bands along the Mid-Atlantic Ridge?

(Glencoe, 2008)

Resources:

✓ National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: Plate Tectonics: http://strandmaps.nsdl.org/?id=SMS-MAP-0049
  Historical Perspectives: Moving the Continents: http://strandmaps.nsdl.org/?id=SMS-MAP-2355

✓ Science Curriculum Topic Study: Plate Tectonics, p. 182

Other Web Based Resources


### E. Energy in Earth Systems: Internal and external sources of energy drive Earth systems.

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Enduring Understandings</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the roles of Earth’s materials and the sun in the transfer of energy within the Earth system?</td>
<td>Both internal and external sources of energy determine the global energy budget.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Statements</th>
<th>Cumulative Progress Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Sun is the major external source of energy for Earth’s global energy budget.</td>
<td>Model and explain the physical science principles that account for the global energy budget. (5.4.12.E.1)</td>
</tr>
</tbody>
</table>

### Instructional Focus:

- Transfer of thermal energy between the atmosphere and the land or oceans produces temperature gradients in the atmosphere and the oceans. Regions at different temperatures rise or sink or mix, resulting in winds and ocean currents. These winds and ocean currents, which are also affected by the earth's rotation and the shape of the land, carry thermal energy from warm to cool areas. *4B/H2* (BSL)

- Earth receives energy in the form of electromagnetic radiation from the Sun. Some of this solar energy is absorbed by the atmosphere, some is scattered back to space, and some is transmitted through the atmosphere to be absorbed or reflected by Earth's surface. The solar energy reflected by Earth's surface is absorbed, scattered, or transmitted by the atmosphere. *2.1* (NOAA, 2008)

- Sunlight reaching the Earth can heat the land, ocean, and atmosphere. Some of that sunlight is reflected back to space by the surface, clouds, or ice. Much of the sunlight that reaches Earth is absorbed and warms the planet. *1.A* (AAAS, NOAA, 2009)

- When Earth emits the same amount of energy as it absorbs, its energy budget is in balance, and its average temperature remains stable. *1.B* (AAAS, NOAA, 2009)

- The amount of solar energy absorbed or radiated by Earth is modulated by the atmosphere and depends on its composition. Greenhouse gases—such as water vapor, carbon dioxide, and methane—occur naturally in small amounts and absorb and release heat energy more efficiently than abundant atmospheric gases like nitrogen and oxygen. Small increases in carbon dioxide concentration have a large effect on the climate system. *2.C* (AAAS, NOAA, 2009)

### Sample Integration of Science Practices:

Use the GLOBE Student Data Archive and visualizations to display current temperatures on a map of the world. Investigate the patterns in the temperature map, looking especially for differences between the Northern and Southern Hemispheres, and between equatorial regions and high latitudes.

Then zoom in for a closer look at a region which has a high density of student reporting stations (such as US and Europe). They examine temperature maps for the region, from four dates during the past year (the solstices and equinoxes). Compare and contrast the patterns in these maps, looking for seasonal patterns.

- a) Summarize the effect of latitude, elevation, and geography on global temperature patterns.
- b) Explain how local and regional seasonal variations are the result of variation in solar heating.


### Resources:

- National Science Digital Library, Science Digital Literacy Maps
- The Physical Setting: Weather and Climate: [http://strandmaps.nsdl.org/?id=SMS-MAP-1698](http://strandmaps.nsdl.org/?id=SMS-MAP-1698)

- **Science Curriculum Topic Study:** Air and Atmosphere, p. 175
Other Web Based Resources


Content Statements

| Earth systems have internal and external sources of energy, both of which create heat. | Predict what the impact on biogeochemical systems would be if there were an increase or decrease in internal and external energy. (5.4.12.E.2) |

Instructional Focus:

- 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. 4C/H3 (BSL)
- Solar energy drives many chemical, biological, and physical processes that affect Earth's atmosphere. These include processes such as photosynthesis, evaporation of liquid water to produce water vapor, formation of smog, and the formation and destruction of ozone. 2.4 (NOAA, 2008)
- Earth also emits energy in the form of electromagnetic radiation. Almost all of the energy emitted comes from the solar energy absorbed by Earth's surface. This terrestrial energy is absorbed by atmospheric trace gases, such as water vapor, carbon dioxide, and other gases in Earth's atmosphere. It may be reemitted from the atmosphere, either to space, where it is lost to the Earth System, or back to Earth, where it is again absorbed, producing a "Greenhouse Effect". This natural Greenhouse Effect is necessary for life to exist on Earth. 2.5 (NOAA, 2008)
- All Earth processes are the result of energy flowing and mass cycling within and between Earth’s systems. This energy is derived from the sun and Earth’s interior. The flowing energy and cycling matter cause chemical and physical changes in Earth’s materials and living organisms. For example, large amounts of carbon continually cycle among systems of rock, water, air, organisms, and fossil fuels such as coal and oil. 3.2 (NSF, 2009)

Sample Assessment Item:

1. Predict what the impact on biogeochemical systems would be if there were an increase or decrease in internal and external energy.

Resources:

- National Science Digital Library, Science Digital Literacy Maps
  - The Physical Setting: Weather and Climate: http://strandmaps.nsdl.org/?id=SMS-MAP-1698
  - The Physical Setting: Plate Tectonics: http://strandmaps.nsdl.org/?id=SMS-MAP-0049
  - The Physical Setting: States of Matter: http://strandmaps.nsdl.org/?id=SMS-MAP-1341

- Science Curriculum Topic Study: Air and Atmosphere, p. 175
- Science Curriculum Topic Study: Structure of the Solid Earth, p. 188
- Science Curriculum Topic Study: Heat and Temperature, p. 216
Other Web Based Resources


### F. Climate and Weather:
Earth’s weather and climate systems are the result of complex interactions between land, ocean, ice, and atmosphere.

<table>
<thead>
<tr>
<th>Essential Questions</th>
<th>Enduring Understandings</th>
</tr>
</thead>
<tbody>
<tr>
<td>What are the factors that control Earth’s climate and</td>
<td>Earth’s energy and climate are controlled by many interacting factors.</td>
</tr>
<tr>
<td>weather?</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Statements</th>
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</thead>
<tbody>
<tr>
<td>Global climate differences result from the uneven</td>
<td>Explain that it is warmer in summer and colder in winter for people</td>
</tr>
<tr>
<td>heating of Earth’s surface by the Sun. Seasonal climate</td>
<td>in New Jersey because the intensity of sunlight is greater and the</td>
</tr>
<tr>
<td>variations are due to the tilt of Earth’s axis with</td>
<td>days are longer in summer than in winter. Connect these seasonal</td>
</tr>
<tr>
<td>respect to the plane of Earth’s nearly circular orbit</td>
<td>changes in sunlight to the tilt of Earth’s axis with respect to the</td>
</tr>
<tr>
<td>around the Sun.</td>
<td>plane of its orbit around the Sun. (5.4.12.F.1)</td>
</tr>
</tbody>
</table>

### Instructional Focus:

- 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 intensity of sunlight and the resulting warming of the earth's surface produces the seasonal variations in temperature. 4B/H3 (BSL)
- Climatic conditions result from latitude, altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as cloud formation, ocean currents, and atmospheric circulation patterns influence climates as well. 4B/H5 (BSL)
- The tilt of Earth’s axis relative to its orbit around the Sun results in predictable changes in the duration of daylight and the amount of sunlight received at any latitude throughout a year. These changes cause the annual cycle of seasons and associated temperature changes. 1.C (AAAS, NOAA, 2009)
- Gradual changes in Earth’s rotation and orbit around the Sun change the intensity of sunlight received in our planet’s polar and equatorial regions. For at least the last 1 million years, these changes occurred in 100,000-year cycles that produced ice ages and the shorter warm periods between them. 1.D (AAAS, NOAA, 2009)

### Common Student Misconceptions:

Students of all ages (including college students and adults) have difficulty understanding what causes the seasons. Students may not be able to understand explanations of the seasons before they reasonably understand the relative size, motion, and distance of the sun and the earth (Sadler, P., 1987). Many students before and after instruction in earth science think that winter is colder than summer because the earth is further from the sun in winter (Atwood, R., Atwood, V., 1996). This idea is often related to the belief that the earth orbits the sun in an elongated elliptical path (Galili, I., Lavrik, V., 1998). Other students, especially after instruction, think that the distance between the northern hemisphere and the sun changes because the earth leans toward the sun in the summer and away from the sun in winter (Galili, I., Lavrik, V., 1998). Students' ideas about how light travels and about the earth-sun relationship, including the shape of the earth's orbit, the period of the earth's revolution around the sun, and the period of the earth's rotation around its axis, may interfere with students' understanding of the seasons (Galili, I., Lavrik, V., 1998). For example, some students believe that the side of the sun not facing the earth experiences winter, indicating a confusion between the daily rotation of the earth and its yearly revolution around the sun (Salierno, C., Edelson, D. C., Sherin, B., 2005).

### Sample Assessment Item:
1. Explain the seasonal lag that occurs between the dates of the solstices and the dates of peak summer and winter. (Glencoe, 2008)
2. Explain the mechanisms that result in most dry climates are located near the tropics.

Resources:

- National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: Weather and Climate: [http://strandmaps.nsdl.org/?id=SMS-MAP-1698](http://strandmaps.nsdl.org/?id=SMS-MAP-1698)
  Common Themes: Patterns of Change: [http://strandmaps.nsdl.org/?id=SMS-MAP-2436](http://strandmaps.nsdl.org/?id=SMS-MAP-2436)

- **Science Curriculum Topic Study:** Weather and Climate, p. 191
- **Science Curriculum Topic Study:** Constancy, Equilibrium, and Change, p. 268

Other Web Based Resources:


### Content Statements

| Climate is determined by energy transfer from the Sun at and near Earth’s surface. This energy transfer is influenced by dynamic processes, such as cloud cover and Earth’s rotation, as well as static conditions, such as proximity to mountain ranges and the ocean. Human activities, such as the burning of fossil fuels, also affect the global climate. | Explain how the climate in regions throughout the world is affected by seasonal weather patterns, as well as other factors, such as the addition of greenhouse gases to the atmosphere and proximity to mountain ranges and to the ocean. (5.4.12.F.2) |

### Instructional Focus:

- Climatic conditions result from latitude, altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as cloud formation, ocean currents, and atmospheric circulation patterns influence climates as well. 4B/H5 (BSL)

- The earth's climates have changed in the past, are currently changing, and are expected to change in the future, primarily due to changes in the amount of light reaching places on the earth and the composition of the atmosphere. The burning of fossil fuels in the last century has increased the amount of greenhouse gases in the atmosphere, which has contributed to Earth's warming. 4B/H6 (BSL)

- Greenhouse gases in the atmosphere, such as carbon dioxide and water vapor, are transparent to much of the incoming sunlight but not to the infrared light from the warmed surface of the earth. When greenhouse gases increase, more thermal energy is trapped in the atmosphere, and the temperature of the earth increases the light energy radiated into space until it again equals the light energy absorbed from the sun. 4B/H4 (BSL)

- 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. 4C/M7 (BSL)

### Sample Assessment Item:

1. You have purchased a large piece of property and your family has decided to build a house that is entirely off the grid. Should you build the house on the leeward or windward side of a mountain? Explain your reasoning.

Resources:

- National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: Weather and Climate: [http://strandmaps.nsdl.org/?id=SMS-MAP-1698](http://strandmaps.nsdl.org/?id=SMS-MAP-1698)

- **Science Curriculum Topic Study:** Weather and Climate, p. 191
Other Web Based Resources


<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Earth’s radiation budget varies globally, but is balanced. Earth’s hydrologic cycle is complex and varies globally, regionally, and locally.</td>
<td>Explain variations in the global energy budget and hydrologic cycle at the local, regional, and global scales. (5.4.12.F.3)</td>
</tr>
</tbody>
</table>

Instructional Focus:

- 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 intensity of sunlight and the resulting warming of the earth's surface produces the seasonal variations in temperature. 4B/H3 (BSL)

- Climatic conditions result from latitude, altitude, and from the position of mountain ranges, oceans, and lakes. Dynamic processes such as cloud formation, ocean currents, and atmospheric circulation patterns influence climates as well. 4B/H5 (BSL)

- Earth’s climate is an example of how complex interactions among systems can result in relatively sudden and significant changes. The geologic record shows that interactions among tectonic events, solar inputs, planetary orbits, ocean circulation, volcanic activity, glaciers, vegetation, and human activities can cause appreciable, and in some cases rapid, changes to global and regional patterns of temperature and precipitation. 3.8 (NSF, 2009)

- The ocean controls weather and climate by dominating the Earth’s energy, water and carbon systems. 3.a (NGS and NOAA, 2005)

- The ocean absorbs much of the solar radiation reaching Earth. The ocean loses heat by evaporation. This heat loss drives atmospheric circulation when, after it is released into the atmosphere as water vapor, it condenses and forms rain. Condensation of water evaporated from warm seas provides the energy for hurricanes and cyclones. 3.b (NGS, NOAA, 2005)

- Climate plays an important role in the global distribution of freshwater resources. Changing precipitation patterns and temperature conditions will alter the distribution and availability of freshwater resources, reducing reliable access to water for many people and their crops. Winter snowpack and mountain glaciers that provide water for human use are declining as a result of global warming. 7.B (AAAS, NOAA, 2009)

Sample Assessment Item:

1. Air in the atmosphere continuously moves by convection. At the equator, air rises; at the poles, it sinks. This occurs because
   A. the Earth's ozone layer is thinner at the equator than at the poles
   B. the Earth's magnetic field is stronger at the poles than at the equator
   C. warm air can hold less water vapor than cold air
   D. **warm air is less dense than cold air** (NAEP)

Resources:

- National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: Weather and Climate: http://strandmaps.nsdl.org/?id=SMS-MAP-1698
  Common Themes: Patterns of Change: http://strandmaps.nsdl.org/?id=SMS-MAP-2436
✓ Science Curriculum Topic Study: Weather and Climate, p. 191
✓ Science Curriculum Topic Study: Constancy, Equilibrium, and Change, p. 268

Other Web Based Resources:


**G. Biogeochemical Cycles:** The biogeochemical cycles in the Earth systems include the flow of microscopic and macroscopic resources from one reservoir in the hydrosphere, geosphere, atmosphere, or biosphere to another, are driven by Earth's internal and external sources of energy, and are impacted by human activity.

<table>
<thead>
<tr>
<th>Essential Questions</th>
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</tr>
</thead>
<tbody>
<tr>
<td>How do natural and human-made changes in one part of the Earth system affect other parts of the system and in what ways can Earth processes be explained as interactions among spheres?</td>
<td>Earth’s components form systems that have cycles and patterns that allow us to make predictions and informed decisions.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Content Statements</th>
<th>Cumulative Progress Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Movement of matter through Earth’s system is driven by Earth’s internal and external sources of energy and results in changes in the physical and chemical properties of the matter.</td>
<td>Demonstrate, using models, how internal and external sources of energy drive the hydrologic, carbon, nitrogen, phosphorus, sulfur, and oxygen cycles. <em>(5.4.12.G.3)</em></td>
</tr>
</tbody>
</table>

**Instructional Focus:**

- All Earth processes are the result of energy flowing and mass cycling within and between Earth’s systems. This energy is derived from the sun and Earth’s interior. The flowing energy and cycling matter cause chemical and physical changes in Earth’s materials and living organisms. For example, large amounts of carbon continually cycle among systems of rock, water, air, organisms, and fossil fuels such as coal and oil. *(3.2)* *(NSF, 2009)*

- Earth exchanges mass and energy with the rest of the Solar System. Earth gains and loses energy through incoming solar radiation, heat loss to space, and gravitational forces from the sun, moon, and planets. Earth gains mass from the impacts of meteoroids and comets and loses mass by the escape of gases into space. *(3.3)* *(NSF, 2009)*

- The chemistry of ocean water is changed by absorption of carbon dioxide from the atmosphere. Increasing carbon dioxide levels in the atmosphere is causing ocean water to become more acidic, threatening the survival of shell-building marine species and the entire food web of which they are a part. *(7.D)* *(AAAS, NOAA, 2009)*

**Sample Integration of Science Practices and Core Content:**

Create a conceptual model, that illustrates how internal and external sources of energy drive the (choose two: hydrologic, carbon, nitrogen, phosphorus, sulfur, oxygen) cycles.

**Sample Assessment Item:**

1. Demonstrate, using models, how internal and external sources of energy drive the hydrologic, carbon, nitrogen, phosphorus, sulfur, and oxygen cycles.

**Resources:**

- National Science Digital Library, Science Digital Literacy Maps
  - The Physical Setting: States of Matter: [http://strandmaps.nsdl.org/?id=SMS-MAP-1341](http://strandmaps.nsdl.org/?id=SMS-MAP-1341)

- *Science Curriculum Topic Study:* Air and Atmosphere, p. 175
- *Science Curriculum Topic Study:* Structure of the Solid Earth, p. 188
- *Science Curriculum Topic Study:* Heat and Temperature, p. 216
- *Science Curriculum Topic Study:* Systems, p. 271
- *Science Curriculum Topic Study:* Models, p. 269

36
Other Web Based Resources:


<table>
<thead>
<tr>
<th>Content Statements</th>
<th>Cumulative Progress Indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Earth is a system in which chemical elements exist in fixed amounts and move through the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles.</td>
<td>Relate information to detailed models of the hydrologic, carbon, nitrogen, phosphorus, sulfur, and oxygen cycles, identifying major sources, sinks, fluxes, and residence times. (5.4.12.G.7)</td>
</tr>
</tbody>
</table>

Instructional Focus:

- The abundance of greenhouse gases in the atmosphere is controlled by biogeochemical cycles that continually move these components between their ocean, land, life, and atmosphere reservoirs. The abundance of carbon in the atmosphere is reduced through seafloor accumulation of marine sediments and accumulation of plant biomass and is increased through deforestation and the burning of fossil fuels as well as through other processes. 2.D (AAAS, NOAA, 2009)
- Earth’s atmosphere plays an important role in biogeochemical cycles in the Earth Systems, For example, the atmosphere is a reservoir of carbon through the Earth System, storing carbon released from natural processes and fossil fuel burning. Plants extract carbon from the atmosphere through photosynthesis. 5.3 (NSF, 2008)
- The ocean dominates the Earth’s carbon cycle. Half the primary productivity on Earth takes place in the sunlit layers of the ocean and the ocean absorbs roughly half of all carbon dioxide added to the atmosphere. 3.e (NOAA, 2005)
- Earth’s systems interact over a wide range of temporal and spatial scales. These scales range from microscopic to global in size and operate over fractions of a second to billions of years. These interactions among Earth’s systems have shaped Earth’s history and will determine Earth’s future. 3.4 (NSF, 2009)
- Earth’s systems are dynamic; they continually react to changing influences. Components of Earth’s systems may appear stable, change slowly over long periods of time, or change abruptly with significant consequences for living organisms. 3.6 (NSF, 2009)

Resources:

- National Science Digital Library, Science Digital Literacy Maps
  The Physical Setting: States of Matter: http://strandmaps.nsdl.org/?id=SMS-MAP-1341
- Science Curriculum Topic Study: Systems, p. 271

Other Web Based Resources:

- National Science Foundation, National Oceanic and Atmospheric Administration, (2008). Essential Principles and


References


