Table 12: Earth and Space Science Content Statements for Grades 4, 8, and 12

GRADE 4	GRADE 8	GRADE 12
Earth in Space and Time		
Objects in the Universe: From patterns in the sky (4) to a model of the solar system (8) to a vision of the universe (12).		
E4.1: Objects in the sky have patterns of movement. The sun, for example, appears to move across the sky in the same way every day, but its path changes slowly over the seasons. The moon appears to move across the sky on a daily basis much like the sun. **E4.2:** The observable shape of the moon changes from day to day in a cycle that lasts about a month.	**E8.1:** In contrast to an earlier theory that Earth is the center of the universe, it is now known that the sun, an average star, is the central and largest body in the solar system. Earth is the third planet from the sun in a system that includes seven other planets and their moons, as well as smaller objects, such as asteroids and comets. **E8.2:** Gravity is the force that keeps most objects in the solar system in regular and predictable motion. Those motions explain such phenomena as the day, the year, phases of the moon, and eclipses.	**E12.1**: The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin approximately 13.7 billion years ago when the universe began in a hot, dense state. According to this theory, the universe has been expanding ever since. **E12.2:** 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 and billions of galaxies. **E12.3:** Stars, like the sun, transform matter into energy in nuclear reactions. When hydrogen nuclei fuse to form helium, a small amount of matter is converted to energy. These and other processes in stars have led to the formation of all the other elements.

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12

GRADE 4	GRADE 8	GRADE 12
Objects in the Universe: Examples, Observations, and Phenomena		
Apparent positions of the sun and moon in the sky at different times of day Differences in the appearance of the moon during different times of the month Sun's apparent path across the sky in different seasons Real-world problems involving knowledge of the sun's daily path (e.g., placement of drapes for sleeping during the day, position of solar panels to take full advantage of solar radiation) <u>Exclusions</u>: ▪ Clouds, birds, or airplanes (since the intention of these statements is to introduce students to "Objects in the Universe") ▪ Observations of stars and galaxies	Moon phases Solar and lunar eclipses Gravity acting between all objects and operating to keep planets and satellites in their orbits Launching rockets and placing satellites in orbit Astronauts in orbit experiencing gravity as they "fall" around Earth <u>Exclusions</u>: ▪ Mathematical formulation of Kepler's laws or the equations for elliptical orbits or parabolic trajectories	Evolution of universe: major features of "big bang" theory Structure of universe: Location of our galaxy among others and role of gravitation in galaxy formation Origin of elements in general: formation of H and He in early universe and formation of heavier elements by fusion in stars Processes in stars: Qualitative understanding about nuclear fusion in stars that release energy and produce heavier elements <u>Exclusions</u>: ▪ Details of the "big bang" such as "inflation" or "decoupling" ▪ Reaction rates in stars ▪ How galaxies are organized into larger structures ▪ Details of nuclear reactions

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12

GRADE 4	GRADE 8	GRADE 12
Objects in the Universe: Instruments, Measurement, and Representations		
Sundial-type devices to find patterns in the sun's movement with respect to Earth: length and position of shadows of a vertical stick placed in the ground (e.g., flagpole) observed at regular intervals during the day (understanding the relationship between position of an object, its shadow, and the sun) Photographs or simple sketches of monthly cycle of moon phases (full, more than half full, about half full, less than half full, "a sliver") Period length of the sun's path across the sky (one day) and moon's phases (about one month) Simple sketches showing the movement of a gnomon's shadow, the path of the sun, moon phases, or changing position and appearance of the moon <u>Exclusions</u>: ▪ Telescope	Unaided eye (e.g., for daytime and early evening observations of sun, moon, and planets) Telescopes and binoculars (e.g., to see stars; planets; and lunar craters, mountains, and large dark areas on the moon) Drawings to represent spatial relationships (using space perspective) Drawings or photographs of the sun and planets in the solar system and their motions Illustrations of mathematical concepts (ellipses, angular measures, and scale) using conventional notation Sketches and diagrams of sun's path, moon phases, planetary movements, rocket launches Qualitative relationships among distance, mass, and gravitational forces <u>Exclusions</u>: ▪ Inverse square relationship of gravitation and distance measurements	Telescopes and binoculars to see stars, nebulae, and galaxies Spectroscopes to determine the composition of stars as well as the speed of stars and galaxies towards or away from us Computer simulations of processes in stars, the formation of galaxies and the "big bang" Technologies (e.g., telescopes, spectroscopes) that provide evidence to test theories about stars and the universe Images taken by large or space-based telescopes and spectra of stars and galaxies Interpretation of graphs in terms of relationships (e.g., brightness versus temperature, distance to galaxies versus redshift) <u>Exclusions</u>: ▪ How to operate spectroscopes or calculate redshift ▪ Naming laws represented by graphs (e.g., Hubble's Law, HR Diagram)
Objects in the Universe: Technical Vocabulary		
<u>Exclusions</u>: ▪ Northern Hemisphere ▪ Technical terms related to moon phases (e.g., waning, waxing, gibbous) ▪ Ecliptic (use term such as "path of the sun") ▪ Gnomon (use term such as "vertical stick")	Common terms in astronomy included, such as trajectory, orbit, and eclipse, and angular measurement in degrees <u>Exclusions</u>: ▪ Technical terms nonessential for conceptual understanding, such as apogee and perigee	Technical vocabulary from physics and chemistry questions as well as commonly used astronomical terms such as galaxy, nebula, and supernova <u>Exclusions</u>: ▪ Exotic objects (e.g., neutron stars, black holes)

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12

GRADE 4	GRADE 8	GRADE 12
Objects in the Universe: Clarification		
Changes and patterns in the sky as seen from Earth—the Earth-centric view In the Northern Hemisphere, in the morning, the sun is generally to the east; at noon, it is toward the south; and during the afternoon, it is to the west. The moon can be seen some of the time during the day and some of the time during the night. It seems to make a daily path across the sky. When the moon can be seen, the lighted side gets its light from the sun. The moon looks a little different every day, but it has the same appearance again in about a month. Proper sequencing of pictures of moon phases during the month. See Appendix H for elaboration of E4.1 and E4.2. <u>Exclusions</u>: ▪ The space perspective in explaining these patterns (moon phases, sun's path across the sky, seasons) ▪ Explanations for sun and moon eclipses; relationships between eclipses and moon phases ▪ Relative distances of sun, moon, Earth	The space perspective of the solar system to explain phenomena such as moon phases Appearance of the sun, moon, and stars going around Earth once a day is due to Earth's rotation on its axis. The moon revolves around Earth about once a month, and Earth revolves around the sun once a year. The space perspective can explain the day-night cycle, moon phases, and solar and lunar eclipses. Gravity pulls things "down" towards the center of Earth. A common naïve conception is that there is no gravity in space because there is no air there. See Appendix H for elaboration of E8.2. <u>Exclusions</u>: ▪ Underlying physics principles of above phenomena	Observational evidence and physics concepts that support theories about how stars shine and the origin of the universe <u>Exclusions</u>: ▪ Phenomena such as neutron stars or black holes

Table 12: Earth and Space Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Earth in Space and Time		
History of Earth: From evidence of change (4) to estimating the timing and sequence of geologic events (8) to theories about Earth's history (12).		
E4.3: The surface of Earth changes. Some changes are due to slow processes, such as erosion and weathering, and some changes are due to rapid processes, such as landslides, volcanic eruptions, and earthquakes.	**E8.3:** Fossils provide important evidence of how life and environmental conditions have changed in a given location. **E8.4:** Earth processes seen today, such as erosion and mountain building, made possible the measurement of geologic time through methods such as observing rock sequences and using fossils to correlate the sequences at various locations.	**E12.4:** Early methods of determining geologic time, such as the use of index fossils and stratigraphic sequences, allowed for the relative dating of geological events. However, absolute dating was impossible until the discovery that certain radioactive isotopes in rocks have known decay rates, making it possible to determine how many years ago a given rock sample formed. **E12.5:** Theories of planet formation and radioactive dating of meteorites and lunar samples have led to the conclusion that the sun, Earth, and the rest of the solar system formed from a nebular cloud of dust and gas 4.6 billion years ago. **E12.6:** Early Earth was very different from today's planet. Evidence for one-celled forms of life—the bacteria—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of Earth's atmosphere, which did not originally contain molecular oxygen. **E12.7:** Earth's current structure has been influenced by both sporadic and gradual events. Changes caused by violent earthquakes and volcanic eruptions can be observed on a human time scale, but many geological processes, such as the building of mountain chains and shifting of entire continents, take place over hundreds of millions of years.

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
History of Earth: Examples, Observations, and Phenomena		
Simple changes such as rust on metals, wood rot on buildings, and mold growth on food Examples of processes that break down Earth structures, such as erosion and landslides Examples of processes that build up Earth structures and materials, such as the slow formation of soils and sedimentary rocks when rivers and streams deposit sand and mud; or the rapid buildup (or destruction) of mountains during volcanic eruptions, or uplift of large land masses during earthquakes <u>Exclusions</u>: ▪ Names of the processes (focus should be on the processes themselves). For example, it is not important that students distinguish between weathering and erosion. ▪ Slow mountain building resulting from plate tectonics	Order of events based on images or drawings of road cuts, sediment cores, or other evidence; evidence of more recent events found closer to the surface (Law of Superposition) Data on current rate of deposition used to determine how long it took a thick layer of sediment to form (keeping numbers simple) Fossil evidence showing that environmental conditions changed over time (a cluster of items may tap this well) Determining if two rock strata that look alike date from the same period of time by examining the fossils within them	Using index fossils to determine time sequences and half-life of radioactive isotopes to determine time spans Key phases in the geologic evolution of Earth (e.g., formation of the planet more than 4 billion years ago, evolution of single-celled animals more than 3 billion years ago, development of an atmosphere with oxygen about 2 billion years ago, multi-celled animals less than 1 billion years ago) Simple quantitative problems based on measured rates of geologic processes, such as mountain-building, deposition, or erosion; calculations of how long it took for major geologic changes to occur <u>Exclusions</u>: ▪ Detailed mechanism of radioactive decay (emphasis should instead be on its use to solve geologic puzzles)

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
History of Earth: Instruments, Measurement, and Representations		
Laboratory experiments or computer simulations of processes that change Earth structures and materials (e.g., stream tables showing modeling consequences of erosion and deposition; rotted log becoming soft and looking more like soil than wood; metal body of a car rusting; comparisons of erosion of slopes with bare soil and slopes with grassy soil) Photographs that capture images at different points in time Images showing how Earth structures have changed over time (e.g., Mt. St. Helens before eruption, just after eruption, one year later, and 20 years later); hypothesize the simple processes that were likely to have caused those changes	Sample cores of a lakebed or other column, revealing the history of deposition over time Simple calculations of time spans given data on rate of deposition Interpretation of fossil replicas (or images of fossils) to reconstruct extinct animals and past environments Drawings, images, charts, and graphs that can be used for paper-and-pencil items Rock samples and fossil replicas that can be used for hands-on tasks Computer simulations showing changes in Earth structures over time that can be used as a part of interactive computer tasks (ICTs)	Data on radioactive isotope decay presented in graph form and used as a tool to determine the age of a rock sample given percentages of different elements in the rock Drawing of rock layers with the location of fossils from an extinct prehistoric animal, along with dates of volcanic rock layers—determined by radioisotope methods above and below the fossils—used to give upper and lower bounds of time during which the extinct animal lived Illustrations of rock sequences, drawings of index fossils, and computer simulations of radioactive decay (can be used to assess understanding of how to measure geologic time) Charts of long time spans (can be used to assess understanding of the sequence and approximate timeframe for changes in Earth history)

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
History of Earth: Technical Vocabulary		
[No special vocabulary]	Common terms in geology (e.g., sedimentation) and paleontology (e.g., fossils) <u>Exclusions</u>: ▪ Names of extinct animals identified by their fossils, except for the most common such as trilobites and better-known dinosaurs ▪ Names of geologic eras, periods, and epochs ▪ Names of the processes (focus should be on the processes themselves). For example, students should be expected to understand and apply but not name "Law of Superposition." ▪ Names of physical mechanisms that caused past environmental changes	Technical vocabulary associated with geology (e.g., index fossils) as well as relevant terms from life sciences (e.g., bacteria, algae, extinct) and chemistry (e.g., radioisotopes, half-life) Names of eras (Pre-Cambrian, Paleozoic, Mesozoic, and Cenozoic) but students are not expected to recall these from memory <u>Exclusions</u>: ▪ Names of specific life forms (e.g., stromatolites) ▪ Geologic periods (e.g., Cambrian, Carboniferous) and epochs ▪ Naming the processes of radioactive decay
History of Earth: Clarification		
Simple changes are noted easily in students' daily lives. Other changes are less noticeable or are observed only occasionally but are still appropriate for assessment at this grade level. (See "Examples" category above.) Some changes in Earth's surface take place rapidly and others take place slowly in terms of a human lifetime. (Note that emphasis should be on changes that take place within a human lifespan, such as decay of wood buildings, erosion, landslides, volcanoes.) See Appendix H for elaboration of E4.3. <u>Exclusions</u>: ▪ Changes not easily observable that take place over very long stretches of time (e.g., Grand Canyon formation, tectonic mountain building, soil development)	Students better able to grasp large spans of time Evidence (e.g., fossils, rock sequences) that enable scientists to "read" Earth history Note connections between this subtopic and the Life Science subtopic, "Evolution and Diversity."	Key idea: Evidence for measuring geologic time and determining a sequence of events. Revisit mechanisms that build up and tear down Earth structures, sources of evidence, and vast span of geologic time. Note connections between this subtopic and the Life Science subtopic, "Evolution and Diversity."

Table 12: Earth and Space Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Earth Structures		
Properties of Earth Materials: From natural and human-made materials (4) to soil analysis and layers of the atmosphere (8).		
E4.4: Earth materials that occur in nature include rocks, minerals, soils, water, and the gases of the atmosphere. **E4.5:** Natural materials have different properties, which sustain plant and animal life. **E4.6:** Some Earth materials have properties that make them useful either in their present form or designed and modified to solve human problems and enhance the quality of life, as in the case of materials used for building or fuels used for heating and transportation.	**E8.5:** Rocks and rock formations bear evidence of the minerals, materials, temperature/pressure conditions, and forces that created them. Some formations show evidence that they were deposited by volcanic eruptions. Others are composed of sand and smaller particles buried and cemented by dissolved minerals to form solid rock again. Still others show evidence that they were once earlier rock types that were exposed to heat and pressure until they changed shape and in some cases melted and recrystallized. **E8.6:** Soil consists of weathered rocks and decomposed organic material from dead plants, animals, and bacteria. Soils are often found in layers with each having a different chemical composition and texture. **E8.7:** The atmosphere is a mixture of nitrogen, oxygen, and trace gases that include water vapor. The atmosphere has a different physical and chemical composition at different elevations.	

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Properties of Earth Materials: Examples, Observations, and Phenomena		
Common Earth materials related to fuels (e.g., oil, wood, coal); building materials (e.g., granite, marble); materials related to plant and animal nutrition (e.g., air, water, minerals); metals (e.g., rocks, ores) Shelter for animals (e.g., trees, bushes, soil, caves) General temperature conditions under which water is solid (ice) or gas (water vapor) Soil as a medium for plant growth <u>Exclusions</u>: ▪ Carbon dioxide and other specific component gases of the atmosphere ▪ Precise temperatures for when liquid water freezes or becomes water vapor	Evidence of how rocks were formed: layers in sedimentary rocks, small crystals in granite indicate slow cooling and crystallization, glassy texture of obsidian indicates rapid cooling, and fossils frequently found in coal indicate formation from decay of once-living matter Igneous (e.g., granite, basalt), metamorphic (e.g., marble, slate), and sedimentary (e.g., sandstone, limestone) rocks Metamorphic rocks identified by evidence that one type of rock was subjected to heat and pressure, such as layers of sedimentary rock that have been folded and twisted Gases in the atmosphere: mainly nitrogen, some oxygen, small amounts of water vapor, and traces of other gases Layers in the atmosphere: bottom layer (troposphere) has all of the clouds, weather, and most of the atmosphere's matter; air is cold and still in next layer up (stratosphere) Trends in temperature and pressure: with increasing elevation in atmosphere, temperature decreases and air pressure decreases Components of soil: rock fragments, sand, clay, decaying plant parts and other organic material, water, and/or other materials <u>Exclusions</u>: ▪ Names of intrusive magma bodies (e.g., batholith) ▪ Names of extrusive lava bodies (e.g., sills, dikes) ▪ Names of atmosphere layers in addition to troposphere and stratosphere (e.g., thermosphere, ionosphere)	[No content statements at this grade]

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Properties of Earth Materials: Instruments, Measurement, and Representations		
Classifying materials as either Earth or human-made materials (Note that this may be complex since some examples could fall in both categories. Materials used in items should fall clearly in one category or the other.) Qualitative descriptions of how Earth materials (e.g., bricks, wood, glass) are used in houses Simple bar graphs and tables, pictures, drawings, and diagrams Simple maps with keys, legends	Quantitative measures of mineral hardness using Moh's Hardness Scale Quantitative measures of soil porosity and permeability Quantitative measures of sediment size using sieves Litmus paper test of soil acidity/alkalinity Qualitative descriptions of instruments that can be used to separate Earth materials (e.g., sieves to separate soil particles of various sizes) Topographic, geologic and physical geographic maps Pie charts, bar graphs Drawings of stratigraphic sequences	[No content statements at this grade]
Properties of Earth Materials: Technical Vocabulary		
Generally limited to common natural materials (e.g., sand, clay, pebbles, oil, stone, wood, grasses, rocks, minerals) Generally limited to common human-made materials (e.g., bricks, tiles, cement, aluminum poles, nails, wire)	Sedimentary rock (sandstone, limestone, shale, coal, salt); igneous rock (granite, basalt, pumice, ash); metamorphic rock (marble, gneiss, schist, coal) Ores: iron, zinc, uranium, aluminum, copper, coal Soil layers, weathering, erosion, climate Soil textures (silt/loam/sand); soil acidity (acidic/alkaline) <u>Exclusions</u>: ▪ Ores: rare earth (e.g., titanium), alloys (e.g., bronze, steel, pewter, ceramics) ▪ Soils: names of soils	[No content statements at this grade]

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Properties of Earth Materials: Clarification		
Distinguishing Earth materials and their properties from human-made materials How humans and other animals use Earth materials for food, shelter, and tools The living and non-living parts of an ecosystem working together See Appendix H for elaboration of E4.4, E4.5, and E4.6.	More in-depth physical and chemical properties of Earth materials and the atmosphere. Evidence in rocks, minerals, and soils can be used to "tell a story" about the environment of formation. Maps are tools for interpreting "rock stories." Knowing that layered rock is formed under conditions of lower heat and pressure (which exist closer to the surface) than rock that contains crystals; existence of crystalline rock at the surface is considered evidence that such rock was pushed up to the surface after being formed far below. <u>Exclusions</u>: ▪ Core physics and chemistry concepts (e.g., chemical reactions, stress and strain)	[No content statements at this grade]

Table 12: Earth and Space Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Earth Structures		
Tectonics: From the basics of tectonic theory and Earth magnetism (8) to the physical mechanism that drives tectonics and its supporting evidence (12).		
	E8.8: The Earth is layered with a lithosphere; hot, convecting mantle; and dense, metallic core. **E8.9:** Lithospheric plates on the scale of continents and oceans constantly move at rates of centimeters per year in response to movements in the mantle. Major geological events, such as earthquakes, volcanic eruptions, and mountain building, result from these plate motions. **E8.10:** Earth as a whole has a magnetic field that is detectable at the surface with a compass. Earth's magnetic field is similar to the field of a natural or human-made magnet with north and south poles and lines of force. For thousands of years, people have used compasses to aid in navigation on land and sea.	**E12.8:** Mapping of the Mid-Atlantic Ridge, evidence of sea floor spreading, and subduction provided crucial evidence in support of the theory of plate tectonics. The theory currently explains plate motion as follows: the outward transfer of Earth's internal heat propels the plates comprising Earth's surface across the face of the globe. Plates are pushed apart where magma rises to form mid-ocean ridges, and the edges of plates are pulled back down where Earth materials sink into the crust at deep trenches.

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Tectonics: Examples, Observations, and Phenomena		
[No content statements at this grade]	Common geographic structures related to plate boundaries (e.g., Pacific ring of fire, deep-sea trenches, volcanoes with subduction plate boundaries) Earth surface features that represent evidence for Continental Drift (e.g., matching continent shapes, mid-ocean ridges, matching rock formations on different continents or on either side of spreading zones) Locations of major mountain chains on geographic maps revealing subduction zones Qualitative descriptions of how mountains are uplifted when plates collide or when volcanoes result where one plate slides under another Alignment of compass needle with Earth's magnetic field	Distinction between less dense continental crust and more dense oceanic crust, and what happens when they collide Historical events, evidence, and arguments for continental movement ("fit" of continents on either side of the Atlantic, continuity of rock and fossil formations across continents) and sea floor spreading (mid-ocean ridges, similar rock depositions on either side of the ridge) Magnetic properties of rocks on the ocean floor as strong evidence in support of sea-floor spreading Mountain-building at the collision of two continental plates Discrepancy between oldest age of ocean floor rocks and continental rocks

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Tectonics: Instruments, Measurement, and Representations		
[No content statements at this grade]	Use of seismometers and quantitative measures of earthquake intensities (e.g., Mercalli and Richter scales) Maps of ocean bottom and continental features associated with plate boundaries Earthquake maps to observe patterns of earthquakes Labeled models/representations of Earth's interior and Earth's magnetic field Maps of locations of active volcanoes	Calculating rate of plate motion using age of rock and distance from spreading ridge Topographic maps to construct elevation profile Drawings, models, or map projections to show earthquake foci and their relationship to plate boundaries Maps, models, or map projections to locate tectonic plates Geologic maps to locate and interpret rock formations and rock sequences resulting from tectonic plate interactions Maps and models to align ores with tectonic activity Maps of the ocean floor revealing the mid-ocean ridge and magnetic orientation of rocks on both sides of the mid-ocean ridge Maps showing movement of major plates since Pangaea
Tectonics: Technical Vocabulary		
[No content statements at this grade]	Names of major continents and oceans; names of plate boundaries (e.g., mid-ocean ridge, subduction zone) Richter and Mercalli scales	Convection, sea floor spreading, continental drift, tectonic theory

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Tectonics: Clarification		
[No content statements at this grade]	Correlation among plate boundaries, earthquakes and volcanoes, and mountain ranges Reading and interpreting physical, topographic, and geologic maps See Appendix H for elaboration of E8.9.	Convection currents in the mantle drive plate movements. Tectonic theory explains both sea-floor spreading and continental drift. Key idea: Historical and contemporary models, mechanisms, and theories associated with tectonics; evidence for the support of the models, mechanisms, and theories See Appendix H for elaboration of E12.8.

Table 12: Earth and Space Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Earth Systems		
Energy in Earth Systems: From role of the sun (4) to the sun's observable effects (8) to internal and external sources of energy in Earth systems (12).		
E4.7: The sun warms the land, air, and water and helps plants grow.	**E8.11:** The sun is the major source of energy for phenomena on Earth's surface. The sun provides energy for plants to grow and drives convection within the atmosphere and oceans, producing winds, ocean currents, and the water cycle. **E8.12:** Seasons result from annual variations in the intensity of sunlight and length of day, due to the tilt of Earth's rotation axis relative to the plane of its yearly orbit around the sun.	**E12.9:** Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from Earth's original formation.

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy in Earth Systems: Examples, Observations, and Phenomena		
Effects of sunlight on Earth: sunlight causes evaporation of water; sunlight melts snow and ice; sunlight is needed for plant growth Earth being warm at equator and cold at poles	Sunlight penetrating the upper layer of the ocean where it provides energy for plant and algae growth Warmer air/water rises; colder air sinks; air colder at higher elevations Sea breezes and land breezes, driven by differences in how water and land absorb energy from the sun Changes associated with seasons: seeing different constellations at different times of year; changes in length of day and average temperature during the year	Phenomena on the surface of Earth driven by the sun's energy, including ocean currents and winds, and the growth of plants and animals Decay of radioactive materials and gravitational energy left over from formation of Earth as sources of Earth's internal energy Phenomena on the surface of Earth driven by Earth's internal energy, including the movement of tectonic plates, which, in turn, causes earthquakes and volcanoes and builds mountains

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy in Earth Systems: Instruments, Measurement, and Representations		
Temperature measures (e.g., of bottled water—one left in sunlight, one left in shade) Location on map projections of hot and cold regions of Earth Pictures and diagrams of simple experiments (e.g., relationship between energy from the sun and temperature of soil)	Measurement of the length of shadows over intervals of months Measurement of the location of sunrise and sunset on the horizon Drawings of convection cells: warm air and water rise, cold air and water sink Drawings of the Earth–sun model: revolution, rotation, tilt-of-axis Drawing showing the position of Earth at the summer and winter solstices and spring and fall equinoxes Maps of major atmospheric and oceanic currents Graphs of mean monthly temperatures showing how temperature varies during the year at different latitudes and in different hemispheres <u>Exclusions</u>: ▪ Precession of the equinoxes ▪ Coriolis effect	Models and diagrams showing the flow of energy from the sun through Earth systems and resulting phenomena Models and diagrams showing the movement of Earth's internal convection currents and resulting phenomena.
Energy in Earth Systems: Technical Vocabulary		
Evaporation, light, heat, warm, cold, temperature, thermometer, absorb	Equinoxes, solstices, incoming solar radiation, mean annual temperatures	Related terms in the "Tectonics" subtopic

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Energy in Earth Systems: Clarification		
Key idea: Energy from the sun makes possible life on Earth. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy.	Energy from the sun drives all surface phenomena, including winds and ocean currents. Seasons arise due to the orientation of Earth's axis with respect to the sun. Earth's axis is tilted 23.5^{o} from the plane of its orbit around the sun. Since the axis stays pointing in the same direction as it circles the sun, the Northern Hemisphere leans toward the sun during one half of the year and away from the sun during the other half of the year. When the Northern Hemisphere leans towards the sun, longer and hotter days (summer) are experienced than when it leans away from the sun when shorter and cooler days (winter) are experienced. Uneven heating causes a convection current to develop. The resulting moving air is experienced as wind. Sea and land breezes can be used as context to assess understanding of forces that drive winds. Note connections between this subtopic and content statements P8.13 and L8.4. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy. See Appendix H for elaboration of E8.11 and E8.12.	Earth has both internal and external energy sources; each of these sources drives different phenomena. Note connections between this subtopic and content statements P12.14, P12.15, P12.16, L12.4, L12.5, L12.6, and E12.12. See pp. 105-106, "Energy Sources and Transfer" and "Uses, Transformations, and Conservation of Energy," for more on the crosscutting nature of energy.

Table 12: Earth and Space Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Earth Systems		
Climate and Weather: From local weather (4) to global weather patterns (8) to systems that influence climate (12).		
E4.8: Weather changes from day to day and over the seasons. **E4.9:** Scientists use tools for observing, recording, and predicting weather changes from day to day and over the seasons.	**E8.13:** Global patterns of atmospheric movement influence local weather. Oceans have a major effect on climate because water in the oceans holds a large amount of heat.	**E12.10:** 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, atmospheric gases, and Earth's rotation, as well as static conditions such as the positions of mountain ranges and of oceans, seas, and lakes.

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Climate and Weather: Examples, Observations, and Phenomena		
Data collected with simple weather instruments Changes in weather conditions during the day, from day to day, and over seasons	Global wind patterns Large scale systems: storms, hurricanes, warm fronts, cold fronts Changes in local weather caused by fronts and storms <u>Exclusions</u>: ▪ Names of convection processes such as Hadley Cells, Coriolis Effect, or Conveyor Belt theory	Application of energy transfer concepts to weather and climate phenomena (e.g., how local topography affects weather; how greenhouse gases "trap" infrared energy; how Earth's rotation affects global wind patterns and storm systems through Coriolis Effect) Major weather and climate phenomena: the jet stream, high and low pressure areas, and phenomena related to weather fronts <u>Exclusions</u>: ▪ Going beyond application of physics principles (i.e., students should not be expected to be meteorologists)

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Climate and Weather: Instruments, Measurement, and Representations		
Images of or actual weather instruments (thermometers, weather vanes, anemometers, rain gauges); use of these simple instruments to measure weather conditions Measurable quantities to describe weather (e.g., temperature, wind direction, wind speed, rainfall) Interpretation of bar graphs (histograms), where the x-axis is hours or days and the y-axis is temperature or rainfall Illustrations or pictures of different weather conditions over hours, days, or months (e.g., cloud cover, observable changes in wind speed) Charts or bar graphs reflecting variations in annual temperature measurements to show seasons Exclusions: ▪ Use of barometers to measure pressure or instruments to measure humidity (both are weather conditions that are harder for 4th graders to visualize and experience) ▪ How weather differs in different climate zones	Computer animations illustrating global patterns (animations can be used to stimulate questions) Reference to weather instruments (even though not explicitly referenced in the 8th grade content statement), including those for 4th grade, plus barometers to measure atmospheric pressure Diagrams of weather systems and/or satellite images of Earth (e.g., in relation to storm systems) Interpretation of weather maps, which generally show weather patterns intermediate between global and local scales	Data on past climates and levels of greenhouse gases provided by ice cores Manipulation of computer simulations to demonstrate how physics principles (and especially energy transfer concepts) help to explain climate (e.g., manipulating factors such as fossil fuel use to mitigate future global warming) Computer simulations to show how geological features result in microclimates Energy flow from the sun through the atmosphere (possible context for assessing understanding of both weather and climate) Interpretation of graphs, charts, and maps, both in print and computer displays
Climate and Weather: Technical Vocabulary		
Common vocabulary related to weather instruments, weather conditions, and units, such as thermometer (temperature in °C), rain gauge (amount of rain in cm), weather vane (direction of wind using compass points) Exclusions: ▪ Terms related to pressure, humidity, and long-term climate trends	Terms relevant to this subtopic, including various names of weather instruments, conditions, and phenomena (e.g., high and low pressure areas, warm and cold fronts); use of the most common terms Exclusions: ▪ Regarding drivers of weather and its effects, avoid technical terms where possible	Technical terms related to both the physics principles and weather and climate phenomena, although emphasis should be on understanding the processes rather than knowing the names of the processes

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Climate and Weather: Clarification		
Observations and direct measurements of weather conditions locally <u>Exclusions</u>: ▪ Relating weather to long-term climate changes	Global weather patterns and how these affect local weather Uneven heating causes global wind patterns as air rises over the tropics and falls closer to the poles, forming huge convection (Hadley) cells. Movements of winds across the surface of the globe cause rotating weather systems to develop. These large-scale systems bring changes in local weather. Extensive worldwide ocean currents (Conveyor Belt), driven by convection due to changes in temperature and salinity play an important role in climate. <u>Exclusions</u>: ▪ Quantitative analysis of energy flow through Earth systems	Application of principles from Life Science and Physical Science to the understanding of weather and long-term climate changes Key idea: How energy moves through Earth systems

Table 12: Earth and Space Science Content Statements for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Earth Systems		
Biogeochemical Cycles: From uses of Earth resources (4) to natural and human-induced changes in Earth materials and systems (8) to biogeochemical cycles in Earth systems (12).		
E4.10: The supply of many Earth resources such as fuels, metals, fresh water, and farmland is limited. Humans have devised methods for extending the use of Earth resources through recycling, reuse, and renewal. **E4.11:** Humans depend on their natural and constructed environment. Humans change environments in ways that can either be beneficial or detrimental for themselves and other organisms.	**E8.14:** Water, which covers the majority of Earth's surface, circulates through the crust, oceans, and atmosphere in what is known as the "water cycle." Water evaporates from Earth's surface, rises and cools as it moves to higher elevations, condenses as clouds, falls as rain or snow, and collects in lakes, oceans, soil, and underground. **E8.15:** 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 Earth's land, oceans, and atmosphere. Studies of plant and animal populations have shown that such activities can reduce the number and variety of wild plants and animals and sometimes result in the extinction of species.	**E12.11:** Earth is a system containing essentially a fixed amount of each stable chemical atom or element. Most elements can exist in several different chemical forms. Earth elements move within and between the lithosphere, atmosphere, hydrosphere, and biosphere as part of biogeochemical cycles. **E12.12:** Movement of matter through Earth's systems is driven by Earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in coal and other fossil fuels, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life. **E12.13:** Natural ecosystems provide an array of basic processes that affect humans. These processes include maintenance of the quality of the atmosphere, generation of soils, control of the hydrologic cycle, disposal of wastes, and recycling of nutrients.

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Biogeochemical Cycles: Examples, Observations, and Phenomena		
Limitations of specific resources: fuels, metals, fresh water, and farmland Resources recycled by humans (e.g., newspapers, glass, cans, rubber, plastics, most metals) Resources that humans can reuse rather than discard (e.g., jars, bottles, computer components, used cars, other manufactured goods) Some materials can be renewed (e.g., allowing farmland to lie fallow) Sources of fresh water: precipitation, rivers, lakes, wells (ground water) Reservoirs and waste treatment plants	Conditions that result in evaporation and condensation of water, both in the lab and in the field Evaporation of salt water: leaving behind salt, therefore rain falling as fresh water Sources of fresh water: precipitation, rivers, lakes, wells (ground water) Tracts of land set aside as parks and preserves for wildlife and water conservation areas Water pollutants: domestic, industrial, and farm sewage, which can affect pH of water, dissolved oxygen, microbes, bacteria Human and natural effects on water flow: ▪ Dams alter river channels and floodplains, which can have adverse effects on plants and animals. ▪ Trees, bushes, and grasses help prevent erosion. Clearing land may have adverse effects on plants and animals as well as downstream where sediment is deposited. ▪ River and stream channeling and the construction of levees and dikes can have adverse effects on floodplains and deltas. Examples of human activity on flood plains, wetlands, forests, watersheds, estuaries, beaches, etc. and human effects on plant and animal populations <u>Exclusions</u>: ▪ Chemistry or physics of absorption of infrared radiation	Examples of cycles of different elements and the energy sources that drive them Different chemical forms of common elements (e.g., carbon is a gas when combined with oxygen to form carbon dioxide, a liquid in carbonic acid or petroleum, or a solid in plant tissue or limestone) How elements move through Earth systems (e.g., when carbon dioxide gas combines with rainwater to form natural acid rain, ending up in rivers and oceans) Carbon and other elements injected into the air by volcanoes Solar energy evaporating water, which condenses into rain that removes carbon dioxide and other substances from the air Solar energy evaporating water from oceans, increasing salinity, which drives ocean currents Short-term carbon cycle: recycling of atmospheric gases needed by plants and animals to survive Natural environments disposing of plant and animal wastes through decomposition Physical processes (e.g., weathering, erosion, deposition) that provide inorganic constituents of soils Decomposition processes that provide organic constituents of soils

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Biogeochemical Cycles: Instruments, Measurement, and Representations		
Scales, rulers, and other measuring devices to determine how much of something Thermometers to monitor change in weather conditions Observing and recording individual animal behavior to see change over time Representations of changes as cyclic (circular) or linear (with a beginning and end) Images showing how people use Earth materials and how they may be recycled, reused, or renewed Distinguishing natural from human-made materials Images of human activities changing natural conditions that may lead to loss of habitats (lakes) or loss of species (fish, birds) Matching organisms to ecosystem, habitat, or niche (e.g., worms with soil, fish with lakes, ponds; frogs with ponds, land, trees)	Rain gauges, thermometers, etc. to measure and record attributes of an environment (e.g., patterns and changes in mean minimum and maximum monthly temperatures, rainfall, cloud coverage) Sampling methods to monitor and describe changes in animal populations and correlate with changes in the environment caused by human activities Diagrams illustrating differences between cyclic and linear changes Maps, diagrams, or charts showing populations of selected plants and animals	Appropriate chemical tests and instruments to monitor quality of soil, water, and air and the health of ecosystems (e.g., wetlands, deserts, plains, rainforests) Illustrations of chemical and physical transformations of matter and material as they move through Earth systems Diagrams or animations of natural processes that produce useful substances (e.g., fossil fuel formation) Models of matter (e.g., carbon, oxygen, nitrogen) and energy (e.g., thermal, chemical) moving through and across boundaries of Earth systems Maps of population boundaries
Biogeochemical Cycles: Technical Vocabulary		
Fallow	Precipitation, hail, physical properties, pollutants, pH, dissolved oxygen	Decomposition

Table 13: Earth and Space Science Content Boundaries for Grades 4, 8, and 12 (cont.)

GRADE 4	GRADE 8	GRADE 12
Biogeochemical Cycles: Clarification		
Human dependence on natural and constructed environments Key idea: Renewable and non-renewable resources and materials Through the use of various technologies over the centuries, humans have impacted environments. Humans have learned and continue to learn how to coexist with natural environments. See p. 107, "Biogeochemical Cycles," for more on the crosscutting nature of the principles in this subtopic.	Key idea: Water systems and their relation with other Earth systems (biosphere, atmosphere, lithosphere) Human activities impacting the Earth systems on local, regional and global scales; some impacts can be reversed; others result in permanent changes (e.g., extinction of species, soil clogging of river harbors, soil contamination from hazardous waste dumping) See p. 107, "Biogeochemical Cycles," for more on the crosscutting nature of the principles in this subtopic. See Appendix H for elaboration of E8.15.	Key idea: Interaction of Earth systems on a global scale with emphasis on a hierarchy of systems and tracing processes within systems (e.g., carbon moving through rock, soils, plants, animals, liquids, and gases) Natural ecosystems provide "services" essential for human life to exist, such as drinkable water, breathable air, and fertile soil for growth of plants. Oceans and continents are dynamic interacting systems that help to maintain Earth's climate by transporting thermal energy and dissolved gases. Note connections between this subtopic and content statements P12.14, P12.15, P12.16, L12.4, L12.5, L12.6, and E12.9. See p. 107, "Biogeochemical Cycles," for more on the crosscutting nature of the principles in this subtopic. See Appendix H for elaboration of E12.13.