

National Science Framework for Grades 6-8

Eight practices to be essential elements of the K-12 science and engineering curriculum:

1. Asking questions (for science) and defining problems (for engineering)
2. Developing and using models
3. Planning and carrying out investigations
4. Analyzing and interpreting data
5. Using mathematics, information and computer technology, and computational thinking
6. Constructing explanations (for science) and designing solutions (for engineering)
7. Engaging in argument from evidence
8. Obtaining, evaluating, and communicating information

SEVEN CROSSCUTTING CONCEPTS OF THE FRAMEWORK

The committee identified seven crosscutting scientific and engineering concepts:

1. *Patterns.* Observed patterns of forms and events guide organization and classification, and they prompt questions about relationships and the factors that influence them.
2. *Cause and effect: Mechanism and explanation.* Events have causes, sometimes simple, sometimes multifaceted. A major activity of science is investigating and explaining causal relationships and the mechanisms by which they are mediated. Such mechanisms can then be tested across given contexts and used to predict and explain events in new contexts.
3. *Scale, proportion, and quantity.* In considering phenomena, it is critical to recognize what is relevant at different measures of size, time, and energy and to recognize how changes in scale, proportion, or quantity affect a system's structure or performance.
4. *Systems and system models.* Defining the system under study—specifying its boundaries and making explicit a model of that system—provides tools for understanding and testing ideas that are applicable throughout science and engineering.
5. *Energy and matter: Flows, cycles, and conservation.* Tracking fluxes of energy and matter into, out of, and within systems helps one understand the systems' possibilities and limitations.
6. *Structure and function.* The way in which an object or living thing is shaped and its substructure determine many of its properties and functions.
7. *Stability and change.* For natural and built systems alike, conditions of stability and determinants of rates of change or evolution of the system are critical elements of study.

PHYSICAL SCIENCE

Core and Component Ideas in the Physical Sciences

Core Idea PS1: Matter and Its Interactions

- PS1.A: Structure and Properties of Matter
- PS1.B: Chemical Reactions
- PS1.C: Nuclear Processes

Core Idea PS2: Motion and Stability: Forces and Interactions

- PS2.A: Forces and Motion
- PS2.B: Types of Interactions
- PS2.C: Stability and Instability in Physical Systems

Core Idea PS3: Energy

- PS3.A: Definitions of Energy
- PS3.B: Conservation of Energy and Energy Transfer
- PS3.C: Relationship Between Energy and Forces
- PS3.D: Energy in Chemical Processes and Everyday Life

Core Idea PS4: Waves and Their Applications in Technologies for Information Transfer

- PS4.A: Wave Properties
- PS4.B: Electromagnetic Radiation
- PS4.C: Information Technologies and Instrumentation.

CORE IDEA PS1: MATTER AND ITS INTERACTIONS

How can one explain the structure, properties, and interactions of matter?

PS1.A: Structure and Properties of Matter

How do particles combine to form the variety of substances one observes?

- **By the end of grade 8.** All substances are made from some 100 different types of atoms, which combine with one another in various ways. Atoms form molecules that range in size from two to thousands of atoms. Pure substances are made from a single type of atom or molecule; each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. Gases and liquids are made of molecules or inert atoms that are moving about relative to each other. In a liquid, the molecules are constantly in contact with others; in a gas, they are widely spaced except when they happen to collide. In a solid, atoms are closely spaced and may vibrate in position but do not change relative locations. Solids may be formed from molecules, or they may be extended structures with repeating subunits (e.g., crystals). The changes of state that occur with variations in temperature or pressure can be described and predicted using these models of matter. (Boundary: Predictions here are qualitative, not quantitative.)

PS1.B: Chemical Reactions

How do substances combine or change (react) to make new substances? How does one characterize and explain these reactions and make predictions about them?

- **By the end of grade 8.** Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants. The total number of each type of atom is conserved, and thus the mass does not change. Some chemical reactions release energy, others capture or store energy.

PS1.C: Nuclear Processes

What forces hold nuclei together and mediate nuclear processes?

- **By the end of grade 8.** Nuclear fusion can result in the merging of two nuclei to form a larger one, along with the release of significantly more energy per atom than any chemical process. It occurs only under conditions of extremely high temperature and pressure. Nuclear fusion taking place in the cores of stars provides the energy released (as light) from those stars and produced all of the more massive atoms from primordial hydrogen. Thus the elements found on Earth and throughout the universe (other than hydrogen and most of helium which are primordial) were formed in the stars by this process.

CORE IDEA PS2: MOTION AND STABILITY: FORCES AND INTERACTIONS

How can one explain and predict interactions between objects and within systems?

PS2.A: Forces and Motion

How can one predict an object's continued motion, changes in motion, or stability?

- **By the end of grade 8.** Any two interacting objects exert forces of equal magnitude on each other in opposite directions (Newton's third law). The motion of an object is determined by the sum of the forces acting on it; if the total force on the object is not zero, its motion will change. The heavier the object, the greater the force needed to achieve the same change in motion. For any given object, a larger force causes a larger change in motion. Forces on an object can also change its shape or orientation. In order to share information with others, all positions of objects and the directions of forces and motions must be described in an arbitrarily chosen reference system and arbitrarily chosen units of size.

PS2.B: Types of Interactions

What underlying forces explain the variety of interactions observed?

- **By the end of grade 8.** Electric and magnetic (electromagnetic) forces can be attractive or repulsive, and their sizes depend on the magnitudes of the charges, currents, or magnetic strengths involved and on the distances between the interacting objects. Gravitational forces are always attractive. There is a gravitational force between any two masses, but it is very small except when one or both of the objects have large mass—e.g., Earth and the sun. Long-range gravitational interactions govern the evolution and maintenance of large-scale systems in space, such as galaxies or the solar system, and determine the patterns of motion within those structures. Forces that act at a distance (gravitational, electric, and magnetic) involve fields that can be mapped by their effect on a test object (mass, charge, or magnet, respectively).

PS2.C: Stability and Instability in Physical Systems

Why are some physical systems more stable than others?

- **By the end of grade 8.** A stable system is one in which any small change leads to forces that return the system to its prior state (e.g., a weight hanging from a string). A system can be static but unstable (e.g., a pencil standing on end). A system can be changing but have a stable repeating cycle of changes; such observed regular patterns allow predictions about the system's future (e.g., Earth orbiting the sun). Many systems, both natural and engineered, rely on feedback mechanisms to maintain stability, but they can function only within a limited range of conditions. With constant conditions, a system starting out in an unstable state will continue to change until it reaches a stable configuration (e.g., sand in an hourglass).

CORE IDEA PS3: ENERGY

How is energy transferred and conserved?

PS3.A: Definitions of Energy

What is energy?

- **By the end of grade 8.** Motion energy is properly called kinetic energy; it is proportional to the mass of the moving object and grows with the square of its speed. A system of objects may also contain stored (potential) energy, depending on their relative positions. For example, energy is stored—in gravitational interaction with Earth—when an object is raised, and energy is released when the object falls or is lowered. Energy is also stored in the electric fields between charged particles and the magnetic fields between magnets, and it changes when these objects are moved relative to one another. Stored energy is decreased in some chemical reactions and increased in others. The term “heat” as used in everyday language refers both to thermal motion (the motion of atoms or molecules within a substance) and radiation (particularly infrared and light). Temperature is not a measure of energy; the relationship between the temperature and the total energy of a system depends on the types, states, and amounts of matter present.

PS3.B: Conservation of Energy and Energy Transfer

What is meant by conservation of energy?

How is energy transferred between objects or systems?

- **By the end of grade 8.** When the motion energy of an object changes, there is inevitably some other change in energy at the same time. For example, the friction that causes a moving object to stop also heats the object and the surrounding environment. Similarly, to make an object start moving or to keep it moving when friction forces transfer energy away from it, energy must be provided from, say, chemical (e.g., burning fuel) or electrical (e.g., an electric motor and battery) processes. The amount of energy transfer needed to change the temperature of a matter sample by a given amount depends on the nature of the matter, the size of the sample, and the environment. Energy is transferred out of hotter regions or objects and into colder ones by the processes of conduction, convection, and radiation.

PS3.C Relationship Between Energy and Forces

How are forces related to energy?

- **By the end of grade 8.** When two objects interact, each one exerts a force on the other, and these forces can transfer energy between them. For example, gravitational interactions between an object and Earth store energy as the object is raised and release energy as the object falls; magnetic and electric forces between two objects at a distance can transfer energy between the interacting objects.

PS3.D: Energy in Chemical Processes and Everyday Life

How do food and fuel provide energy?

If energy is conserved, why do people say it is produced or used?

- **By the end of grade 8.** The chemical reaction by which plants produce complex food molecules (sugars) requires an energy input (i.e., from sunlight) to occur. In this reaction, carbon dioxide and water combine to form carbon-based organic molecules and release oxygen. (Boundary: Further details of the photosynthesis process are not taught at this grade level). Both the burning of fuel and cellular digestion in plants and animals involve chemical reactions with oxygen that release stored energy. In these processes, complex molecules containing carbon react with oxygen to produce carbon dioxide and other materials. Machines can be made more efficient, that is, require less fuel input to perform a given task, by reducing friction between their moving parts and through aerodynamic design. Friction increases energy transfer to the surrounding environment by heating the affected materials.

CORE IDEA PS4: WAVES AND THEIR APPLICATIONS IN TECHNOLOGIES FOR INFORMATION TRANSFER

How are waves used to transfer energy and information?

PS4.A: Wave Properties

What are the characteristic properties and behaviors of waves?

- **By the end of grade 8.** A simple wave has a repeating pattern with a specific wavelength, frequency, and amplitude. A sound wave needs a medium through which it is transmitted. Geologists use seismic waves and their reflection at interfaces between layers to probe structures deep in the planet.

PS4.B: Electromagnetic Radiation

What is light?

How can one explain the varied effects that involve light?

What other forms of electromagnetic radiation are there?

- **By the end of grade 8.** When light shines on an object, it is reflected, absorbed, or transmitted through the object, depending on the object's material and the frequency (color) of the light. The path that light travels can be traced as straight lines, except at surfaces between different transparent materials (e.g., air and water, air and glass) where the light path bends. Lenses and prisms are applications of this effect. A wave model of light is useful for explaining brightness, color, and the frequency dependent bending of light at a surface between media (prisms). However, because light can travel through space, it cannot be a matter wave, like sound or water waves. (Boundary: Students will ask,

“Then what is it?” so the teacher may introduce the idea that light is a wave consisting of regularly changing electric and magnetic fields, but students at this level should not be held responsible for retaining that fact.)

PS4.C: Information Technologies and Instrumentation

How are instruments that transmit and detect waves used to extend human senses?

- ***By the end of grade 8.*** Appropriately designed technologies (e.g., radio, television, cell phones, wired and wireless computer networks) make it possible to detect and interpret many types of signals that cannot be sensed directly. Designers of such devices must understand both the signal and its interactions with matter. Many modern communication devices use digitized signals (sent as wave pulses) as a more reliable way to encode and transmit information.

LIFE SCIENCE

Core and Component Ideas in Life Sciences

Core Idea LS1: From Molecules to Organisms: Structures and Processes

- LS1.A: Structure and Function
- LS1.B: Growth and Development of Organisms
- LS1.C: Organization for Matter and Energy Flow in Organisms
- LS1.D: Information Processing

Core Idea LS2: Ecosystems: Interactions, Energy, and Dynamics

- LS2.A: Interdependent Relationships in Ecosystems
- LS2.B: Cycles of Matter and Energy Transfer in Ecosystems
- LS2.C: Ecosystem Dynamics, Functioning, and Resilience
- LS2.D: Social Interactions and Group Behavior

Core Idea LS3: Heredity: Inheritance and Variation of Traits

- LS3.A: Inheritance of Traits
- LS3.B: Variation of Traits

Core Idea LS4: Biological Evolution: Unity and Diversity

- LS4.A: Evidence of Common Ancestry and Diversity
- LS4.B: Natural Selection
- LS4.C: Adaptation
- LS4.D: Biodiversity and Humans

CORE IDEA LS1: FROM MOLECULES TO ORGANISMS: STRUCTURES AND PROCESSES

How do organisms live, grow, respond to their environment, and reproduce?

LS1.A: Structure and Function

How do the structures of organisms enable life's functions?

- **By the end of grade 8.** All living things are made up of cells. They may consist of one single cell (unicellular) or many different numbers and types of cells (multicellular). Unicellular organisms (microorganisms), like multicellular organisms, need food, water, a way to dispose of waste, and an environment in which they can live. Within cells, special structures are responsible for particular functions, and the cell membrane forms the boundary that controls what enters and leaves the cell. In multicellular organisms, the body is a system of multiple interacting subsystems and groups of cells that work together to form tissues and organs that are specialized for particular body functions. (Boundary: At this grade level, only a few major cell structures should be introduced.)

LS1.B: Growth and Development of Organisms

How do organisms grow and develop?

- **By the end of grade 8.** Organisms reproduce, either sexually or asexually, and transfer their genetic information to their offspring. Animals engage in characteristic behaviors that increase the odds of reproduction. Plants reproduce in a variety of ways, sometimes depending on animal behavior and specialized features (such as attractively colored flowers) for reproduction. Plant growth can continue throughout the plant's life through production of plant matter in photosynthesis. Genetic factors as well as local conditions affect the size of the adult plant. The growth of an animal is controlled by genetic factors, food intake, and interactions with other organisms, and each species has a typical adult size range. (Boundary: Reproduction is not treated in any detail here; for more specifics about grade level, see LS3.A.)

LS1.C: Organization for Matter and Energy Flow in Organisms

How do organisms obtain and use the matter and energy they need to live and grow?

- **By the end of grade 8.** Plants, algae (including phytoplankton), and many microorganisms use the energy from light to make sugars (food) from carbon dioxide from the atmosphere and water through the process of photosynthesis, which also releases oxygen. These sugars can be used immediately or stored for growth or later use. Animals obtain food from eating plants or eating other animals. Within individual organisms, food moves through a series of chemical reactions in which it is broken down and rearranged to form new molecules, to support growth, or to release energy. In most animals and plants, oxygen reacts with carbon containing molecules (sugars) to provide energy and produce waste carbon dioxide; anaerobic bacteria achieve their energy needs in other chemical processes that do not require oxygen.

LS1.D: Information Processing

How do organisms detect, process, and use information about the environment?

- **By the end of grade 8.** Each sense receptor responds to different inputs (electromagnetic, mechanical, chemical), transmitting them as signals that travel along nerve cells to the brain. The signals are then processed in the brain, resulting in immediate behaviors or memories. Changes in the structure and functioning of many millions of interconnected nerve cells allow combined inputs to be stored as memories for long periods of time.

CORE IDEA LS2: ECOSYSTEMS: INTERACTIONS, ENERGY, AND DYNAMICS

How and why do organisms interact with their environment, and what are the effects of these interactions?

LS2.A: Interdependent Relationships in Ecosystems

How do organisms interact with the living and nonliving environment to obtain matter and energy?

- **By the end of grade 8.** Organisms and populations of organisms are dependent on their environmental interactions both with other living things and with nonliving factors. Growth of organisms and population increases are limited by access to resources. In any ecosystem, organisms and populations with similar requirements for food, water, oxygen, or other resources may compete with each other for limited resources, access to which consequently constrains their growth and reproduction. Similarly, predatory interactions may reduce the number of organisms or eliminate whole populations of organisms. Mutually beneficial interactions, in contrast, may become so interdependent that each organism requires the other for survival. Although the species involved in these competitive, predatory, and mutually beneficial interactions vary across ecosystems, the patterns of interactions of organisms with their environments, both living and nonliving, are shared.

LS2.B: Cycles of Matter and Energy Transfer in Ecosystems

How do matter and energy move through an ecosystem?

- **By the end of grade 8.** Food webs are models that demonstrate how matter and energy is transferred between producers (generally plants and other organisms that engage in photosynthesis), consumers, and decomposers as the three groups interact—primarily for food— within an ecosystem. Transfers of matter into and out of the physical environment occur at every level, for example when molecules from food react with oxygen captured from the environment, the carbon dioxide and water thus produced are transferred back to the environment, and ultimately so are waste products, such as fecal material. Decomposers recycle nutrients from dead plant or animal matter back to the soil in terrestrial environments or to the water in aquatic environments. The atoms that make up the organisms in an ecosystem are cycled repeatedly between the living and nonliving parts of the ecosystem.

LS2.C: Ecosystem Dynamics, Functioning, and Resilience

What happens to ecosystems when the environment changes?

- **By the end of grade 8.** Ecosystems are dynamic in nature; their characteristics can vary over time. Disruptions to any physical or biological component of an ecosystem can lead to shifts in all its populations. Biodiversity describes the variety of species found in Earth's terrestrial and oceanic ecosystems. The completeness or integrity of an ecosystem's biodiversity is often used as a measure of its health.

LS2.D: Social Interactions and Group Behavior

How do organisms interact in groups so as to benefit individuals?

- **By the end of grade 8.** Groups may form because of genetic relatedness, physical proximity, or other recognition mechanisms (which may be species-specific). They engage in a variety of signaling behaviors to maintain the group's integrity or to warn of threats. Groups often dissolve if they no longer function to meet individuals' needs, if dominant members lose their place, or if other key members are removed from the group through death, predation, or exclusion by other members.

CORE IDEA LS3: HEREDITY: INHERITANCE AND VARIATION OF TRAITS

How are characteristics of one generation passed to the next?

How can individuals of the same species and even siblings have different characteristics?

LS3.A: Inheritance of Traits

How are the characteristics of one generation related to the previous generation?

- **By the end of grade 8.** Genes are located in the chromosomes of cells, with each chromosome pair containing two variants of each of many distinct genes. Each distinct gene chiefly controls the production of specific proteins, which in turn affect the traits of the individual (e.g., human skin color results from the actions of proteins that control the production of the pigment melanin). Changes (mutations) to genes can result in changes to proteins, which can affect the structures and functions of the organism and thereby change traits. Sexual reproduction provides for transmission of genetic information to offspring through egg and sperm cells. These cells, which contain only one chromosome of each parent's chromosome pair, unite to form a new individual (offspring). Thus offspring possess one instance of each parent's chromosome pair (forming a new chromosome pair). Variations of inherited traits between parent and offspring arise from genetic differences that result from the subset of chromosomes (and therefore genes) inherited or (more rarely) from mutations. (Boundary: The stress here is on the impact of gene transmission in reproduction, not the mechanism.)

LS3.B: Variation of Traits

Why do individuals of the same species vary in how they look, function, and behave?

- **By the end of grade 8.** In sexually reproducing organisms, each parent contributes half of the genes acquired (at random) by the offspring. Individuals have two of each chromosome and hence two alleles of each gene, one acquired from each parent. These versions may be identical or may differ from each other. In addition to variations that arise from sexual reproduction, genetic information can be altered because of mutations. Though rare, mutations may result in changes to the structure and function of proteins. Some changes are beneficial, others harmful, and some neutral to the organism.

IDEA LS4: BIOLOGICAL EVOLUTION: UNITY AND DIVERSITY

How can there be so many similarities among organisms yet so many different kinds of plants, animals, and microorganisms?

How does biodiversity affect humans?

LS4.A: Evidence of Common Ancestry and Diversity

What evidence shows that different species are related?

- **By the end of grade 8.** Fossils are mineral replacements, preserved remains, or traces of organisms that lived in the past. Thousands of layers of sedimentary rock not only provide evidence of the history of Earth itself but also of changes in organisms whose fossil remains have been found in those layers. The collection of fossils and their placement in chronological order (e.g., through the location of the sedimentary layers in which they are found or through radioactive dating) is known as the fossil record. It documents the existence, diversity, extinction, and change of many life forms throughout the history of life on Earth. Because of the conditions necessary for their preservation, not all types of organisms that existed in the past have left fossils that can be retrieved. Anatomical similarities and differences between various organisms living today and between them and organisms in the fossil record enable the reconstruction of evolutionary history and the inference of lines of evolutionary descent. Comparison of the embryological development of different species also reveals similarities that show relationships not evident in the fully formed anatomy.

LS4.B: Natural Selection

How does genetic variation among organisms affect survival and reproduction?

- **By the end of grade 8.** Genetic variations among individuals in a population give some individuals an advantage in surviving and reproducing in their environment. This is known as natural selection. It leads to the predominance of certain traits in a population and the suppression of others. In *artificial* selection, humans have the capacity to influence certain characteristics of organisms by selective breeding. One can choose desired parental traits determined by genes, which are then passed on to offspring.

LS4.C: Adaptation

How does the environment influence populations of organisms over multiple generations?

- **By the end of grade 8.** Adaptation by natural selection acting over generations is one important process by which species change over time in response to changes in environmental conditions. Traits that support successful survival and reproduction in the new environment become more common; those that do not become less common. Thus, the distribution of traits in a population changes. In separated populations with different conditions, the changes can be large enough that the populations, provided they remain separated (a process called reproductive isolation), evolve to become separate species.

LS4.D: Biodiversity and Humans

What is biodiversity, how do humans affect it, and how does it affect humans?

- **By the end of grade 8.** Biodiversity is the wide range of existing life forms that have adapted to the variety of conditions on Earth, from terrestrial to marine ecosystems. Biodiversity includes genetic variation within a species, in addition to species variation in different habitats and ecosystem types (e.g., forests, grasslands, wetlands). Changes in biodiversity can influence humans' resources, such as food, energy, and medicines, as well as ecosystem services that humans rely on—for example, water purification and recycling.

EARTH SCIENCE

Core and Component Ideas in Earth and Space Sciences

Core Idea ESS1: Earth's Place in the Universe

- ESS1.A: The Universe and Its Stars
- ESS1.B: Earth and the Solar System
- ESS1.C: The History of Planet Earth

Core Idea ESS2: Earth's Systems

- ESS2.A: Earth Materials and Systems
- ESS2.B: Plate Tectonics and Large-Scale System Interactions
- ESS2.C: The Roles of Water in Earth's Surface Processes
- ESS2.D: Weather and Climate
- ESS2.E: Biogeology

Core Idea ESS3: Earth and Human Activity

- ESS3.A: Natural Resources
- ESS3.B: Natural Hazards
- ESS3.C: Human Impacts on Earth Systems
- ESS3.D: Global Climate Change

CORE IDEA ESS1: EARTH'S PLACE IN THE UNIVERSE

What is the universe, and what is Earth's place in it?

ESS1.A: The Universe and Its Stars

What is the universe, and what goes on in stars?

- **By the end of grade 8.** Patterns of the apparent motion of the sun, the moon, and stars in the sky can be observed, described, predicted, and explained with models. The universe began with a period of extreme and rapid expansion known as the Big Bang. Earth and its solar system are part of the Milky Way galaxy, which is one of many galaxies in the universe.

ESS1.B: Earth and the Solar System

What are the predictable patterns caused by Earth's movement in the solar system?

- **By the end of grade 8.** The solar system consists of the sun and a collection of objects, including planets, their moons, and asteroids that are held in orbit around the sun by its gravitational pull on them. This model of the solar system can explain tides, eclipses of the sun and the moon, and the motion of the planets in the sky relative to the stars. Earth's spin axis is fixed in direction but tilted relative to its orbit around the sun; the seasons are a result of that tilt, as is the differential intensity of sunlight on different areas of the earth across the year.

ESS1.C: The History of Planet Earth

How do people reconstruct and date events in Earth's planetary history?

- **By the end of grade 8.** The geological time scale interpreted from rock strata provides a way to organize Earth's history. Major historical events include the formation of mountain chains and ocean basins, the evolution and extinction of particular living organisms, volcanic eruptions, periods of massive glaciation, and development of watersheds and rivers through glaciation and water erosion. Analyses of rock strata and the fossil record provide only relative dates, not an absolute scale.

CORE IDEA ESS2: EARTH'S SYSTEMS

How and why is the earth constantly changing?

ESS2.A: Earth Materials and Systems

How do the major earth systems interact?

- **By the end of grade 8.** All earth processes are the result of energy flowing and matter cycling within and among the planet's systems. This energy is derived from the sun and the earth's hot interior. The energy that flows and matter that cycles produce chemical and physical changes in Earth's materials and living organisms. The planet's systems interact over scales that range from microscopic to global in size, and they operate over fractions of a second to billions of years. These interactions have shaped Earth's history and will determine its future.

ESS2.B: Plate Tectonics and Large-Scale System Interactions

Why do the continents move, and what causes earthquakes and volcanoes?

- **By the end of grade 8.** Plate tectonics is the unifying theory that explains the past and current movements of the rocks at Earth's surface and provides a framework for understanding its geological history. Plate movements are responsible for most continental and ocean floor features and for the distribution of most rocks and minerals within Earth's crust. Maps of ancient land and water patterns, based on investigations of rocks and fossils, make clear how Earth's plates have moved great distances, collided, and spread apart.

ESS2.C: The Roles of Water in Earth's Surface Processes

How do the properties and movements of water shape Earth's surface and affect its systems?

- **By the end of grade 8.** Water continually cycles among land, ocean, and atmosphere via transpiration, evaporation, condensation, and precipitation as well as downhill flows on land. The complex patterns of the changes and the movement of water in the atmosphere, determined by winds, landforms, and ocean temperatures and currents, are major determinants of local weather patterns. Global movements of water and its changes in form are propelled by sunlight and gravity. Variations in density due to variations in temperature and salinity drive a global pattern of interconnected ocean currents. Water's movements both on the land and underground cause weathering and erosion, which change the land's surface features and create underground formations.

ESS2.D: Weather and Climate

What regulates weather and climate?

- **By the end of grade 8.** Weather and climate are influenced by interactions involving sunlight, the ocean, the atmosphere, ice, landforms, and living things. These interactions vary with latitude, altitude, and local and regional geography, all of which can affect oceanic and atmospheric flow patterns. Because these patterns are so complex, weather can be predicted only probabilistically. The ocean exerts a major influence on weather and climate by absorbing energy from the sun, releasing it over time, and globally redistributing it through ocean currents. Greenhouse gases in the atmosphere absorb and retain the energy radiated from land and ocean surfaces, thereby regulating Earth's average surface temperature and keeping it habitable.

ESS2.E: Biogeology

How do living organisms alter Earth's processes and structures?

- **By the end of grade 8.** Evolution is shaped by Earth's varying geological conditions. Sudden changes in conditions (e.g., meteor impacts, major volcanic eruptions) have caused mass extinctions, but these changes, as well as more gradual ones, have ultimately allowed other life forms to flourish. The evolution and proliferation of living things over geological time have in turn changed the rates of weathering and erosion of land surfaces, altered the composition of Earth's soils and atmosphere, and affected the distribution of water in the hydrosphere.

CORE IDEA ESS3: EARTH AND HUMAN ACTIVITY

How do Earth's surface processes and human activities affect each other?

ESS3.A: Natural Resources

How do humans depend on Earth's resources?

- **By the end of grade 8.** Humans depend on Earth's land, ocean, atmosphere, and biosphere for many different resources. Minerals, fresh water, and biosphere resources are limited, and many are not renewable or replaceable over human lifetimes. These resources are distributed unevenly around the planet as a result of past geological processes (link to ESS2.B). Renewable energy resources, and the technologies to exploit them, are being rapidly developed.

ESS3.B: Natural Hazards

How do natural hazards affect individuals and societies?

- **By the end of grade 8.** Some natural hazards, such as volcanic eruptions and severe weather, are preceded by phenomena that allow for reliable predictions. Others, such as earthquakes, occur suddenly and with no notice, and thus they are not yet predictable. However, mapping the history of earthquakes in a region and an understanding of related geological forces can help forecast the locations and likelihoods of future events.

ESS3.C: Human Impacts on Earth Systems

How do humans change the planet?

- **By the end of grade 8.** Human activities have significantly altered the biosphere, sometimes damaging or destroying natural habitats and causing the extinction of many other species. But changes to Earth's environments can have different impacts (negative and positive) for different living things. Typically, as human populations and per-capita consumption of natural resources increase, so do the negative impacts on the earth unless the activities and technologies involved are engineered otherwise.

ESS3.D: Global Climate Change

How do people model and predict the effects of human activities on Earth's climate?

- **By the end of grade 8.** Human activities, such as the release of carbon dioxide from burning fossil fuels, are major factors in global warming. Reducing the level of climate change and reducing human vulnerability to whatever climate changes do occur depend on the understanding of climate science, engineering capabilities, and other kinds of knowledge, such as understanding of human behavior and on applying that knowledge wisely in decisions and activities.

ENGINEERING, TECHNOLOGY, AND APPLICATION OF SCIENCE

Core and Component Ideas in Engineering, Technology, and Application of Science

Core Idea ETS1: Engineering Design

- ETS1.A: Defining and Delimiting an Engineering Problem
- ETS1.B: Developing Possible Solutions
- ETS1.C: Optimizing the Design Solution

Core Idea ETS2: Links Among Engineering, Technology, Science, and Society

- ETS2.A: Interdependence of Science, Engineering, and Technology
- ETS2.B: Influence of Engineering, Technology and Science on Society and the Natural World

CORE IDEA ETS1: ENGINEERING DESIGN

How do engineers solve problems?

ETS1.A. Defining and Delimiting an Engineering Problem

What is a design for?

What are the criteria and constraints of a successful solution?

- **By the end of grade 8.** The more precisely a design task's criteria and constraints can be defined, the more likely it is that the designed solution will be successful. Specification of constraints includes consideration of scientific principles and other relevant knowledge that are likely to limit possible solutions (e.g., familiarity with the local climate may rule out certain plants for the school garden).

ETS1.B: Developing Possible Solutions

What is the process for developing potential design solutions?

- **By the end of grade 8.** A solution needs to be tested, and then modified on the basis of the test results, in order to improve it. There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Sometimes parts of different solutions can be combined to create a solution that is better than any of its predecessors. In any case, it is important to be able to communicate and explain solutions to others. Models of all kinds are important for testing solutions, and computers are a valuable tool for simulating systems. Simulations are useful for predicting what would happen if various parameters of the model were changed, as well as for making improvements to the model based on peer and leader (e.g., teacher) feedback.

ETS1.C: Optimizing the Design Solution

How can the various proposed design solutions be compared and improved?

- **By the end of grade 8.** There are systematic processes for evaluating solutions with respect to how well they meet the criteria and constraints of a problem. Comparing different designs could involve running them through the same kinds of tests and systematically recording the results to determine which design performs best. Although one design may not perform the best across all tests, identifying the characteristics of the design that performed the best in each test can provide useful information for the redesign process—that is, some of those characteristics may be incorporated into the new design. This iterative process of testing the most promising solutions and modifying what is proposed on the basis of the test results leads to greater refinement and ultimately to an optimal solution. Once such a suitable solution is determined, it is important to describe that solution, explain how it was developed, and describe the features that make it successful.

CORE IDEA ETS2: LINKS AMONG ENGINEERING, TECHNOLOGY, SCIENCE, AND SOCIETY

How are engineering, technology, science, and society interconnected?

ETS2.A: Interdependence of Science, Engineering, and Technology

What are the relationships among science, engineering, and technology?

- **By the end of grade 8.** Engineering advances have led to important discoveries in virtually every field of science, and scientific discoveries have led to the development of entire industries and engineered systems. In order to design better technologies, new science may need to be explored (e.g., materials research prompted by desire for better batteries or solar cells, biological questions raised by medical problems). Technologies in turn extend the measurement, exploration, modeling, and computational capacity of scientific investigations.

ETS2.B: Influence of Engineering, Technology and Science on Society and the Natural World

How do science, engineering, and the technologies that result from them affect the ways in which people live? How do they affect the natural world?

- **By the end of grade 8.** All human activity draws on natural resources and has both short and long-term consequences, positive as well as negative, for the health of both people and the natural environment. The uses of technologies and any limitations on their use are driven by individual or societal needs, desires, and values; by the findings of scientific research; and by differences in such factors as climate, natural resources, and economic conditions. Thus technology use varies from region to region and over time. Technologies that are beneficial for a certain

purpose may later be seen to have impacts (e.g., health-related, environmental) that were not foreseen. In such cases, new regulations on use or new technologies (to mitigate the impacts or eliminate them) may be required.