

Science Standards

Earth and Space Sciences

1. Understands atmospheric processes and the water cycle
2. Understands Earth's composition and structure
3. Understands the composition and structure of the universe and the Earth's place in it

Life Sciences

4. Understands the principles of heredity and related concepts
5. Understands the structure and function of cells and organisms
6. Understands relationships among organisms and their physical environment
7. Understands biological evolution and the diversity of life

Physical Sciences

8. Understands the structure and properties of matter
9. Understands the sources and properties of energy
10. Understands forces and motion

Nature of Science

11. Understands the nature of scientific knowledge
12. Understands the nature of scientific inquiry
13. Understands the scientific enterprise
14. Understands the effective use of technology

Earth and Space Sciences

Standard 1: Understands atmospheric processes and the water cycle

Level 1 (Grade K-2)

1. Knows that short-term weather conditions (e.g., temperature, rain, snow) can change daily, and weather patterns change over the seasons

Level 2 (Grade 3-5)

1. Knows that water exists in the air in different forms (e.g., in clouds and fog as tiny droplets; in rain, snow, and hail) and changes from one form to another through various processes (e.g., freezing, condensation, precipitation, evaporation)
2. Knows that the Sun provides the light and heat necessary to maintain the temperature of the Earth
3. Knows that air is a substance that surrounds us, takes up space, and moves around us as wind

4. Knows that most of Earth's surface is covered by water, that most of that water is salt water in oceans, and that fresh water is found in rivers, lakes, underground sources, and glaciers

Level 3 (Grade 6-8)

1. Knows the composition and structure of the Earth's atmosphere (e.g., temperature and pressure in different layers of the atmosphere, circulation or air masses)
2. Knows the processes involved in the water cycle (e.g., evaporation, condensation, precipitation, surface run-off, percolation) and their effects on climatic patterns
3. Knows that the Sun is the principle energy source for phenomena on the Earth's surface (e.g., winds, ocean currents, the water cycle, plant growth)
4. Knows factors that can impact the Earth's climate (e.g., changes in the composition of the atmosphere; changes in ocean temperature; geological shifts such as meteor impacts, the advance or retreat of glaciers, or a series of volcanic eruptions)
5. Knows how the tilt of the Earth's axis and the Earth's revolution around the Sun affect seasons and weather patterns (i.e., heat falls more intensely on one part or another of the Earth's surface during its revolution around the Sun)
6. Knows ways in which clouds affect weather and climate (e.g., precipitation, reflection of light from the Sun, retention of heat energy emitted from the Earth's surface)
7. Knows the properties that make water an essential component of the Earth system (e.g., its ability to act as a solvent, its ability to remain a liquid at most Earth temperatures)

Level 4 (Grade 9-12)

1. Understands heat and energy transfer in and out of the atmosphere and its involvement in weather and climate (e.g., radiation, conduction, convection/advection)
2. Knows the major external and internal sources of energy on Earth (e.g., the Sun is the major external source of energy; the decay of radioactive isotopes and gravitational energy from the Earth's original formation are primary sources of internal energy)

Standard 2: Understands Earth's composition and structure

Level 1 (Grades K-2)

1. Knows that fossils provide evidence about the plants and animals that lived long ago and the nature of the environment at that time
2. Knows that Earth materials consist of solid rocks, soils, liquid water, and the gases of the atmosphere
3. Knows that rocks come in many different shapes and sizes (e.g., boulders, pebbles, sand)

Level 2 (Grade 3-5)

1. Knows how features on the Earth's surface are constantly changed by a combination of slow and rapid processes (e.g., weathering, erosion, transport, and deposition of

sediment caused by waves, wind, water, and ice; landslides, volcanic eruptions, earthquakes, drought)

2. Knows that smaller rocks come from the breakage and weathering of larger rocks and bedrock
3. Knows that rock is composed of different combinations of minerals
4. Knows the composition and properties of soils (e.g., components of soil such as weathered rock, living organisms, products of plants and animals; properties of soil such as color, texture, capacity to retain water, ability to support plant growth)
5. Knows that fossils provide evidence about the plants and animals that lived long ago and the nature of the environment at that time

Level 3 (Grade 6-8)

1. Knows that the Earth is comprised of layers including a core, mantle, lithosphere, hydrosphere, and atmosphere
2. Knows how land forms are created through a combination of constructive and destructive forces (e.g., constructive forces such as crustal deformation, volcanic eruptions, and deposition of sediment; destructive forces such as weathering and erosion)
3. Knows components of soil and other factors that influence soil texture, fertility, and resistance to erosion (e.g., plant roots and debris, bacteria, fungi, worms, rodents)
4. Knows that the Earth's crust is divided into plates that move at extremely slow rates in response to movements in the mantle
5. Knows processes involved in the rock cycle (e.g., old rocks at the surface gradually weather and form sediments that are buried, then compacted, heated, and often recrystallized into new rock; this new rock is eventually brought to the surface by the forces that drive plate motions, and the rock cycle continues)
6. Knows that sedimentary, igneous, and metamorphic rocks contain evidence of the minerals, temperatures, and forces that created them
7. Knows how successive layers of sedimentary rock and the fossils contained within them can be used to confirm the age, history, and changing life forms of the Earth, and how this evidence is affected by the folding, breaking, and uplifting of layers
8. Knows that fossils provide important evidence of how environmental conditions have changed on the Earth over time (e.g., changes in atmospheric composition, movement of lithospheric plates, impact of an asteroid or comet)

Level 4 (Grade 9-12)

1. Knows that elements exist in fixed amounts and move through the solid Earth, oceans, atmosphere, and living things as part of geochemical cycles (e.g., carbon cycle, nitrogen cycle)
2. Knows that throughout the rock cycle (e.g., formation, weathering, sedimentation, reformation), the total amount of material stays the same as its form changes
3. Knows the conditions of Earth that enable it to support life (e.g., force of gravity that enables the planet to retain an adequate atmosphere, intensity of radiation from the Sun that allows water to cycle between liquid and vapor)

Standard 3: Understands the composition and structure of the universe and the Earth's place in it

Level 1 (Grade K-2)

1. Knows basic patterns of the Sun and Moon (e.g., the Sun appears every day and the Moon appears sometimes at night and sometimes during the day; the Sun and Moon appear to move from east to west across the sky; the Moon appears to change shape over the course of a month; the Sun's position in the sky changes through the seasons)
2. Knows that the stars are innumerable, unevenly dispersed, and of unequal brightness

Level 2 (Grade 3-5)

1. Knows that night and day are caused by the Earth's rotation on its axis
2. Knows that the Earth is one of several planets that orbit the Sun and that the Moon orbits the Earth
3. Knows that the patterns of stars in the sky stay the same, although they appear to slowly move from east to west across the sky nightly and different stars can be seen in different seasons
4. Knows that planets look like stars, but over time they appear to wander among the constellations
5. Knows that astronomical objects in space are massive in size and are separated from one another by vast distances (e.g., many stars are more massive than our Sun but so distant they look like points of light)
6. Knows that telescopes magnify distant objects in the sky (e.g., the Moon, planets) and dramatically increase the number of stars we can see

Level 3 (Grade 6-8)

1. Knows characteristics and movement patterns of the nine planets in our Solar System (e.g., planets differ in size, composition, and surface features; planets move around the Sun in elliptical orbits; some planets have moons, rings of particles, and other satellites orbiting them)
2. Knows how the regular and predictable motions of the Earth and Moon explain phenomena on Earth (e.g., the day, the year, phases of the Moon, eclipses, tides, shadows)
3. Knows characteristics of the Sun and its position in the universe (e.g., the Sun is a medium-sized star; it is the closest star to Earth; it is the central and largest body in the Solar System; it is located at the edge of a disk-shaped galaxy)
4. Knows that gravitational force keeps planets in orbit around the Sun and moons in orbit around the planets
5. Knows characteristics and movement patterns of asteroids, comets, and meteors
6. Knows that the universe consists of many billions of galaxies (each containing many billions of stars) and that incomprehensible distances (measured in light years) separate these galaxies and stars from one another and from the Earth

7. Knows that the planet Earth and our Solar System appear to be somewhat unique (e.g., the Earth is the only celestial body known to support life), although similar systems might yet be discovered in the universe

Level 4 (Grade 9-12)

1. Knows that although the origin of the universe remains one of the greatest questions in science, current scientific evidence supports the Big Bang theory, which states that between 10 and 20 billion years ago, the entire contents of the universe expanded explosively into existence from a single, hot, dense chaotic mass; our Solar System formed from a nebular cloud of dust and gas about 4.6 billion years ago

2. Knows that evidence suggests that our universe is expanding (e.g., the Doppler shift of light from distant galaxies reaching telescopes on Earth suggests that galaxies are moving away from the Earth and provides support for the Big Bang theory of the origin of the universe)

3. Knows the ongoing processes involved in star formation and destruction (e.g., stars condense by gravity out of clouds of molecules of the lightest elements; nuclear fusion of light elements into heavier ones occurs in the stars' extremely hot, dense cores, releasing great amounts of energy; some stars eventually explode, producing clouds of material from which new stars and planets condense)

4. Knows common characteristics of stars in the universe (e.g., types of stars include red and blue giants, white dwarfs, neutron stars; stars differ in size, temperature, and age, but they all appear to be made up of the same elements and to behave according to the same principles; most stars exist in systems of two or more stars orbiting around a common point)

5. Knows ways in which technology has increased our understanding of the universe (e.g., visual, radio, and x-ray telescopes collect information about the universe from electromagnetic waves; space probes gather information from distant parts of the Solar System; mathematical models and computer simulations are used to study evidence from many sources in order to form a scientific account of events in the universe)

Life Sciences

Standard 4: Understands the principles of heredity and related concepts

Level 1 (Grade K-2)

1. Knows that plants and animals closely resemble their parents

2. Knows that differences exist among individuals of the same kind of plant or animal

Level 2 (Grade 3-5)

1. Knows that many characteristics of an organism are inherited from its parents (e.g., eye color in human beings, fruit or flower color in plants), and other characteristics result from an individual's interactions with the environment (e.g., people's table manners, ability to ride a bicycle)

Level 3 (Grade 6-8)

1. Knows that reproduction is a characteristic of all living things and is essential to the continuation of a species
2. Knows that for sexually reproducing organisms, a species comprises all organisms that can mate with one another to produce fertile offspring
3. Understands asexual and sexual reproduction (e.g., in asexual reproduction, all the genes come from a single parent; in sexual reproduction, an egg and sperm unite and half of the genes come from each parent, so the offspring is never identical to either of its parents; sexual reproduction allows for greater genetic diversity; asexual reproduction limits the spread of disadvantageous characteristics through a species)
4. Knows that hereditary information is contained in genes (located in the chromosomes of each cell), each of which carries a single unit of information; an inherited trait of an individual can be determined by either one or many genes, and a single gene can influence more than one trait
5. Knows that the characteristics of an organism can be described in terms of a combination of traits; some traits are inherited and others result from interactions with the environment

Level 4 (Grade 9-12)

1. Knows the chemical and structural properties of DNA and its role in specifying the characteristics of an organism (e.g., DNA is a large polymer formed from four kinds of subunits; genetic information is encoded in genes as a string of these subunits; each DNA molecule in a cell forms a single chromosome and is replicated by a templating mechanism)
2. Knows ways in which genes (segments of DNA molecules) may be altered and combined to create genetic variation within a species (e.g., recombination of genetic material; mutations; errors in copying genetic material during cell division)
3. Knows that new heritable characteristics can only result from new combinations of existing genes or from mutations of genes in an organism's sex cells; other changes in an organism cannot be passed on
4. Knows that mutations and new gene combinations may have positive, negative, or no effects on the organism
5. Understands the concepts of Mendelian genetics (e.g., segregation, independent assortment, dominant and recessive traits, sex-linked traits)
6. Knows features of human genetics (e.g., most of the cells in a human contain two copies of each of 23 chromosomes; in addition, one pair of chromosomes determines sex [XX or XY]; transmission of genetic information to offspring occurs through egg and sperm cells that contain only one representative from each chromosome pair; dominant and recessive traits explain how variations that are hidden in one generation can be expressed in the next)

Standard 5: Understands the structure and function of cells and organisms

Level 1 (Grade K-2)

1. Knows the basic needs of plants and animals (e.g., air, water, nutrients, light or food, shelter)
2. Knows that plants and animals have features that help them live in different environments

Level 2 (Grade 3-5)

1. Knows that plants and animals progress through life cycles of birth, growth and development, reproduction, and death; the details of these life cycles are different for different organisms
2. Knows that living organisms have distinct structures and body systems that serve specific functions in growth, survival, and reproduction (e.g., various body structures for walking, flying, or swimming)
3. Knows that the behavior of individual organisms is influenced by internal cues (e.g., hunger) and external cues (e.g., changes in the environment), and that humans and other organisms have senses that help them to detect these cues

Level 3 (Grade 6-8)

1. Knows that all organisms are composed of cells, which are the fundamental units of life; most organisms are single cells, but other organisms (including humans) are multicellular
2. Knows that cells convert energy obtained from food to carry on the many functions needed to sustain life (e.g., cell growth and division, production of materials that the cell or organism needs)
3. Knows the levels of organization in living systems, including cells, tissues, organs, organ systems, whole organisms, ecosystems, and the complementary nature of structure and function at each level
4. Knows that multicellular organisms have a variety of specialized cells, tissues, organs, and organ systems that perform specialized functions (e.g., digestion, respiration, reproduction, circulation, excretion, movement, control and coordination, protection from disease)
5. Knows that organisms have a great variety of body plans and internal structures that serve specific functions for survival (e.g., digestive structures in vertebrates, invertebrates, unicellular organisms, and plants)
6. Knows how an organism's ability to regulate its internal environment enables the organism to obtain and use resources, grow, reproduce, and maintain stable internal conditions while living in a constantly changing external environment
7. Knows that organisms can react to internal and environmental stimuli through behavioral response (e.g., plants have tissues and organs that react to light, water, and other stimuli; animals have nervous systems that process and store information from the environment), which may be determined by heredity or from past experience
8. Knows that disease in organisms can be caused by intrinsic failures of the system or infection by other organisms

Level 4 (Grade 9-12)

1. Knows the structures of different types of cell parts (e.g., cell wall; cell membrane; cytoplasm; cell organelles such as the nucleus, chloroplast, mitochondrion, Golgi apparatus, vacuole) and the functions they perform (e.g., transport of materials, storage of genetic information, photosynthesis and respiration, synthesis of new molecules, waste disposal)
2. Understands the chemical reactions involved in cell functions (e.g., food molecules taken into cells are broken down to provide the chemical constituents needed to synthesize other molecules; enzymes facilitate the breakdown and synthesis of molecules)
3. Understands the processes of photosynthesis and respiration in plants (e.g., chloroplasts in plant cells use energy from sunlight to combine molecules of carbon dioxide and water into complex, energy-rich organic compounds and release oxygen to the environment)
4. Knows how cell functions are regulated through changes in the activity of the functions performed by proteins and through the selective expression of individual genes, and how this regulation allows cells to respond to their environment and to control and coordinate cell growth and division
5. Knows that the complexity and organization of organisms accommodates the need for obtaining, transforming, transporting, releasing, and eliminating the matter and energy used to sustain the organism
6. Understands the processes of cell division and differentiation (e.g., meiosis, mitosis, embryo formation, cellular replication and differentiation into the many specialized cells, tissues, and organs that comprise the final organism; each cell retains the basic information needed to reproduce itself)
7. Knows the structures of proteins (e.g., long, usually folded chain molecules made of specific sequences of amino acids coded by DNA) and the role of proteins in cell function
8. Understands the structure and functions of nervous systems in multicellular animals (e.g., nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves; nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules)

Standard 6: Understands relationships among organisms and their physical environment

Level 1 (Grade K-2)

1. Knows that plants and animals need certain resources for energy and growth (e.g., food, water, light, air)

Level 2 (Grade 3-5)

1. Knows the organization of simple food chains and food webs (e.g., green plants make their own food with sunlight, water, and air; some animals eat the plants; some animals eat the animals that eat the plants)

2. Knows that the transfer of energy (e.g., through the consumption of food) is essential to all living organisms
3. Knows that an organism's patterns of behavior are related to the nature of that organism's environment (e.g., kinds and numbers of other organisms present, availability of food and resources, physical characteristics of the environment)
4. Knows that changes in the environment can have different effects on different organisms (e.g., some organisms move in, others move out; some organisms survive and reproduce, others die)
5. Knows that all organisms (including humans) cause changes in their environments, and these changes can be beneficial or detrimental

Level 3 (Grade 6-8)

1. Knows that all individuals of a species that exist together at a given place and time make up a population, and all populations living together and the physical factors with which they interact compose an ecosystem
2. Knows factors that affect the number and types of organisms an ecosystem can support (e.g., available resources; abiotic factors such as quantity of light and water, range of temperatures, and soil composition; disease; competition from other organisms within the ecosystem; predation)
3. Knows ways in which organisms interact and depend on one another through food chains and food webs in an ecosystem (e.g., producer/consumer, predator/prey, parasite/host, relationships that are mutually beneficial or competitive)
4. Knows how energy is transferred through food webs in an ecosystem (e.g., energy enters ecosystems as sunlight, and green plants transfer this energy into chemical energy through photosynthesis; this chemical energy is passed from organism to organism; animals get energy from oxidizing their food, releasing some of this energy as heat)
5. Knows how matter is recycled within ecosystems (e.g., matter is transferred from one organism to another repeatedly, and between organisms and their physical environment; the total amount of matter remains constant, even though its form and location change)

Level 4 (Grade 9-12)

1. Knows how the interrelationships and interdependencies among organisms generate stable ecosystems that fluctuate around a state of rough equilibrium for hundreds or thousands of years (e.g., growth of a population is held in check by environmental factors such as depletion of food or nesting sites, increased loss due to larger numbers of predators or parasites)
2. Knows how the amount of life an environment can support is limited by the availability of matter and energy and the ability of the ecosystem to recycle materials
3. Knows that as matter and energy flow through different levels of organization in living systems and between living systems and the physical environment, chemical elements (e.g., carbon, nitrogen) are recombined in different ways

4. Knows that because all matter tends toward more disorganized states, living systems require a continuous input of energy to maintain their chemical and physical organizations
5. Knows ways in which humans can alter the equilibrium of ecosystems, causing potentially irreversible effects (e.g., human population growth, technology, and consumption; human destruction of habitats through direct harvesting, pollution, and atmospheric changes)

Standard 7: Understands biological evolution and the diversity of life

Level 1 (Grade K-2)

1. Knows that some kinds of organisms that once lived on Earth have completely disappeared (e.g., dinosaurs, trilobites, mammoths, giant tree ferns, horsetail trees)
2. Knows that there are similarities and differences in the appearance and behavior of plants and animals

Level 2 (Grade 3-5)

1. Knows different ways in which living things can be grouped (e.g., plants/animals, bones/no bones, insects/spiders, live on land/live in water) and purposes of different groupings

Level 3 (Grade 6-8)

1. Knows basic ideas related to biological evolution (e.g., diversity of species is developed through gradual processes over many generations; biological adaptations, such as changes in structure, behavior, or physiology, allow some species to enhance their reproductive success and survival in a particular environment)
2. Understands the concept of extinction and its importance in biological evolution (e.g., when the environment changes, the adaptive characteristics of some species are insufficient to allow their survival; extinction is common; most of the species that have lived on the Earth no longer exist)
3. Knows evidence that supports the idea that there is unity among organisms despite the fact that some species look very different (e.g., similarity of internal structures in different organisms, similarity of chemical processes in different organisms, evidence of common ancestry)
4. Knows ways in which living things can be classified (e.g., taxonomic groups of plants, animals, and fungi; groups based on the details of organisms' internal and external features; groups based on functions served within an ecosystem such as producers, consumers, and decomposers)

Level 4 (Grade 9-12)

1. Knows that heritable characteristics, which can be biochemical and anatomical, largely determine what capabilities an organism will have, how it will behave, and how likely it is to survive and reproduce

2. Understands the concept of natural selection (e.g., when an environment changes, some inherited characteristics become more or less advantageous or neutral, and chance alone can result in characteristics having no survival or reproductive value; this process results in organisms that are well suited for survival in particular environments)
3. Knows how variation of organisms within a species increases the chance of survival of the species, and how the great diversity of species on Earth increases the chance of survival of life in the event of major global changes
4. Knows that the basic idea of evolution is that the Earth's present-day life forms have evolved from earlier, distinctly different species as a consequence of the interactions of (1) the potential for a species to increase its numbers, (2) the genetic variability of offspring due to mutation and recombination of genes, (3) a finite supply of the resources required for life, and (4) the ensuing selection by the environment of those offspring better able to survive and leave offspring
5. Knows the history of the origin and evolution of life on Earth (e.g., life on Earth is thought to have begun 3.5-4 billion years ago as simple, unicellular organisms; cells with nuclei evolved about a billion years ago, after which increasingly complex multicellular organisms evolved)
6. Knows how natural selection and its evolutionary consequences provide a scientific explanation for the diversity and unity of past and present life forms on Earth (e.g., recurring patterns of relationship exist throughout the fossil record; molecular similarities exist among the diverse species of living organisms; the millions of different species living today appear to be related by descent from common ancestors)
7. Knows how organisms are classified into a hierarchy of groups and subgroups based on similarities that reflect their evolutionary relationships (e.g., shared derived characteristics inherited from a common ancestor; degree of kinship estimated from the similarity of DNA sequences)

Physical Sciences

Standard 8: Understands the structure and properties of matter

Level 1 (Grade K-2)

1. Knows that different objects are made up of many different types of materials (e.g., cloth, paper, wood, metal) and have many different observable properties (e.g., color, size, shape, weight)

Level 2 (Grade 3-5)

1. Knows that matter has different states (i.e., solid, liquid, gas) and that each state has distinct physical properties; some common materials such as water can be changed from one state to another by heating or cooling
2. Knows that substances can be classified by their physical and chemical properties (e.g., magnetism, conductivity, density, solubility, boiling and melting points)
3. Knows that materials may be composed of parts that are too small to be seen without magnification

Level 3 (Grade 6-8)

1. Knows that matter is made up of tiny particles called atoms, and different arrangements of atoms into groups compose all substances
2. Knows that atoms often combine to form a molecule (or crystal), the smallest particle of a substance that retains its properties
3. Knows that states of matter depend on molecular arrangement and motion (e.g., molecules in solids are packed tightly together and their movement is restricted to vibrations; molecules in liquids are loosely packed and move easily past each other; molecules in gases are quite far apart and move about freely)
4. Knows that substances containing only one kind of atom are elements and do not break down by normal laboratory reactions (e.g., heating, exposure to electric current, reaction with acids); over 100 different elements exist
5. Knows that many elements can be grouped according to similar properties (e.g., highly reactive metals, less-reactive metals, highly reactive nonmetals, almost completely nonreactive gases)
6. Understands the conservation of mass in physical and chemical change (e.g., no matter how substances within a closed system interact with one another, the total weight of the system remains the same; the same number of atoms weighs the same, no matter how the atoms are arranged)
7. Knows methods used to separate mixtures into their component parts (boiling, filtering, chromatography, screening)
8. Knows that substances react chemically in characteristic ways with other substances to form new substances (compounds) with different characteristic properties
9. Knows factors that influence reaction rates (e.g., types of substances involved, temperature, concentration of reactant molecules, amount of contact between reactant molecules)
10. Knows that oxidation involves the combining of oxygen with another substance (e.g., burning, rusting)

Level 4 (Grade 9-12)

1. Knows the structure of an atom (e.g., negative electrons occupy most of the space in the atom; neutrons and positive protons make up the nucleus of the atom; protons and neutrons are almost two thousand times heavier than an electron; the electric force between the nucleus and electrons holds the atom together)
2. Understands how elements are arranged in the periodic table, and how this arrangement shows repeating patterns among elements with similar properties (e.g., numbers of protons, neutrons, and electrons; relation between atomic number and atomic mass)
3. Knows how the electron configuration of atoms governs the chemical properties of an element as atoms interact with one another by transferring or sharing the outermost electrons
4. Knows that atoms may be bonded together into molecules or crystalline solids, and compounds are formed from chemical bonds between two or more different kinds of

atoms

5. Knows that the physical properties of a compound are determined by its molecular structure (e.g., constituent atoms, distances and angles between them) and the interactions among these molecules
6. Knows that the number of electrons in an atom determines whether the atom is electrically neutral or an ion (i.e., electrically neutral atoms contain equal numbers of protons and electrons; a positively charged atom has lost one or more electrons; a negatively charged atom has gained one or more electrons)
7. Knows that most elements have two or more isotopes (i.e., atoms that differ in the number of neutrons in the nucleus); although the number of neutrons has little effect on how the atom interacts with others, it does affect the mass and stability of the nucleus
8. Knows how radioactive isotopes can be used to estimate the age of materials that contain them because radioactive isotopes undergo spontaneous nuclear reactions and emit particles and/or wavelike radiation; the decay of any one nucleus cannot be predicted, but a large group of identical nuclei decay at a predictable rate, which can be used to estimate the material's age
9. Knows that neutrons and protons are made up of even smaller constituents
10. Understands that chemical reactions either release or consume energy (i.e., some changes of atomic or molecular configuration require an input of energy; others release energy)
11. Knows that chemical reactions can take place at vastly different rates (e.g., from the few femtoseconds required for an atom to move a fraction of a chemical bond distance to geologic times scales of billions of years) and reaction rates depend on a variety of factors that influence the frequency of collision of reactant molecules (e.g., shape and surface area of the reacting species, temperature, pressure, the presence or absence of a catalyst).
12. Knows that chemical reactions can be accelerated by catalysts (e.g., metallic surfaces, enzymes)
13. Understands the complete mole concept and ways in which it can be used (e.g., actual mass vs. relative mass; relationship between the mole and the volume of a mole of molecules; relevance of molar volume and Avogadro's hypothesis)
14. Knows the variety of structures that may be formed from the bonding of carbon atoms (e.g., synthetic polymers, oils, the large molecules essential to life) and their roles in various chemical reactions, including those required for life processes
15. Knows that a large number of important reactions involve the transfer of either electrons (oxidation/reduction reactions) or hydrogen ions (acid/base reactions) between reacting ions, molecules, or atoms
16. Understands radical reactions and their role in natural and human processes (e.g., ozone and green house gases in the atmosphere; burning and processing of fossil fuels; formation of polymers; explosions)
17. Understands the relationships and characteristics of gases.
18. Can describe the composition and relationship between acids, bases, and salts.
19. Understands the difference between homogeneous and heterogeneous mixtures.

Standard 9: Understands the sources and properties of energy

Level 1 (Grade K-2)

1. Knows that the Sun supplies heat and light to Earth
2. Knows that sound is produced by vibrating objects
3. Knows that light travels in a straight line until it strikes an object

Level 2 (Grade 3-5)

1. Knows that heat is often produced as a byproduct when one form of energy is converted to another form (e.g., when machines and living organisms convert stored energy to motion)
2. Knows that heat can move from one object to another by conduction and that some materials conduct heat better than others
3. Knows the organization of a simple electrical circuit (e.g., battery or generator, wire, a complete loop through which the electrical current can pass)
4. Knows that light can be reflected, refracted, or absorbed
5. Knows that the pitch of a sound depends on the frequency of the vibration producing it

Level 3 (Grade 6-8)

1. Knows that energy is a property of many substances (e.g., heat energy is in the disorderly motion of molecules and in radiation; chemical energy is in the arrangement of atoms; mechanical energy is in moving bodies or in elastically distorted shapes; electrical energy is in the attraction or repulsion between charges)
2. Understands the law of conservation of energy (i.e., energy cannot be created or destroyed but only changed from one form to another)
3. Knows that heat energy flows from warmer materials or regions to cooler ones through conduction, convection, and radiation
4. Knows how the Sun acts as a major source of energy for changes on the Earth's surface (i.e., the Sun loses energy by emitting light; some of this light is transferred to the Earth in a range of wavelengths including visible light, infrared radiation, and ultraviolet radiation)
5. Knows that electrical circuits provide a means of transferring electrical energy to produce heat, light, sound, and chemical changes
6. Knows that most chemical and nuclear reactions involve a transfer of energy (e.g., heat, light, mechanical motion, electricity)
7. Knows that vibrations (e.g., sounds, earthquakes) move at different speeds in different materials, have different wavelengths, and set up wave-like disturbances that spread away from the source
8. Knows ways in which light interacts with matter (e.g., transmission, including refraction; absorption; scattering, including reflection)
9. Knows that only a narrow range of wavelengths of electromagnetic radiation can be seen by the human eye; differences of wavelength within that range of visible light are perceived as differences in color

10. Knows how sound travels and how it behaves
11. Knows how light, mirrors, lenses and color work together
12. Knows how electricity is produced, travels and works

Level 4 (Grade 9-12)

1. Understands the concept of entropy (e.g., although the total energy of the universe remains constant, matter tends to become steadily less ordered as various energy transfers occur; the energy tends to spread out uniformly, thereby decreasing the amount of useful energy)
2. Knows that all energy can be considered to be either kinetic energy (energy of motion), potential energy (depends on relative position), or energy contained by a field (electromagnetic waves)
3. Understands the relationship between heat and temperature (heat energy consists of the random motion and vibrations of atoms, molecules, and ions; the higher the temperature, the greater the atomic or molecular motion)
4. Knows how the energy associated with individual atoms and molecules can be used to identify the substances they comprise; each kind of atom or molecule can gain or lose energy only in particular discrete amounts, and thus can absorb and emit light only at wavelengths corresponding to these amounts
5. Knows that nuclear reactions convert a fraction of the mass of interacting particles into energy (fission involves the splitting of a large nucleus into smaller pieces; fusion is the joining of two nuclei at extremely high temperature and pressure) and release much greater amounts of energy than atomic interactions
6. Knows that waves (e.g., sound, seismic, water, light) have energy and can transfer energy when they interact with matter
7. Knows the range of the electromagnetic spectrum (e.g., radio waves, microwaves, infrared radiation, visible light, ultraviolet radiation, x-rays, gamma rays); electromagnetic waves result when a charged object is accelerated or decelerated, and the energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength

Standard 10: Understands forces and motion

Level 1 (Grade K-2)

1. Knows that magnets can be used to make some things move without being touched

Level 2 (Grade 3-5)

1. Knows that magnets attract and repel each other and attract certain kinds of other materials (e.g., iron, steel)
2. Knows that the Earth's gravity pulls any object toward it without touching it
3. Knows that electrically charged material pulls on all other materials and can attract or repel other charged materials
4. Knows that when a force is applied to an object, the object either speeds up, slows down, or goes in a different direction

5. Knows the relationship between the strength of a force and its effect on an object (e.g., the greater the force, the greater the change in motion; the more massive the object, the smaller the effect of a given force)

Level 3 (Grade 6-8)

1. Understands general concepts related to gravitational force (e.g., every object exerts gravitational force on every other object; this force depends on the mass of the objects and their distance from one another; gravitational force is hard to detect unless at least one of the objects, such as the Earth, has a lot of mass)
2. Knows that just as electric currents can produce magnetic forces, magnets can cause electric currents
3. Knows that an object's motion can be described and represented graphically according to its position, direction of motion, and speed
4. Understands effects of balanced and unbalanced forces on an object's motion (e.g., if more than one force acts on an object along a straight line, then the forces will reinforce or cancel one another, depending on their direction and magnitude; unbalanced forces such as friction will cause changes in the speed or direction on an object's motion)
5. Knows that an object that is not being subjected to a force will continue to move at a constant speed and in a straight line

Level 4 (Grade 9-12)

1. Knows that magnetic forces are very closely related to electric forces and can be thought of as different aspects of a single electromagnetic force (moving electric charges produce magnetic forces and moving magnets produce electric forces); the interplay of these forces is the basis for electric motors, generators, radio, television, and many other modern technologies
2. Knows that nuclear forces are much stronger than electromagnetic forces, which are vastly stronger than gravitational forces; the strength of nuclear forces explains why great amounts of energy are released from the nuclear reactions in atomic or hydrogen bombs, and in the Sun and other stars
3. Knows that the strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them
4. Knows that the strength of the electric force between two charged objects is proportional to the charges (opposite charges attract whereas like charges repel) and, as with gravitation, inversely proportional to the square of the distance between them
5. Knows that electromagnetic forces exist within and between atoms (e.g., electric forces between oppositely charged electrons and protons hold atoms and molecules together, and are involved in all chemical reactions; electric forces hold solid and liquid materials together and act between objects when they are in contact)
6. Knows how different kinds of materials respond to electric forces (e.g., as insulators, semiconductors, conductors, superconductors)

7. Knows that materials that contain equal proportions of positive and negative charges are electrically neutral, but a very small excess or deficit of negative charges in a material produces noticeable electric forces
8. Knows that laws of motion can be used to determine the effects of forces on the motion of objects (e.g., objects change their motion only when a net force is applied; whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object; the magnitude of the change in motion can be calculated using the relationship $F=ma$, which is independent of the nature of the force)
9. Knows that apparent changes in wavelength can provide information about changes in motion because the observed wavelength of a wave depends upon the relative motion of the source and the observer; if either the source or observer is moving toward the other, the observed wavelength is shorter; if either is moving away, the wavelength is longer
10. Understands general concepts related to the theory of special relativity (e.g., in contrast to other moving things, the speed of light is the same for all observers, no matter how they or the light source happen to be moving; the laws of physics are the same in any inertial frame of reference)
11. Understands the relationship between force, motion, work, and power.
12. Knows how machines assist in doing work and can describe it through mechanical advantage, ideal mechanical advantage and % efficiency.

Nature of Science

Standard 11: Understands the nature of scientific knowledge

Level 1 (Grade K-2)

1. Knows that scientific investigations generally work the same way in different places and normally produce results that can be duplicated

Level 2 (Grade 3-5)

1. Knows that although the same scientific investigation may give slightly different results when it is carried out by different persons, or at different times or places, the general evidence collected from the investigation should be replicable by others
2. Knows that good scientific explanations are based on evidence (observations) and scientific knowledge
3. Knows that scientists make the results of their investigations public; they describe the investigations in ways that enable others to repeat the investigations
4. Knows that scientists review and ask questions about the results of other scientists' work

Level 3 (Grade 6-8)

1. Knows that an experiment must be repeated many times and yield consistent results before the results are accepted as correct

2. Understands the nature of scientific explanations (e.g., use of logically consistent arguments; emphasis on evidence; use of scientific principles, models, and theories; acceptance or displacement of explanations based on new scientific evidence)
3. Knows that all scientific ideas are tentative and subject to change and improvement in principle, but for most core ideas in science, there is much experimental and observational confirmation

Level 4 (Grade 9-12)

1. Knows ways in which science distinguishes itself from other ways of knowing and from other bodies of knowledge (e.g., use of empirical standards, logical arguments, skepticism)
2. Knows that scientific explanations must meet certain criteria to be considered valid (e.g., they must be consistent with experimental and observational evidence about nature, make accurate predictions about systems being studied, be logical, respect the rules of evidence, be open to criticism, report methods and procedures, make a commitment to making knowledge public)
3. Understands how scientific knowledge changes and accumulates over time (e.g., all scientific knowledge is subject to change as new evidence becomes available; some scientific ideas are incomplete and opportunity exists in these areas for new advances; theories are continually tested, revised, and occasionally discarded)
4. Knows that from time to time, major shifts occur in the scientific view of how the world works, but usually the changes that take place in the body of scientific knowledge are small modifications of prior knowledge

Standard 12: Understands the nature of scientific inquiry

Level 1 (Grade K-2)

1. Knows that tools (e.g., thermometers, magnifiers, rulers, balances) can be used to gather information and extend the senses

Level 2 (Grade 3-5)

1. Knows that scientific investigations involve asking and answering a question and comparing the answer to what scientists already know about the world
2. Knows that scientists use different kinds of investigations (e.g., naturalistic observation of things or events, data collection, controlled experiments), depending on the questions they are trying to answer
3. Plans and conducts simple investigations (e.g., formulates a testable question, makes systematic observations, develops logical conclusions)
4. Uses appropriate tools and simple equipment (e.g., thermometers, magnifiers, microscopes, calculators, graduated cylinders) to gather scientific data and extend the senses
5. Knows that different people may interpret the same set of observations differently

Level 3 (Grade 6-8)

1. Knows that there is no fixed procedure called "the scientific method," but that investigations involve systematic observations, carefully collected, relevant evidence, logical reasoning, and some imagination in developing hypotheses and explanations
2. Understands that questioning, response to criticism, and open communication are integral to the process of science (e.g., scientists often differ with one another about the interpretation of evidence or theory in areas where there is not a great deal of understanding; scientists acknowledge conflicting interpretations and work towards finding evidence that will resolve the disagreement)
3. Designs and conducts a scientific investigation (e.g., formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations, proposes alternative explanations for observations, critiques explanations and procedures)
4. Knows that observations can be affected by bias (e.g., strong beliefs about what should happen in particular circumstances can prevent the detection of other results)
5. Uses appropriate tools (including computer hardware and software) and techniques to gather, analyze, and interpret scientific data
6. Establishes relationships based on evidence and logical argument (e.g., provides causes for effects)
7. Knows that scientific inquiry includes evaluating results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists (e.g., reviewing experimental procedures, examining evidence, identifying faulty reasoning, identifying statements that go beyond the evidence, suggesting alternative explanations)
8. Knows possible outcomes of scientific investigations (e.g., some may result in new ideas and phenomena for study; some may generate new methods or procedures for an investigation; some may result in the development of new technologies to improve the collection of data; some may lead to new investigations)

Level 4 (Grade 9-12)

1. Understands the use of hypotheses in science (e.g., selecting and narrowing the focus of data, determining additional data to be gathered; guiding the interpretation of data)
2. Designs and conducts scientific investigations (e.g., formulates testable hypotheses; identifies and clarifies the method, controls, and variables; organizes, displays, and analyzes data; revises methods and explanations; presents results; receives critical response from others)
3. Knows that, when conditions of an investigation cannot be controlled, it may be necessary to discern patterns by observing a wide range of natural occurrences
4. Uses technology (e.g., hand tools, measuring instruments, calculators, computers) and mathematics (e.g., measurement, formulas, charts, graphs) to perform accurate scientific investigations and communications
5. Knows that conceptual principles and knowledge guide scientific inquiries; historical and current scientific knowledge influence the design and interpretation of investigations and the evaluation of proposed explanations made by other scientists

6. Knows that scientists conduct investigations for a variety of reasons (e.g., to discover new aspects of the natural world, to explain recently observed phenomena, to test the conclusions of prior investigations, to test the predictions of current theories)

7. Knows that investigations and public communication among scientists must meet certain criteria in order to result in new knowledge and methods (e.g., arguments must be logical and demonstrate connections between natural phenomena, investigations, and the historical body of scientific knowledge; the methods and procedures used to obtain evidence must be clearly reported to enhance opportunities for further investigation)

Standard 13: Understands the scientific enterprise

Level 1 (Grade K-2)

1. Knows that in science it is helpful to work with a team and share findings with others

Level 2 (Grade 3-5)

1. Knows that people of all ages, backgrounds, and groups have made contributions to science and technology throughout history

2. Knows that although people using scientific inquiry have learned much about the objects, events, and phenomena in nature, science is an ongoing process and will never be finished

3. Knows that scientists and engineers often work in teams to accomplish a task

Level 3 (Grade 6-8)

1. Knows that people of all backgrounds and with diverse interests, talents, qualities, and motivations engage in fields of science and engineering; some of these people work in teams and others work alone, but all communicate extensively with others

2. Knows that the work of science requires a variety of human abilities, qualities, and habits of mind (e.g., reasoning, insight, energy, skill, creativity, intellectual honesty, tolerance of ambiguity, skepticism, openness to new ideas)

3. Knows various settings in which scientists and engineers may work (e.g., colleges and universities, businesses and industries, research institutes, government agencies)

4. Understands ethics associated with scientific study (e.g., potential subjects must be fully informed of the risks and benefits associated with the research and their right to refuse to participate; potential subjects must be fully informed of possible risks to community and property)

5. Knows that throughout history, many scientific innovators have had difficulty breaking through accepted ideas of their time to reach conclusions that are now considered to be common knowledge

6. Knows ways in which science and society influence one another (e.g., scientific knowledge and the procedures used by scientists influence the way many individuals think about themselves, others, and the environment; societal challenges often inspire questions for scientific research; social and economic forces strongly influence which science research programs are pursued and funded)

Level 4 (Grade 9-12)

1. Knows that, throughout history, diverse cultures have developed scientific ideas and solved human problems through technology
2. Understands that individuals and teams contribute to science and engineering at different levels of complexity (e.g., an individual may conduct basic field studies; hundreds of people may work together on a major scientific question or technological problem)
3. Understands the ethical traditions associated with the scientific enterprise (e.g., commitment to peer review, truthful reporting about the methods and outcomes of investigations, publication of the results of work) and that scientists who violate these traditions are censored by their peers
4. Knows that science and technology are essential social enterprises, but alone they can only indicate what can happen, not what should happen
5. Understands that science involves different types of work in many different disciplines (e.g., scientists in different disciplines ask different questions, use different methods of investigation, and accept different types of evidence to support their explanations; many scientific investigations require the contributions of individuals from different disciplines; new disciplines of science, such as geophysics and biochemistry, often emerge at the interface of older disciplines)
6. Knows that creativity, imagination, and a good knowledge base are all required in the work of science and engineering

Standard 14: Understands the effective use of technology

Level 1 (Grade K-2)

1. Knows that technology comes in many forms and can aid in the study of science

Level 2 (Grade 3-5)

1. Knows how to use computers and microscopes in the study of science

Level 3 (Grade 6-8)

1. Knows how to use technology as a tool to learn through experimentation

Level 4 (Grade 9-12)

1. Knows that technology comes in many forms and can aid in the study of science
2. Knows how to use computers and microscopes in the study of science
3. Knows how to use technology as a tool to learn through experimentation
4. Knows how to use computers, laboratory equipment, internet and microscopes in the study of science

Source *Mid-continent Regional Educational Laboratory K-12 Standards and Benchmarks 2002*

