IA_Core Curriculum - Science (2009)
High School

Strand 1 Science as Inquiry

Concept 1.1 Identify questions and concepts that guide scientific investigations.

Skill 1.1.1 Students formulate a testable hypothesis and demonstrate the logical connections between the scientific concepts guiding a hypothesis and the design of an experiment. They should demonstrate appropriate procedures, a knowledge base, and conceptual understanding of scientific investigations. The key is that the student demonstrates knowledge of the scientific concepts through the investigation.

Concept 1.2 Design and conduct a scientific investigation.

Skill 1.2.1 Designing and conducting a scientific investigation requires introduction to the major concepts in the area being investigated, proper equipment, safety precautions, assistance with methodological problems, recommendations for use of technologies, clarification of ideas that guide the inquiry, and scientific knowledge obtained from sources other than the actual investigation. The investigation may also require student clarification of the question, method, controls, and variables; student organization and display of data; student revision of methods and explanations; and a public presentation of the results with a critical response from peers. Regardless of the scientific investigation performed, students must use evidence, apply logic, and construct an argument for their proposed explanations.

Concept 1.5 Think critically and logically to make the relationships between evidence and explanations.

Skill 1.5.1 Thinking critically about evidence includes deciding what evidence should be used and accounting for anomalous data. Specifically, students review data from a simple experiment, summarize the data, and form a logical argument about the cause-and-effect relationships in the experiment.

Concept 1.6 Recognize and analyze alternative explanations and predictions.

Skill 1.6.1 This aspect of the standard emphasizes the critical abilities of analyzing an argument by reviewing current scientific understanding, weighing the evidence, and examining the logic so as to decide which explanations and models are best. In other words, although there may be several plausible explanations, they do not all have equal weight. Students use scientific criteria to find the preferred explanations.

Concept 1.7 Communicate and defend scientific procedures and explanations.

Skill 1.7.1 Students in school science programs develop the abilities associated with accurate and effective communication. These include writing and following procedures, expressing concepts, reviewing information, summarizing data, using language appropriately, developing diagrams and charts, explaining statistical analysis, speaking clearly and logically, constructing a reasoned argument, and responding appropriately to critical comments.

Concept 1.8 Use mathematics in all aspects of scientific inquiry.

Skill 1.8.1 Mathematics is essential to asking and answering questions about the natural world. Mathematics can be used to ask questions; to gather, organize, and present data; and to structure convincing explanations.

Concept 1.3 Uses technology and mathematics to improve investigations and communications.

Skill 1.3.1 A variety of technologies, such as hand tools, measuring instruments, and calculators should be an integral component of scientific investigations. The use of computers for the collection, analysis, and display of data is also a part of this standard. Mathematics plays an essential role in all aspects of an inquiry investigation. For example, measurement is used for posing questions, formulas are used for developing explanations, and charts and graphs are used for communicating results.

Concept 1.4 Formulates and revises scientific explanations and models using logic and evidence.

Skill 1.4.1 Student inquiries culminate in formulating an explanation or model. Models should be physical, conceptual, and mathematical. In the process of answering the questions, the students engage in discussions and arguments that result in the revision of their explanations. These discussions should be based on scientific knowledge, the use of logic, and evidence from their investigation.

Strand 2 Earth and Space

Concept 2.1 Understand and apply knowledge of energy in the earth system.

Skill 2.1.1 Earth systems have internal and external sources of energy, both of which create heat. The sun is the major external source of energy. Two primary sources of internal energy are the decay of radioactive isotopes and the gravitational energy from the earth's original formation.

Skill 2.1.2 The outward transfer of Earth's internal heat drives convection circulation in the mantle that propels the plates comprising the earth's surface across the face of the globe.

Skill 2.1.3 Heating of the earth's surface and atmosphere by the sun drives convection within the atmosphere and oceans, producing winds and ocean currents.

Skill 2.1.4 Global climate is determined by energy transfer from the sun at and near the earth's surface. This energy transfer is influenced by dynamic processes such as cloud cover and the earth's rotation, and static conditions such as the position of mountain ranges and oceans.

Concept 2.2 Understand and apply knowledge of Geochemical cycles.

Skill 2.2.1 The earth is a system containing essentially a fixed amount of each stable chemical atom or element. Each element can exist in several different chemical reservoirs. Each element on Earth moves among reservoirs in the solid Earth, oceans, atmosphere, and organisms as part of geochemical cycles.

Skill 2.2.2 Movement of matter between reservoirs is driven by the earth's internal and external sources of energy. These movements are often accompanied by a change in the physical and chemical properties of the matter. Carbon, for example, occurs in carbonate rocks such as limestone, in the atmosphere as carbon dioxide gas, in water as dissolved carbon dioxide, and in all organisms as complex molecules that control the chemistry of life.

Concept 2.3 Understand and apply knowledge of origin and evolution of the earth system.

Skill 2.3.1 The sun, the earth, and the rest of the solar system formed from a nebular cloud of dust and gas 10 to 15 billion years ago. The early Earth was very different from the planet on which we live today.

Skill 2.3.2 Geologic time can be estimated by observing rock sequences and using fossils to correlate the sequences at various locations. Current methods for measuring geologic time include using the known decay rates of radioactive isotopes present in rocks to measure the time since the rock was formed.

Skill 2.3.3 Interactions among the solid Earth, the oceans, the atmosphere, and organisms have resulted in the ongoing evolution of the earth system. We can observe some changes such as earthquakes and volcanic eruptions on a human time scale, but many processes such as mountain building and plate movements take place over hundreds of millions of years.

Skill 2.3.4 Evidence for one-celled forms of life—the microbes—extends back more than 3.5 billion years. The evolution of life caused dramatic changes in the composition of the earth's atmosphere, which did not originally contain oxygen.

Concept 2.4 Understand and apply knowledge of origin and evolution of the Universe.

Skill 2.4.1 The origin of the universe remains one of the greatest questions in science. The "big bang" theory places the origin between 10 and 20 billion years ago, when the universe began in a hot dense state: According to this theory, the universe has been expanding ever since.

Skill 2.4.2 Early in the history of the universe, matter—primarily the light atoms hydrogen and helium — clumped together through gravitational attraction to form countless trillions of stars. Billions of galaxies, each of which is a gravitationally bound cluster of billions of stars, now form most of the visible mass in the universe.

Skill 2.4.3 Stars produce energy from nuclear reactions, primarily the fusion of hydrogen to form helium. These and other processes in stars have led to the formation of all the other elements.

Strand 3 Physical Science

Concept 3.1 Understand and apply knowledge of the structure of atoms.

Skill 3.1.1 Matter is made of minute particles called atoms, and atoms are composed of even smaller components. These components have measurable properties, such as mass and electrical charge. Each atom has a positively charged nucleus surrounded by negatively charged electrons. The electric force between the nucleus and electrons holds the atom together.

Skill 3.1.2 The atom's nucleus is composed of protons and neutrons, which are much more massive than electrons. When an element has atoms that differ in the number of neutrons, these atoms are called different isotopes of the element.

Skill 3.1.3 The nuclear forces that hold the nucleus of an atom together, at nuclear distances, are usually stronger than the electric forces that would make it fly apart. Nuclear reactions convert a fraction of the mass of interacting particles into energy, and they can release much greater amounts of energy than atomic interactions. Fission is the splitting of a large nucleus into smaller pieces. Fusion is the joining of two nuclei at extremely high temperature and pressure, and is the process responsible for the energy of the sun and other stars.

Skill 3.1.4 Radioactive isotopes are unstable and undergo spontaneous nuclear reactions, emitting 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. This predictability can be used to estimate the age of materials that contain radioactive isotopes.

Concept 3.2 Understand and apply knowledge of the structure and properties of matter.

Skill 3.2.1 Atoms interact with one another by transferring or sharing electrons that are the furthest from the nucleus. These outer electrons govern the chemical properties of the element.

Skill 3.2.2 An element is composed of a single type of atom. When elements are listed in order according to the number of protons (called the atomic number), repeating patterns of physical and chemical properties identify families of elements with similar properties. This "Periodic Table" is a consequence of the repeating pattern of outermost electrons and their permitted energies.

Skill 3.2.3 Bonds between atoms are created when electrons are paired up by being transferred or shared. A substance composed of a single kind of atom is called an element. The atoms may be bonded together into molecules or crystalline solids. A compound is formed when two or more kinds of atoms bind together chemically.

Skill 3.2.4 Solids, liquids, and gases differ in the distances and angles between molecules or atoms and, therefore, the energy that binds them together. In solids the structure is nearly rigid; in liquids molecules or atoms move around each other but do not move apart; and in gases molecules or atoms move almost independently of each other and are mostly far apart.

Skill 3.2.5 Carbon atoms can bond to one another in chains, rings, and branching networks to form a variety of structures, including synthetic polymers, oils, and the large molecules essential to life.

Concept 3.3 Understand and apply knowledge of chemical reactions.

Skill 3.3.1 "Chemical reactions" is an essential concept of a world-class secondary science curriculum. Included in "chemical reactions" is the following content: Chemical reactions occur all around us, for example in health care, cooking, cosmetics, and automobiles. Complex chemical reactions involving carbon-based molecules take place constantly in every cell in our bodies.

Skill 3.3.2 Chemical reactions may release or consume energy. Some reactions such as the burning of fossil fuels release large amounts of energy by losing heat and by emitting light. Light can initiate many chemical reactions such as photosynthesis and the evolution of urban smog.

Skill 3.3.3 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. In other reactions, chemical bonds are broken by heat or light to form very reactive radicals with electrons ready to form new bonds. Radical reactions control many processes such as the presence of ozone and greenhouse gases in the atmosphere, burning and processing of fossil fuels, the formation of polymers, and explosions.

Skill 3.3.4 Chemical reactions can take place in time periods ranging from the few femtoseconds (10 – 15 seconds) required for an atom to move a fraction of a chemical bond distance to geologic time scales of billions of years. Reaction rates depend on how often the reacting atoms and molecules encounter one another, the temperature, and the properties—including shape—of the reacting elements.

Skill 3.3.5 Objects change their motion only when a net force is applied. Laws of motion are used to calculate precisely the effects of forces on the motion of objects. The magnitude of the change in motion can be calculated using the relationship F = ma, which is independent of the nature of the force. Whenever one object exerts force on another, a force equal in magnitude and opposite in direction is exerted on the first object.

Concept 3.4 Understand and apply knowledge of motions and forces.

Skill 3.4.1 Gravitation is a universal force that each mass exerts on any other mass. The strength of the gravitational attractive force between two masses is proportional to the masses and is inversely proportional to the square of the distance between them.

Skill 3.4.2 The electric force is a universal force that exists between any two charged objects. Opposite charges attract, while like charges repel. The strength of the force is proportional to the charges, and, as with gravitation, inversely proportional to the square of the distance between them.

Skill 3.4.3 Between any two charged particles, electric force is vastly greater than the gravitational force. Most observable forces such as those exerted by a coiled spring or friction may be traced to electric forces acting between atoms and molecules.

Skill 3.4.4 Electricity and magnetism are two aspects of a single electromagnetic force. Moving electric charges produce magnetic forces, and moving magnets produce electric forces. These effects help students understand electric motors and generators.

Concept 3.5 Understand and apply knowledge of conservation of energy and increase in disorder.

Skill 3.5.1 “Conservation of energy and increase in disorder” is an essential concept of a world-class secondary science curriculum. Included in “conservation of energy and increase in disorder” is the following content: The total energy of the universe is constant. Energy can be transferred by collisions in chemical and nuclear reactions, by light waves and other radiations, and in many other ways. However, it can never be destroyed. As these transfers occur, the matter involved becomes steadily less ordered.

Skill 3.5.2 All energy can be considered to be either kinetic energy, which is the energy of motion; potential energy, which depends on relative position; or energy contained by a field, such as electromagnetic waves.

Concept 3.6 Understand and apply knowledge of interactions of energy and matter.

Skill 3.6.1 “Interactions of energy and matter” is an essential concept of a world-class secondary science curriculum. Included in “interactions of energy and matter” is the following content: Waves, including sound and seismic waves, waves on water, and light waves have energy and can transfer energy when they interact with matter.

Skill 3.6.2 Electromagnetic waves result when a charged object is accelerated or decelerated. Electromagnetic waves include radio waves (the longest wavelength), microwaves, infrared radiation (radiant heat), visible light, ultraviolet radiation, X-rays, and gamma rays. The energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelength.

Strand 4 Life Science

Concept 4.1 Understand and apply knowledge of the cell.

Skill 4.1.1 Cells have particular structures that underlie their functions. Every cell is surrounded by a membrane that separates it from the outside world. Inside the cell is a concentrated mixture of thousands of different molecules which form a variety of specialized structures, notably the nucleus, mitochondria, ribosomes, chloroplasts, and the endoplasmic reticulum. Some cells have external structures facilitating movement (cilia and flagella).

Skill 4.1.2 Most cell functions involve chemical reactions. Food molecules taken into cells react to provide the chemical constituents needed to synthesize other molecules. Both breakdown and synthesis are made possible by protein catalysts, called enzymes.

Skill 4.1.3 The chemical bonds of food molecules contain energy. Energy is released when the bonds of food molecules are broken and new compounds with lower energy bonds are formed. Cells temporarily store this energy in phosphate bonds of a small high-energy compound called ATP.

Skill 4.1.4 Cell regulation allows cells to respond to their environment and to control and coordinate cell growth and division. Environmental factors can influence cell division.

Skill 4.1.5 Plant cells contain chloroplasts as sites of photosynthesis. Plants and many microorganisms use solar energy to combine molecules of carbon dioxide and water into complex, energy rich organic compounds and release oxygen to the environment.

Concept 4.2 Understand and apply knowledge of the molecular basis of heredity.

Skill 4.2.1 In all organisms, the instructions for specifying the characteristics of the organism are carried in DNA, a large polymer formed from subunits of four kinds (A, G, C, and T). The chemical and structural properties of DNA explain how the genetic information that underlies heredity is both encoded in genes (as a string of molecular “letters”) and replicated (by a templating mechanism). DNA mutations occur spontaneously at low rates. Some of these changes make no difference to the organism, whereas others can change cells and organisms. Some mutations can be caused by environmental factors.

Skill 4.2.2 Each DNA molecule in a cell forms a single chromosome.

Skill 4.2.3 Most of the cells in a human contain two copies of each of 22 different chromosomes plus two chromosomes that determine sex: a female contains two X chromosomes and a male contains one X and one Y. Transmission of genetic information to offspring occurs through meiosis that produces egg and sperm cells that contain only one representative from each chromosome pair. An egg and a sperm unite to form a new individual.

Skill 4.2.4 The fact that an organism is formed from cells that contain two copies of each chromosome, and therefore two copies of each gene, explains many features of heredity, such as how variations that are hidden in one generation can be expressed in the next. Different genes coding for the same feature code for it in different ways thus leading to identifiable patterns in heritable traits. These patterns of inheritance can be identified and predicted.

Concept 4.3 Understand and apply knowledge of biological evolution.

Skill 4.3.1 Species evolve over time. Evolution is the 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, and (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.

Skill 4.3.2 Natural selection and its evolutionary consequences provide a scientific explanation for the fossil record of ancient life forms, as well as for the striking molecular similarities observed among the diverse species of living organisms. The great diversity of organisms is the result of more than 3.5 billion years of evolution that has filled every available niche with life forms.

Skill 4.3.3 The millions of different species of plants, animals, and microorganisms that live on Earth today are related by descent from common ancestors.

Skill 4.3.4 Biological classifications are based on how organisms are related. Organisms are classified into a hierarchy of groups and subgroups based on similarities in development and DNA sequences which reflect their evolutionary relationships. Species is the most fundamental unit of classification.

Concept 4.4 Understand and apply knowledge of the interdependence of organisms.

Skill 4.4.1 The atoms and molecules on the earth cycle among the living and nonliving components of the biosphere.

Skill 4.4.2 Energy flows through ecosystems in one direction, from photosynthetic organisms to herbivores to carnivores and decomposers. These tropic levels can be illustrated by food chains and food webs.

Skill 4.4.3 Organisms both cooperate and compete in ecosystems. The interrelationships and interdependencies of these organisms may generate ecosystems that are stable for hundreds or thousands of years.

Skill 4.4.4 Human beings live within the world's ecosystems. Increasingly, humans modify ecosystems as a result of population growth, technology, and consumption. Human destruction of habitats through direct harvesting, pollution, atmospheric changes, and other factors are threatening current global stability, and if not addressed, ecosystems will be irreversibly affected.

Concept 4.5 Understand and apply knowledge of the interdependence of matter, energy, and organization of living systems.

Skill 4.5.1 Living systems require a continuous input of energy, derived primarily from the sun, to maintain their chemical and physical organization. Plants capture energy by absorbing light and using it to form strong (covalent) chemical bonds between the atoms of carbon containing (organic) molecules. These molecules can be used to assemble larger molecules (proteins, DNA, sugars, and fats). The chemical energy stored in bonds between the atoms can be used as sources of energy for life processes.

Skill 4.5.2 Living organisms have the capacity to produce populations of infinite size, but environments and resources are finite. The distribution and abundance of organisms and populations in ecosystems are limited by the availability of matter and energy and the ability of the ecosystem to recycle materials.

Skill 4.5.3 All matter tends toward more disorganized states. Living systems require a continuous input of energy to maintain their chemical and physical organizations.

Skill 4.5.4 As matter and energy flows through different levels of organization of living systems—cells, organs, organisms, communities—and between living systems and the physical environment, chemical elements are recombined in different ways. Each recombination results in storage and dissipation of energy into the environment as heat. Matter and energy are conserved in each change.

Concept 4.6 Understand and apply knowledge of the interdependence of the behavior of organisms.

Skill 4.6.1 Multicellular animals have nervous systems that generate behavior. Nervous systems are formed from specialized cells that conduct signals rapidly through the long cell extensions that make up nerves. The nerve cells communicate with each other by secreting specific excitatory and inhibitory molecules. In sense organs, specialized cells detect light, sound, and specific chemicals and enable animals to monitor what is going on in the world around them.