

Important Science Standards Related to Structure and Evolution of the Universe Themes

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

Level I (Grade K-2)

Item 2: Knows that the stars are innumerable, unevenly dispersed, and of unequal brightness

Level II (Grade 3-5)

Item 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)

Item 6: Knows that telescopes magnify distant objects in the sky (e.g. the Moon, planets) and dramatically increases the number of stars we can see

Level III (Grade 6-8)

Item 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)

Item 4: Knows that the gravitational force keeps planets in orbit around the sun and moons in orbit around other planets

Item 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 galaxies and stars from one another and from the Earth

Level IV (Grade 9-12)

Item 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

[SEU Note: ...current best estimate for age of universe is 13.7 billion years (since WMAP findings)]

Item 2: Knows that evidence suggests our universe is expanding (e.g. the Doppler shift of light from distant galaxies reaching the 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)

Item 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)

Item 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)

Item 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)

Physical Sciences Standard 8: Understands the structure and properties of matter

Level III (Grade 3-5)

Item 1: Knows that matter is made up of tiny particles called atoms, and different arrangements of atoms into groups compose all substances

Item 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 electrical current, reaction with acids); over 100 different elements exist

Level IV (Grade 9-12)

Item 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)

Item 2: Understands how elements are arranged in the periodic table, and how this arrangement shows repeating patterns among elements with similar properties (e.g. number of protons, neutrons, and electrons; relation between atomic number and atomic mass)

Item 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 tiny particles and/or wavelike radiation; the decay of 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

Physical Sciences Standard 9: Understands the sources and properties of energy

Level III (Grade 6-8)

Item 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)

[Item 2: Understands the law of conservation of energy (i.e. energy cannot be created or destroyed but only changed from one form to another)]

Item 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 is a range of wavelengths including visible light, infrared radiation, and ultraviolet radiation)

Item 8: Knows ways in which light interacts with matter (e.g. transmission, including refraction; absorption; scattering; inducing reflection)

Item 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.

Level IV (Grade 9-12)

Item 1: Understand the concept of entropy (e.g. although the total energy of the universe remains constant, matter tends to become less steadily ordered as various energy transfers occur; the energy tends to spread out uniformly, thereby decreasing the amount of useful energy)

Item 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)

Item 3: Understand 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)

Item 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 at wavelengths corresponding to these amounts

Item 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 interaction

Item 6: Knows that waves (e.g. sound seismic, water, light) have energy and can transfer energy when they interact with matter

Item 7: Knows the range of the electromagnetic spectrum (e.g. radio waves, microwaves, infrared radiation, visible light, ultraviolet energy of electromagnetic waves is carried in packets whose magnitude is inversely proportional to the wavelengths)

Physical Sciences Standard 10: Understands force and motion

Level III (Grade 6-8)

Item 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 one of the objects, such as Earth, has a lot of mass)

Item 2: Knows that just as electric currents can produce magnetic forces, magnets can cause electric currents

Item 3: Knows that an object's motion can be described and represented graphically according to its position, direction of motion, and speed

Item 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 of an object's motion).

Item 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 IV (Grade 9-12)

Item 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

Item 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

Item 3: Knows that strength of the gravitational force between two masses is proportional to the masses and inversely proportional to the square of the distance between them

Item 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)

Item 8: Knows that laws of motion can be used to determine the effects of forces on the 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

Item 9: Knows that apparent change 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

Item 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 happens to be moving; the laws of physics are the same in any inertial frame of reference)

Nature of Science Standard 11: Understands the nature of scientific knowledge

Level III (Grade 6-8)

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

Item 2: Understands the nature of scientific explanation (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)

Item 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 IV (Grade 9-12)

Item 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)

Item 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)

Item 3: Understands how scientific knowledge changes and accumulates over time (e.g. 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)

Item 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 or prior knowledge

Nature of Science Standard 12: Understands the nature of science inquiry

Level II (Grade 6-8)

Item 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

Item 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)

Item 3: Designs and conducts a scientific investigation (e.g. formulates hypotheses, designs and executes investigations, interprets data, synthesizes evidence into explanations, proposed alternative explanations for observations, critiques explanations and procedures)

Item 4: Knows that observations can be affected by bias (e.g. strong beliefs about what should happen in particular circumstances prevent the detection of other results)

Item 5: Use appropriate tools (including computer hardware and software) and techniques to gather, analyze, and interpret scientific data

Item 6: Establishes relationships based on evidence and logical argument (e.g. provides causes for effects)

Item 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 evidence, suggesting alternative explanations)

Item 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 IV (Grade 9-12)

Item 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)

Item 2: Designs and conducts scientific investigations (e.g. formulates testable hypotheses; identifies and clarifies the method, control, and variables; organizes, displays, and analyzes data; revises methods and explanations; presents results; receives critical response from others)

Item 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

Item 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

Item 5: Knows that conceptual principles and knowledge guide scientific inquiries; historical and current scientific knowledge influence the design and interpretation of investigations and evaluation of proposed explanations made by other scientists

Item 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)

Item 7: Knows that the 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)

Nature of Science Standard 1: Understands the scientific enterprise

Level III (Grade 6-8)

Item 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

Item 2: Knows that the word 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)

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

Item 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 participation; potential subjects must be fully informed of possible risks to community and property)

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

Item 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 IV (Grade 9-12)

Item 1: Knows that, throughout history, diverse cultures have developed scientific ideas and solved human problems through technology

Item 2: Understands that individuals and teams contribute to science and engineering on 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)

Item 3: Understand 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

Item 4: Knows that science and technology are essential social enterprise, but alone they can only indicate what can happen, not what *should* happen.

Item 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 contribution of individuals from different disciplines; new disciplines of science, such as geophysics, biochemistry, often emerge at the interface of older disciplines

Item 6: Knows that creativity, imagination, and a good knowledge base are all required in the work of science and engineering

Life Sciences Standard 7: Understands biological evolution and the diversity of life

Item 5: Knows 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)