| **Test Content Categories** | **Required Course Numbers** | | | | | | | | | | | | | | |
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| I . Nature and Impact of Science and Engineering |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Nature of Science |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Nature of scientific knowledge |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Based on empirical evidence collected through observation or experimentation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interdisciplinary in nature |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Asking questions and forming hypotheses |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Use of laws and theories to describe and explain natural phenomena |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Development and application of models to explain natural phenomena |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Utilizes many processes, including observing, categorizing, comparing, generalizing, inferring, and concluding |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Develops and changes over time based on new evidence |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Investigation design, data collection, and analysis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Standard units of measurement, dimensional analysis, unit conversion, and scale (orders of magnitude) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Scientific notation and use of significant figures |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Investigation design, including identifying variables, planning data collection, and how design supports answering the question or testing the hypothesis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Processing, organizing, and reporting of data |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Error analysis, including accuracy and precision, mean, and percent error |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Identifying the sources and effects of error (e.g., systematic, random, sampling) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interpreting, extrapolating, and drawing conclusions from data, including data presented in various forms such as maps, models, and cross sections |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Use and limitations of technologies to gather and analyze data |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Mathematical and computer modeling |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Remote sensing technologies and geophysical methods (e.g., satellites, space probes, telescopes, spectral analysis, ground-penetrating radar, seismology, magnetic surveying) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Exploration and research vehicles (e.g., submersibles, research vessels, drones, and spacecraft) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Appropriate and safe use of materials and equipment in the laboratory and field |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Preparation, use, storage, and disposal of materials |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Use of equipment (e.g., selection, calibration, and maintenance) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Safety and emergency procedures |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Science, Engineering, Technology, Society, and the Environment |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Engineering design and the interdependence of science, engineering, and technology |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Defining problems, including identifying criteria and constraints for success |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Designing solutions, including proposing and evaluating in terms of criteria, constraints, ethical considerations, and limitations |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Optimizing the design, including systematic modification and refinement |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Engineering and technological advances leading to important discoveries in science |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. How science and technology drive each other forward |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Using science and engineering to identify and address adverse impacts on the environment and society |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Air pollution and acid rain (e.g., tropospheric ozone, sulfur and nitrogen oxides) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Greenhouse gases and their effects (e.g., global climate change, sea-level rise, and ocean acidification) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Stratospheric ozone depletion |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Water pollution (e.g., plastics, thermal, and excess nutrient runoff) and management of water resources (e.g., wetlands, aquifers, flooding, irrigation, treatment, and desalination) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Loss of habitat and biodiversity |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Issues associated with the use and extraction of energy and natural resources |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Renewable and nonrenewable energy sources |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Energy conservation and responsible management of natural resources |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Advantages and disadvantages of energy resources (e.g., fossil fuel, nuclear, hydro, solar, wind, and geothermal) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Global distribution, extraction, and use of resources (e.g., ores and groundwater, mineral, and energy resources) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Land surface use (e.g., urban development, recreational use, agricultural practices, degradation and erosion of soil, deforestation) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Consumer products and lifecycle cost analysis (e.g., production, use, disposal, and recycling) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Applications and contributions of Earth and space sciences in daily life |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Scientific ethics and decision making |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of resources (e.g., recycling, sustainable technology) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Waste management and remediation of contaminated sites |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Technology (e.g., satellites, G​P​S,  G​I​S, mapping) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Human health (e.g., radon mitigation, water treatment) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Identification, prediction, and risk management of natural hazards (e.g., tsunamis, earthquakes, tornadoes, hurricanes, coastal erosion, wildfires) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| II. Earth’s Processes and Materials |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Basic Principles of Matter and Energy in Earth and Space Systems |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Structure and properties of matter |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Atoms, molecules, ions, elements, and compounds |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Mixtures, solutions, and precipitates |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Solids, liquids, gases, plasmas |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Applications of kinetic molecular theory of gases and the ideal gas law |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Chemical and physical properties and changes (e.g., chemical bonding, solubility, pH, oxidation, phase changes, density) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationships between energy and matter |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of matter in physical and chemical processes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Conservation of energy |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Forms of energy (e.g., thermal, chemical) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Waves |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Wave properties and phenomena (e.g., wavelength, frequency, amplitude, reflection, refraction, interference, Doppler effect) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Mechanical waves (e.g., seismic, water, sound) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Electromagnetic spectrum (e.g., visible, infrared, ultraviolet, gamma) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Methods and applications of energy transfer (e.g., convection, conduction, radiation) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Applications of heat capacities and specific heats of Earth’s materials (e.g., land versus water) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Energy required for phase transitions and its implications for the water cycle and Earth’s energy budget (e.g., latent heat) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Temperature scales and measurement |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Thermal expansion and contraction |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Tectonics and Internal Earth Processes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Theory of plate tectonics and its supporting evidence |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Plate movement (e.g., rates and direction) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Convergent, divergent, and transform boundaries |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Potential driving forces (e.g., mantle convection, ridge push and slab pull) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evidence (e.g., seismic, magnetic, fossil, hot spots) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Geographic features (e.g., trenches, mountains, rift zones) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Deformation of Earth’s crust and resulting features |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Folds and faults (e.g., anticlines and synclines; normal, reverse, and strike-slip) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Mountain building and rifting |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Compression, tension, and shear stresses |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Isostasy (e.g., postglacial rebound and mountain erosion) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of earthquakes and how they provide information about Earth’s interior |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Distribution (e.g., epicenter, focus, patterns in depth and location, frequency) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnitude and intensity (e.g., Richter, Mercalli, and other measurement scales) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Seismic waves, seismometers, and seismograms |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Natural and anthropogenic causes of earthquakes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Layered structure of Earth and related processes Types of solutions |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of the crust, mantle, and core (e.g., relative thickness, composition, internal heat) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Properties of the lithosphere and asthenosphere (e.g., plasticity, density, temperature) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evidence (e.g., seismic waves) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Magnetic field and geomagnetic reversals |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Volcanic characteristics and processes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Formation and distribution of volcanoes (e.g., hot spots, subduction zones, divergent boundaries, Ring of Fire) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Features of volcanoes (e.g., vent, magma chamber) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Types of volcanoes (e.g., shield, composite, cinder cones) and their characteristics |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Eruptive products and volcanic hazards (e.g., pyroclastic flows, ash falls, lava, atmospheric ash, earthquakes, outgassing, irregular frequency) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Earth’s Materials and Surface Processes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Earth’s materials |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Minerals |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Definition of a mineral |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Physical properties and identification (e.g., density, streak, cleavage, luster, crystal structure, hardness) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics and formation of rocks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Rock identification and classification |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * The rock cycle - formation and characteristics of the following: |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Intrusive and extrusive igneous rock |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Clastic, chemical, and biological sedimentary rocks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Regional and contact metamorphic rocks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Biogeochemical cycles |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Carbon cycle processes (e.g., photosynthesis, respiration, diffusion) and reservoirs (e.g., sediments, ocean, biosphere, atmosphere) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Nitrogen cycle (e.g., nitrogen fixation, sinks and sources) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Nutrient cycling and the law of conservation of matter |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Earth’s surface processes and changes over time |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Chemical and physical weathering |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Erosion and deposition |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interactions and feedback effects between the biosphere and the geosphere (e.g., weathering caused by plants, nutrient uptake from soil by plants, uplift changing climate and affecting local ecosystems) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interactions and feedback effects between the hydrosphere and the geosphere (e.g., cave formation, ocean salinity, streams, drainage systems, and glacial rebound) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Processes of soil formation and resulting characteristics (e.g., soil profiles and factors such as geology, climate, biological components, and rate of formation) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. History of Earth and its Life-forms |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. How rocks provide a record of Earth’s history and are used to determine geologic time |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Principle of uniformitarianism (e.g., definition, applications, limitations) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relative age dating (e.g., principles of original horizontality, superposition, and crosscutting relationships) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Absolute (radiometric) age dating and radioactive decay processes, including isotopes and half-lives |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Stratigraphy |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. History, theories, and supporting evidence of the formation and development of Earth’s major systems |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Scale of geologic time (e.g., Earth’s age, major divisions of time, including Cenozoic, Mesozoic, Paleozoic, Precambrian) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Major events in geological history (e.g., end of the last ice age, mass-extinction events, great oxidation) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Changes in atmospheric composition over time |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Hydrosphere (e.g., origin of ocean water and salinity) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Geosphere (e.g., ages of cratons and oldest rock formations, fossil record, paleogeology) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Fossil record as evidence of the origin and development of early life on Earth |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Emergence of major groups of life-forms correlated to major divisions of geologic time (e.g., stromatolites, cyanobacteria, mammals) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Fossilization processes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Mass extinctions |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationship between fossil evidence for major episodes in Earth’s history and divisions in the geologic time scale |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| III. Earth’s Hydrosphere and Atmosphere |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Earth’s Hydrosphere |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Unusual properties of water and effect on Earth systems |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Hydrogen bonding |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Density (e.g., ice floats in water) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Excellent solvent |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. High specific heat |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. High heat of vaporization |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Exists as solid, liquid, and gas on Earth |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Water cycle and the energy transfers involved Aerobic and anaerobic cellular respiration |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Phase changes (e.g., vaporization, condensation, sublimation) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Models of the water cycle |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Distribution of water on Earth (e.g., surface- and groundwater, salt- and freshwater) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Role of water in the transfer of heat from the equator toward the poles |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics and processes of surface fresh water and groundwater |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Streams (e.g., erosion, deposition, channel migration) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Lakes and wetlands |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Groundwater, aquifers, springs, water table, porosity and permeability |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Hazards (e.g., flooding, sinkholes, droughts) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Human interactions (e.g., wells, levees, dams, diversion for irrigation, saltwater intrusion) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of the cryosphere and changes over time |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Components of the cryosphere (e.g., continental ice sheets, alpine glaciers, sea ice, permafrost) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Glacial-interglacial cycles, advance and retreat |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Depositional and erosional features of glaciers |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Impact of the cryosphere on Earth’s systems (e.g., sea level, ocean circulation, albedo, salinity) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Physical and chemical characteristics and processes of the oceans |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of the water column (e.g., salinity, temperature, density, and light penetration) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Surface currents, deep-ocean circulation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Wave formation, characteristics, and phenomena |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Seafloor topography (e.g., continental shelves, abyssal plains, trenches, midocean ridges) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interrelationships between the oceans and the solid Earth |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Tidal effects (e.g., causes, tidal range, tidal patterns) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Coastal processes (e.g., coastal erosional and depositional processes, longshore currents) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Tsunamis |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Island formation and change (e.g., barrier islands, volcanic islands, atolls) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Estuaries (e.g., characteristics, formation) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Marine sediments (e.g., origin, rate of deposition) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Sea-level changes |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interrelationships between the hydrosphere and the biosphere/atmosphere |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Photosynthesis and gas exchange in the oceans |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Upwelling of nutrients |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Coral reefs |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Extreme environments (e.g., hydrothermal vents, salt lakes, geysers) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Earth’s Atmosphere |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Basic structure and composition of the atmosphere |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Chemical composition |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Layers and physical properties (e.g., temperature and pressure profiles, ozone layers) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Role of the atmosphere in biogeochemical cycles (e.g., respiration, transpiration, photosynthesis, nitrogen fixation, evaporation, precipitation, effect of the atmosphere on weathering) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Basic physical principles and processes involved in meteorology |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Variations in atmospheric temperature, pressure, and density |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Energy budget (e.g., energy transfer mechanisms, absorption, reflection, and scattering) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. The greenhouse effect and its associated gases (e.g., water vapor, methane, ozone, carbon dioxide) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Global atmospheric circulation (e.g., circulation cells, surface winds, pressure gradients, Coriolis effect) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Humidity (e.g., absolute and relative, dew point and frost point) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Cyclical variations in weather (e.g., sea/land breezes, valley/mountain breezes, monsoons) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Development and movement of weather systems |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Cloud development and types |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Formation and characteristics of various types of precipitation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Air masses, fronts, and associated weather patterns |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Severe weather (e.g., lightning, hurricanes, tornadoes, storms) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Interpretation of atmospheric data (e.g., dew point, isobars, wind velocity) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Factors and processes that influence climate and lead to climate zones |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Effects of the following: |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Latitude, geographical location, and elevation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Atmospheric circulation (e.g., trade winds, jet stream) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ocean circulation (e.g., effects of warm and cold currents, such as the Gulf Stream and Humboldt Current) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * El Niño Southern Oscillation (ENSO) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Characteristics and locations of climate zones (e.g., climographs) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Natural drivers of climate variability and supporting evidence |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Proxy data used to reconstruct climate history (e.g., ice cores, sediment cores, tree rings) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Volcanic eruptions |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Asteroid impacts |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Milankovitch cycles (e.g., variations in solar radiation, tilt of Earth’s axis, and direction of Earth’s axis) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Plate tectonics (e.g., changes in landmass positions) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| IV. Astronomy |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. The Sun-Earth-Moon System |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Earth’s motions and their characteristics and consequences |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Rotation (spin) and revolution (orbit) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Observations of the sky from Earth (e.g., sunrise/sunset, seasonal stars, time zones) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Effects of axial tilt (e.g., seasons, solstices, and equinoxes) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Relationships within the Sun-Earth-Moon system |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Phases of the Moon |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Tides (e.g., causes, cycles, spring, neap) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Eclipses (solar, lunar) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Effect of the solar activity on Earth (e.g., solar wind, solar flares, sunspots) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Variability in Sun-Earth-Moon motions (e.g., precession, rotation, orbits) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. The Solar System and the Universe |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of the components of our solar system and how they formed |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Laws of motion (e.g., Newton’s law of universal gravitation, Kepler’s laws of motion) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Theory of planetary system formation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Location, orbits, and characteristics of the planets (e.g., relative sizes, composition, rotational rates) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Structure and characteristics of the Sun (e.g., layers, sunspots, prominences, fusion, composition, magnetic field) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Structure, characteristics, and orbit of the Moon |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of other solar-system objects (e.g., asteroids, meteoroids, comets, dwarf planets, minor planets, natural satellites) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of stars and the processes that occur within them |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Stages in the life cycle of stars (e.g., nebulae, protostar, main sequence, white dwarf, supernova, black holes) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Variations among stars (e.g., mass, color, temperature, luminosity, apparent brightness, Hertzsprung-Russell diagram) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Nuclear fusion and the formation of elements (e.g., carbon, iron, gold) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Detection and prevalence of other planetary systems |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Spectral evidence of composition and temperature |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Origin, evolution, and characteristics of the universe |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Characteristics of galaxies (e.g., dark matter, shape, distribution, motions, supermassive black holes) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evidence for the origin and evolution of the universe (e.g., redshift, cosmic microwave background, composition) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Spectral evidence of motion |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Science and Engineering Practices** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| The SEPs represent eight practices that scientists and engineers—and students and teachers—use to investigate the world and to design and build systems. Many test questions will integrate one or more of these practices. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Asking questions (for science) and defining problems (for engineering |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions that arise from careful observation of phenomena, models, or unexpected results, to clarify and/or seek additional information. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions that arise from examining models or a theory, to clarify and/or seek additional information and relationships. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions to determine relationships, including quantitative relationships, between independent and dependent variables. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions to clarify and refine a model, an explanation, or an engineering problem. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask questions that can be investigated within the scope of the school laboratory, research facilities, or field (e.g., outdoor environment) with available resources and, when appropriate, frame a hypothesis based on a model or theory. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Ask and/or evaluate questions that challenge the premise(s) of an argument, the interpretation of a data set, or the suitability of a design. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Define a design problem that can be solved through the development of an object, tool, process or system and includes multiple criteria and constraints, including scientific knowledge that may limit possible solutions. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Developing and using models |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate merits and limitations of two different models of the same proposed tool, process, mechanism, or system in order to select or revise a model that best fits the evidence or design criteria. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Design a test of a model to ascertain its reliability. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Develop, revise, and/or use a model based on evidence to illustrate and/or predict the relationships between systems or between components of a system. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Develop and/or use multiple types of models to provide mechanistic accounts and/or predict phenomena, and move flexibly between model types based on merits and limitations. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Develop a complex model that allows for manipulation and testing of a proposed process or system. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Develop and/or use a model (including mathematical and computational) to generate data to support explanations, predict phenomena, analyze systems, and/or solve problems. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Planning and carrying out investigations |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Plan an investigation or test a design individually and collaboratively to produce data to serve as the basis for evidence as part of building and revising models, supporting explanations for phenomena, or testing solutions to problems. Consider possible confounding variables or effects and evaluate the investigation’s design to ensure variables are controlled. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Plan and conduct an investigation individually and collaboratively to produce data to serve as the basis for evidence, and in the design: decide on types, how much, and accuracy of data needed to produce reliable measurements and consider limitations on the precision of the data (e.g., number of trials, cost, risk, time), and refine the design accordingly. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Plan and conduct an investigation or test a design solution in a safe and ethical manner including considerations of environmental, social, and personal impacts. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Select appropriate tools to collect, record, analyze, and evaluate data. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Make directional hypotheses that specify what happens to a dependent variable when an independent variable is manipulated. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Manipulate variables and collect data about a complex model of a proposed process or system to identify failure points or improve performance relative to criteria for success or other variables. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Analyzing and interpreting data |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Analyze data using tools, technologies, and/or models (e.g., computational, mathematical) in order to make valid and reliable scientific claims or determine an optimal design solution. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply concepts of statistics and probability (including determining function fits to data, slope, intercept, and correlation coefficient for linear fits) to scientific and engineering questions and problems, using digital tools when feasible. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Consider limitations of data analysis (e.g., measurement error, sample selection) when analyzing and interpreting data. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Compare and contrast various types of data sets (e.g., self-generated, archival) to examine consistency of measurements and observations. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate the impact of new data on a working explanation and/or model of a proposed process or system. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Analyze data to identify design features or characteristics of the components of a proposed process or system to optimize it relative to criteria for success. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Using mathematics and computational thinking |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Create and/or revise a computational model or simulation of a phenomenon, designed device, process, or system. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Use mathematical, computational, and/or algorithmic representations of phenomena or design solutions to describe and/or support claims and/or explanations. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply techniques of algebra and functions to represent and solve scientific and engineering problems. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Use simple limit cases to test mathematical expressions, computer programs, algorithms, or simulations of a process or system to see if a model “makes sense” by comparing the outcomes with what is known about the real world. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply ratios, rates, percentages, and unit conversions in the context of complicated measurement problems involving quantities with derived or compound units (such as , , acre-feet, etc.). |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Constructing explanations (for science) and designing solutions (for engineering) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Make a quantitative and/or qualitative claim regarding the relationship between dependent and independent variables. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Construct and revise an explanation based on valid and reliable evidence obtained from a variety of sources (including students’ own investigations, models, theories, simulations, peer review) and the assumption that theories and laws that describe the natural world operate today as they did in the past and will continue to do so in the future. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply scientific ideas, principles, and/or evidence to provide an explanation of phenomena and solve design problems, taking into account possible unanticipated effects. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Apply scientific reasoning, theory, and/or models to link evidence to the claims to assess the extent to which the reasoning and data support the explanation or conclusion. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Design, evaluate, and/or refine a solution to a complex real-world problem, based on scientific knowledge, student-generated sources of evidence, prioritized criteria, and tradeoff considerations. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Engaging in argument from evidence |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Compare and evaluate competing arguments or design solutions in light of currently accepted explanations, new evidence, limitations (e.g., trade-offs), constraints, and ethical issues. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate the claims, evidence, and/or reasoning behind currently accepted explanations or solutions to determine the merits of arguments. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Respectfully provide and/or receive critiques on scientific arguments by probing reasoning and evidence and challenging ideas and conclusions, responding thoughtfully to diverse perspectives, and determining what additional information is required to resolve contradictions. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Construct, use, and/or present an oral and written argument or counter-arguments based on data and evidence. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Make and defend a claim based on evidence about the natural world or the effectiveness of a design solution that reflects scientific knowledge, and student-generated evidence. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate competing design solutions to a real-world problem based on scientific ideas and principles, empirical evidence, and/or logical arguments regarding relevant factors (e.g. economic, societal, environmental, ethical considerations). |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Obtaining, evaluating, and communicating information |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Critically read scientific literature adapted for classroom use to determine the central ideas or conclusions and/or to obtain scientific and/or technical information to summarize complex evidence, concepts, processes, or information presented in a text by paraphrasing them in simpler but still accurate terms. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Compare, integrate and evaluate sources of information presented in different media or formats (e.g., visually, quantitatively) as well as in words in order to address a scientific question or solve a problem. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Gather, read, and evaluate scientific and/or technical information from multiple authoritative sources, assessing the evidence and usefulness of each source. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Evaluate the validity and reliability of and/or synthesize multiple claims, methods, and/or designs that appear in scientific and technical texts or media reports, verifying the data when possible. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| * Communicate scientific and/or technical information or ideas (e.g. about phenomena and/or the process of development and the design and performance of a proposed process or system) in multiple formats (including orally, graphically, textually, and mathematically). |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Tasks of Teaching Science** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| This list includes instructional tasks that teachers engage in that are essential for effective Earth and Space Science teaching. Many test questions will measure content through application to one or more of these tasks |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Instructional Goals, Big Ideas, and Topics** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Selecting or sequencing appropriate instructional goals or big ideas for a topic |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Identifying the big idea or instructional goal of an instructional activity |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Choosing which science ideas or instructional activities are most closely related to a particular instructional goal |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Linking science ideas to one another and to particular activities, models, and representations within and across units |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Investigations and Demonstrations** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. demonstrations, including virtual, that facilitate understanding of disciplinary core ideas, scientific practices, or crosscutting concepts |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating investigation questions for quality (e.g., testable, empirical) |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Determining the variables, techniques, or tools that are appropriate for use by students to address a specific investigation question |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Critiquing scientific procedures, data, observations, or results for their quality, accuracy, or appropriateness |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Supporting students in generating questions for investigation or identifying patterns in data and observations |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Resources (texts, curriculum materials, journals, and other print and media-based resources)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating instructional materials and other resources for their ability to address scientific concepts; engage students with relevant phenomena; develop and use scientific ideas; promote students’ thinking about phenomena, experiences, and knowledge; take account of students’ ideas and background; and assess student progress |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Choosing resources that support the selection of accurate, valid, and appropriate goals for science learning |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Student Ideas (including common misconceptions, alternate conceptions, and partial conceptions)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Analyzing student ideas for common misconceptions regarding intended scientific learning |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Selecting diagnostic items and eliciting student thinking about scientific ideas and practices to identify common student misconceptions and the basis for those misconceptions |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Developing or selecting instructional moves, approaches, or representations that provide evidence about common student misconceptions and help students move toward a better understanding of the idea, concept, or practice |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Language, Discourse, Vocabulary, and Definitions** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Selecting scientific language that is precise, accurate, grade-appropriate, and illustrates key scientific concepts |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Anticipating scientific language and vocabulary that may be difficult for students |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Modeling the use of appropriate verbal and written scientific language in critiquing arguments or explanations, in describing observations, or in using evidence to support a claim, etc. |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Supporting and critiquing students’ participation in and use of verbal and written scientific discourse and argumentation |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Explanations (includes claim, evidence, and reasoning)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Critiquing student-generated explanations or descriptions for their generalizability, accuracy, precision, or consistency with scientific evidence |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Selecting explanations of natural phenomena that are accurate and accessible to students |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| **Scientific Models and Representations (analogies, metaphors, simulations, illustrations, diagrams, data tables, performances, videos, animations, graphs, and examples)** |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating or selecting scientific models and representations that predict or explain scientific phenomena or address instructional goals |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Engaging students in using, modifying, creating, and critiquing scientific models and representations that are matched to an instructional goal |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating student models or representations for evidence of scientific understanding |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Generating or selecting diagnostic questions to evaluate student understanding of specific models or representations |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |
| 1. Evaluating student ideas about what makes for good scientific models and representations |  |  |  |  |  |  |  |  |  |  |  |  |  |  |  |